

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HANWHA SOLUTIONS CORPORATION,
Petitioner

v.

MAXEON SOLAR PTE. LTD.,
Patent Owner

Case No. IPR2024-01203
U.S. Patent No. 8,222,516

PATENT OWNER'S RESPONSE

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PATENT OWNER’S EXHIBIT LIST

Exhibit No.	Description
2001	<i>Intentionally Left Blank</i>
2002	<i>Intentionally Left Blank</i>
2003	Gan, Jon-Yiew, Polysilicon emitters for silicon concentrator solar cells, Stanford University (July 1990) (“Gan Thesis”)
2004	<i>Intentionally Left Blank</i>
2005	<i>Intentionally Left Blank</i>
2006	Federal Court Management Statistics (June 30, 2024)
2007	<i>Intentionally Left Blank</i>
2008	<i>Intentionally Left Blank</i>
2009	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. 8,222,516
2013	<i>Intentionally Left Blank</i>
2014	<i>Intentionally Left Blank</i>
2015	<i>Intentionally Left Blank</i>
2016	<i>Intentionally Left Blank</i>
2017	<i>Intentionally Left Blank</i>

Exhibit No.	Description
2018	<i>Intentionally Left Blank</i>
2019	U.S. Patent no. 8,222,516 to Cousins
2020	<i>Intentionally Left Blank</i>
2021	Docket Sheet, <i>Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.</i> , Case No. 2:24-cv-00210-JRG (E.D. Tex.)
2022	Docket Sheet, <i>Maxeon Solar Pte. Ltd. v. Hanwha Solutions Corp.</i> , Case No. 2:24-cv-00262-JRG (E.D. Tex.)
2023	Docket Sheet, <i>Maxeon Solar Pte. Ltd. v. REC Solar Holdings AS</i> , Case No. 2:24-cv-00260-JRG (E.D. Tex.)
2024	Counterclaims, <i>Maxeon Solar Pte. Ltd. v. Hanwha Solutions Corp.</i> , Case No. 2:24-cv-00262-JRG (E.D. Tex. Nov. 15, 2024)
2025	IPR2024-01040 Petition
2026	Declaration of Mary K. Bolin
2027	Declaration of Douglas Ruby, Ph.D.
2028	Curriculum Vitae of Douglas Ruby, Ph.D.
2029	Transcript of Deposition of Petitioner's Expert Zachary Holman, Ph.D. (May 8, 2025)

I. INTRODUCTION

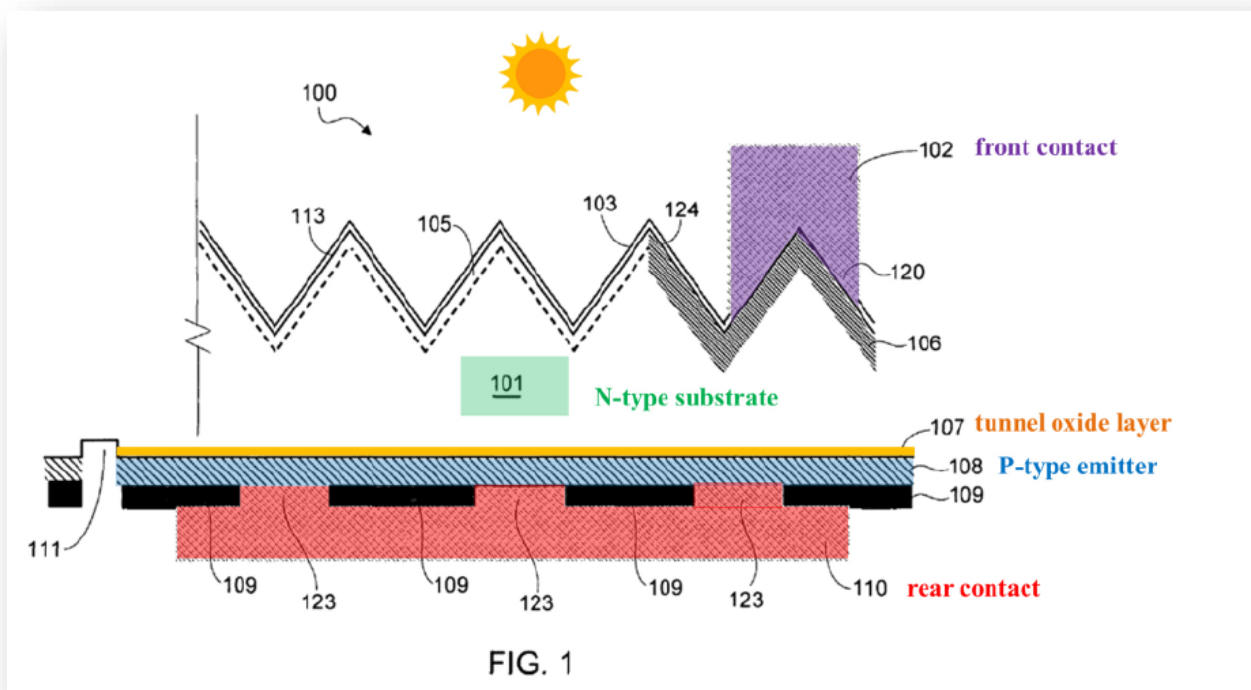
Maxeon Solar Private Limited submits its Patent Owner Response to Petitioner Hanwha Solutions Corporation's Petition for *Inter Partes* Review.

II. OVERVIEW OF THE '516 PATENT

A. The '516 Patent

The '516 patent discloses and claims a novel front contact solar cell with formed emitter. Ex. 1001, 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. Ex. 1001, 1:66-67.



Paper 3, 15 (citing Ex. 1001, Fig. 1) (annotation in Petition).

In this embodiment, an N-type silicon substrate 101 is formed from a crystalline silicon wafer. Ex. 1001, 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.* at 2:27. A tunnel oxide 107, which can be silicon dioxide, is provided on the back side of the substrate 101. *Id.* at 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). Ex. 1001, 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.* at 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.* at 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.* at 4:20-27.

Exposed surfaces of the substrate 101 (on the front side) are etched to form pyramid 113 like structures. Ex. 1001, 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.* at

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.* at 2:37-41; *id.* at 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.” Ex. 1001, 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.* at 4:58-60; *id.* at 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.* at 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. Ex. 1001, 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.* at 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.* at 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. Ex. 1001, 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.* at 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. Ex. 2027, ¶93. 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.

Ex. 1001, 6:4-22 (claim 1); *id.* at 6:42-57 (claim 9) (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. Ex. 2027, ¶94.

B. Prosecution History of the '516 Patent

The '516 patent was filed as application number 12/070,742 on February 20, 2008. Ex. 1001, 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"). Ex. 1002, 59-65 (November 5, 2009 Requirement for Restriction/Election); *id.* at 68-70 (December 1, 2009 Amended Claims); *id.* at 74-84 (December 24, 2009 Non-final

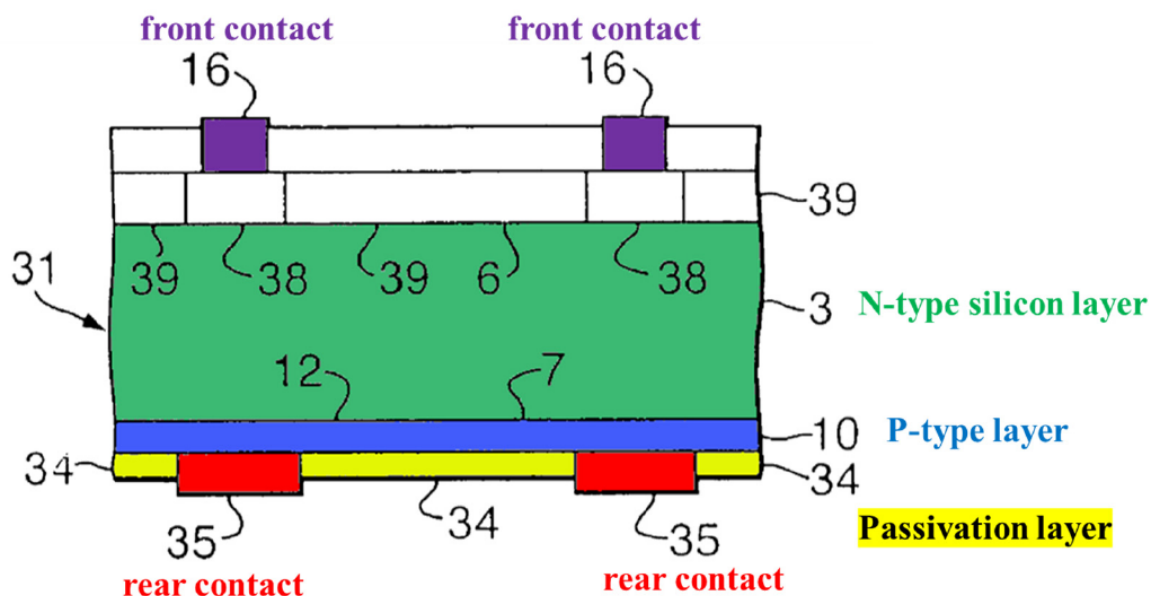
Rejection). The applicant eventually overcame the Examiner's rejections by specifying that the P-type polysilicon emitter is "formed over the N-type silicon substrate" and adding the limitation of "an oxide layer formed between the P-type polysilicon emitter and the N-type silicon substrate." *Id.* at 106-13 (March 19, 2010 Request for Reconsideration and Arguments/Remarks); *id.* at 116-29 (May 26, 2010 Final Rejection); *id.* at 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." Ex. 1002, 152.

III. THE PRIOR ART

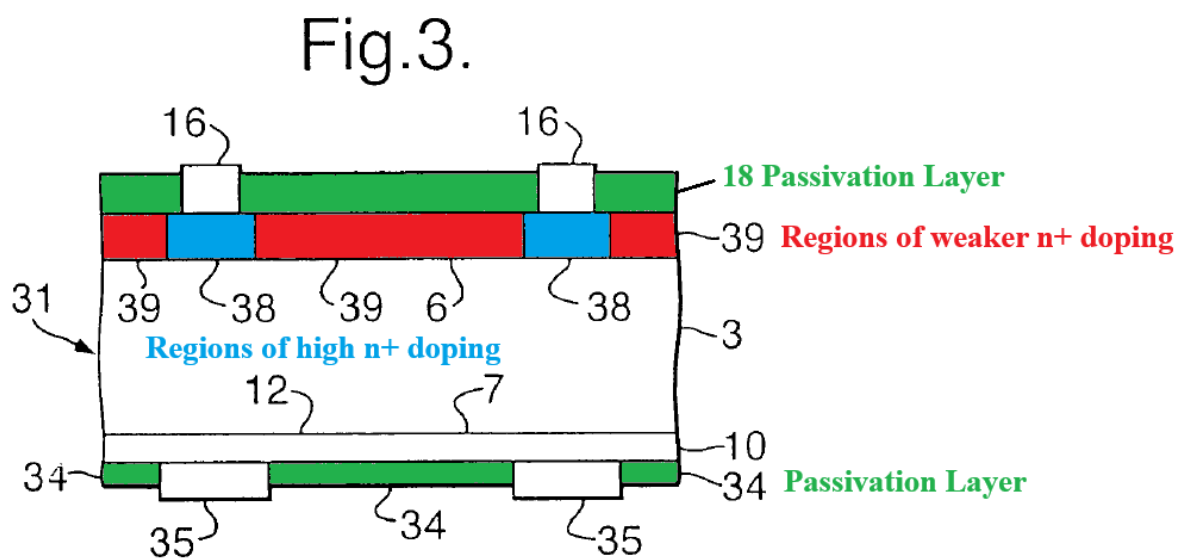
A. Froitzheim

Froitzheim (Ex. 1004) is directed to a solar cell with a non-alloyed p-type doped region that forms a p/n junction with a rear side of a body layer. Ex. 1004, 1 at (57). Below is the relevant embodiment Petitioner references in its Petition:



Paper 3, 18 (citing Ex. 1004, Fig. 3) (annotations in Petition).

Additional labels to Figure 3 of Froitzheim are shown below:



Ex. 2027, ¶110 (citing Ex. 1004, Fig. 3) (annotated); *see also* Ex. 1004, Fig. 1 (illustrating layer 18).

This embodiment of Froitzheim's solar cell includes "a silicon body layer 3 of n-type bulk doping having a front side 6 and a rear side 7." Ex. 1004, ¶24. At the front side 6, screen-printed front side contacts 16 are provided in electrical connection with the n-type silicon body layer. Ex. 1004, ¶25. The front side contacts 16 are arranged between "n+ doped regions 18." *Id.* at ¶34; *see also id.* at Fig. 1 (illustrating passivation layer 18). Further, the front side contacts are surrounded by "regions 38 of high n+ doping" and "regions 39 of weaker n+ doping [are arranged] in between front contact fingers." *Id.* According to Froitzheim, "the weaker n+ doping can be achieved by a doping concentration intermediate between that of the n-type body layer and that of the n+ doped regions 18, and/or in that regions 39 are shallower than regions 38." *Id.* at ¶34.

At the rear side 7, a p-doped layer 10 is formed by "introduc[ing] dopant, preferably boron, only by diffusion into the rear surface of the body layer [3]." Ex. 1004, ¶40. According to Froitzheim, the dopant is driven into the body layer 3 (the n-doped silicon wafer) by treating the wafer "in an atmosphere that contains oxygen at a temperature of 900 to 1200 degree centigrade, preferably between 1000 and 1100 degree C." *Id.* at ¶¶41-42. The p-doped layer 10 forms a p/n junction 12 with the body layer 3. *Id.* at ¶25. Further, rear contacts 35 are

“arranged in a finger structure,” and a passivation layer 34 is arranged between the fingers. *Id.* at 33.

B. Gan

Gan (Ex. 1005) is a research paper discussing the use of high temperature anneals to break up interfacial oxide, and the effect that has on polysilicon emitters in test devices.

1. Gan’s Experiments

Gan discloses “there always exists a very thin oxide (interfacial oxide), which can be the by-product of the cleaning process or is grown intentionally.”

This interfacial oxide is not stable:

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_0) [1,2,3,4,5,6,7] upon either the anneal condition or the oxide integrity.

Ex. 1005, 245.

Using two high temperature anneals, Gan breaks up the interfacial oxide to varying degrees to study its effects: “The 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.” Ex. 1005, 245. Gan’s first-step anneal

is at 1050 °C, and Gan's second-step anneal is at 900-1000 °C. *Id.* at 246 (steps 4, 10).

Gan then measures the emitter saturation current density (J_o) and contact resistivity (ρ_c) of its polysilicon emitter. Ex. 1005, Abstract; *id.* at 245. Gan teaches that it is optimal to have low values for both J_o and ρ_c , and this is achieved when “when both carriers are mostly blocked by the interfacial oxide.” *Id.* at 245, 249.

Gan also teaches that when the anneal temperature is high and the oxide layer 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.

Ex. 1005, 245.

2. *Gan's Test Devices*

Gan discloses manufacturing steps to create test devices that include “[p]olysilicon emitters with a thermally grown interfacial oxide.” Ex. 1005, Abstract. Gan uses these test devices to measure the emitter saturation current density (J_o) and contact resistivity (ρ_c) of its polysilicon emitter when annealed

under various conditions. *Id.* Specifically, Gan discloses a test device using FZ wafers to measure J_o , and a test device using CZ wafers to measure ρ_c . *Id.* at 245.

Gan discloses the following steps to create its test devices.

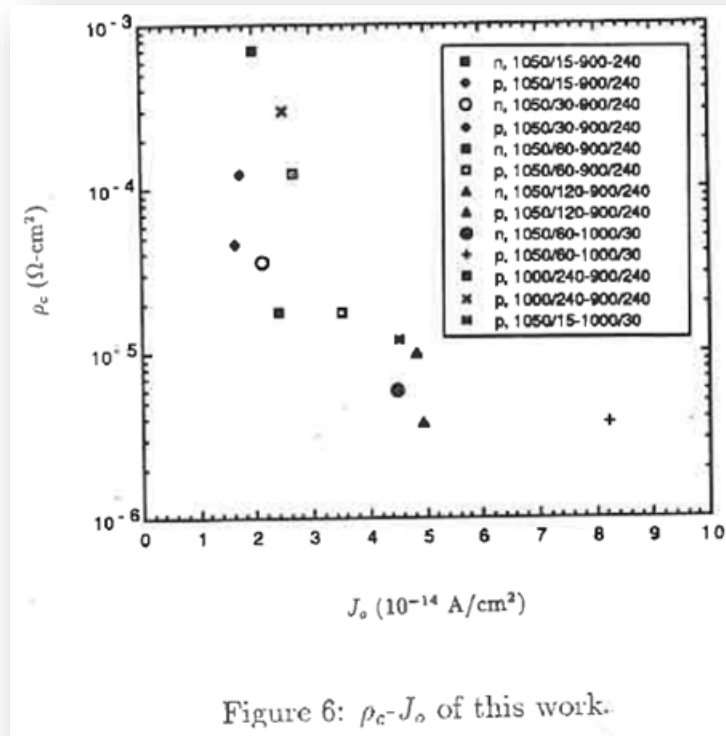
1. Field oxidation (2000 Å)*.
2. Polysilicon-substrate contact opening*.
3. Thin thermal oxide growth at 800 °C*. (10-minute oxygen flow)[.]
4. Polysilicon deposition (6000 Å) and first-step anneal (1050 °C)*.
5. First-step anneal*.
6. Polysilicon finger definition.
7. Undoped glass deposition (2000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

Ex. 1005, 246 (emphasis added). According to Gan, “the J_o and ρ_c were measured independently for each type of polysilicon emitter (or contact). J_o was measured with photoconductivity decay method. . .” and “the steps marked with “*” are the steps for J_o -measurement samples.” *Id.*

3. *Gan’s Results*

Gan ran multiple experiments for combinations of temperatures for the first anneal (oxide break up) and the second anneal (dopant drive in) and reported the

results in a plot of ρ_c versus J_o , with a key in the top right that shows “the [dopant] type of polysilicon emitter, the first-step anneal (temperature/minute), and the second-step anneal (temperature/minute).” Ex. 1005, 249, Fig. 6. The goal was to achieve a low value for J_o .



Ex. 1005, 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 . Ex. 2027, ¶127. This was true even though the duration (30 minutes) for the high temperature anneals performed at 1000°C was 1/8th of the duration (240 minutes) of the low temperature anneals performed at 900°C). Gan then discusses this figure

and observes for regimes 1 (900°C) “ J_o is almost constant while ρ_c drops drastically” and for regime 2 (1000°C) “ ρ_c decreases very slowly and J_o increases in much faster pace.” Ex. 1005, 249.

Gan also explains that the second step anneal is optimal when performed at “900 °C for 4 hours.” Ex. 1005, 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 [steps 5 and 10] to optimize J_o .” *Id.*

Gan provided further analysis of the experimental results in 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	

Ex. 1005, Table 1.

C. Gan Thesis

Jon-Yiew Gan’s thesis titled “*Polysilicon emitters for silicon concentrator solar cells*,” published by the Stanford University in July 1990, provides a

comprehensive review of the experiments and methodologies described in Gan (Ex. 1004), *see, e.g.*, Ex. 2003, Chapter 5, and provides significantly more details about the theory, experimental results, and conclusions set forth in Gan (Ex. 1004). Ex. 2027, ¶131.

The Gan Thesis was published and publicly available in the Stanford Library on April 10, 1991, which is prior to the priority date of the '053 patent. Ex. 2026, ¶23. Thus, a POSITA would have had knowledge of the information in both Gan and the Gan Thesis before that priority date.

The Gan Thesis posits that making a concentrator solar cell with polysilicon emitter and interfacial oxide is theoretically possible. For example, the Gan Thesis makes the following statements:

- “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.” Ex. 2003, 53 (emphasis added).
- “Theoretically, a model was proposed to make the polysilicon emitter with both low J_o ($\sim 3 \times 10^{-14} \text{ A/cm}^2$) and low contact resistance ($\rho_c \leq 1 \times 10^{-5} \Omega\text{-cm}^2$).” Ex. 2003, Abstract (emphasis added).
- “The polysilicon emitter with low J_o and ρ_c can be made with a very small fraction of interfacial oxide breakup.” Ex. 2003, 107 (emphasis added).

- “With 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 .”
Ex. 2003, 69 (emphasis added).

However, the Gan Thesis provides experimental data showing poor results when attempting to implement the theories above. For example, 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. . .” Ex. 2003, 116-17 (emphasis added).

The Gan Thesis was trying to obtain a low J_o of 1×10^{-14} A/cm² to 2×10^{-14} A/cm². *See, e.g.*, Ex. 2003, Abstract (disclosing that polysilicon emitters, particularly n-type polysilicon emitters, “have been reported to have J_o of around 1×10^{-14} A/cm²); *id.* at 3 (disclosing that cell efficiency “falls off rapidly as the J_o increases over 1×10^{-14} A/cm².”); *id.* at 22 (disclosing that “the J_o of each type of emitters should be around 2×10^{-14} A/cm².”). This is understandable because Gan and the Gan Thesis are both trying to solve the same problem, namely a very small and consistent breakup of the interfacial oxide to achieve low J_o .

However, it is evident that Gan was not successful. For example, the Gan Thesis documented Gan's failure to implement the polysilicon emitter and interfacial oxide structure in a real solar cell:

Later, in the real solar cell runs, the situation got even worse. The solar cells made in the experiment are the 15- μm -contact-line IBC which have been shown and simulated in Chapter 2. We found that, with the OCVD measurement, the total specific contact resistivity ($\rho_n + \rho_p$) was higher than $1 \times 10^{-3} \Omega\text{-cm}^2$. Although the ($J_{on} + J_{op}$) measured from those cells are between 8×10^{-14} and $4 \times 10^{-14} \text{ A/cm}^2$, the cell efficiency is greatly degraded by such a high emitter resistance. . .

As shown in the figure, the cell is in fact plagued by two things: the high surface recombination velocity ($S = 50 \text{ cm/sec}$), and high emitter resistance ($\rho_n + \rho_p = 1 \times 10^{-3} \Omega\text{-cm}^2$). . .

From the low emitter recombination and high emitter resistance, it is clear that the interfacial oxide did not break as we expected.

Ex. 2003, 110.

Further, the Gan Thesis showed that there was no known method for getting the oxide thickness reliably to obtain his best results:

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.

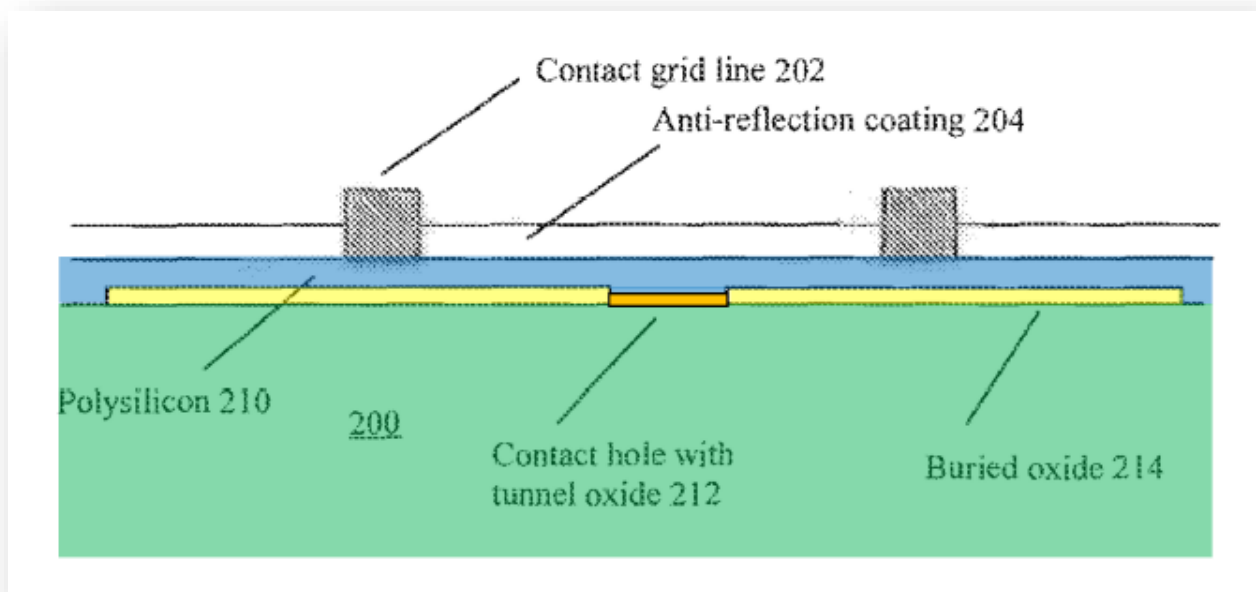
Ex. 2003, 119 (emphasis added).

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.

Ex. 2003, 107 (emphasis added); *see also id.* at 111 (“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.”); *id.* at 114 (“It becomes clear that the wide fluctuation of our results is mainly due to the poor control over the oxide thickness.”); *id.* at 114-17 (“[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.”) (emphasis added); *id.* at 56 (“With a window so narrow, it is not possible to have good control over the characteristics of a polysilicon SIS emitter.”).

D. Borden-575

Borden-575 (Ex. 1006) is directed to contact isolation in solar cells. Ex. 1006, Abstract. Borden-575 is concerned with contact isolation in solar cells, and the difficulty of implementing prior art selective emitter structures that provide contact isolation. *Id.* at ¶¶3-4, 6. Borden-575's purported innovation is a "buried oxide under the emitter of a polysilicon emitter solar cell." *Id.* at Abstract. The buried oxide proves "an excellent passivation layer" that "isolates the contacts from the substrate," such that a selective emitter structure can be used "without requiring deep diffusions." *Id.*; see also *id.* at ¶16, 19.



Paper 3, 68 (citing Ex. 1006, Fig. 2) (annotation in Petition); see also Ex. 1006, ¶19 ("[T]he cell structure includes an insulating (e.g. oxide) [buried oxide] layer

214 under the doped region 210 and the contact 202. This insulating layer 214 isolates the contact 202 from the substrate 200.”).

The buried oxide 214 features contact holes 212 that “allow current flow” between the emitter and the substrate. Ex. 1006, ¶¶8, 9, 19, 20. Borden-575 describes its contact holes as typically being “20 to 200 μm ,” while “spacing between openings 212 can be 1-5 mm.” *Id.* at ¶21. But Borden-575 also broadly construes the term “contact hole”:

[T]he term contact hole should be construed broadly so as to relate to many types of openings through insulating layer 214 and many types of solar cell contacts. For example, the holes can provide for point contacts or they can provide for grid line contacts. Those skilled in the art of solar cell contacts will appreciate how the teachings of the invention can be applied to these and other various types of contacts and openings.

Ex. 1006, ¶20.

Borden-575 also discloses an optional thin tunnel oxide in the contact holes. Ex. 1006, ¶¶19, 22, 26. This tunnel oxide is “typically 8 to 15Å thick” and “provides passivation between the substrate and the polysilicon.” *Id.* at ¶22. But Borden-575 notes the hardship of reliably forming thin tunnel oxides:

Another method to passivate contacts is to place a thin tunnel oxide – typically 15Å thick - under the metal contacts. Such types of contacts are also well known, and have been used commercially by Schott solar to manufacture MIS solar cells. However, such solar cells have

not been commercially introduced, possibly because of the difficulty of reliably forming a thin tunnel oxide.

Ex. 1006, ¶5 (emphasis added).

E. Borden-575 Is Not Prior Art

Petitioner failed to establish that Borden-575 is effective prior art for multiple reasons, including that (1) Petitioner’s selected Borden-575 claim is not fully supported in the Borden-575 Provisional, and (2) at least a portion of Borden-575’s disclosure that the Petition relies upon is not present in the provisional.

1. Borden-575 Cannot Be Prior Art Because the Provisional Fails to Support Its Claims

Petitioner bears the burden to show that the Borden-575 Provisional supports at least one claim in Borden-575. *Forescout Tech., Inc. v. Fortinet, Inc.*, IPR2021-01328, Paper 12, 9-10 (PTAB Jan. 27, 2022) (cited in Paper 3, 21) (Holding that the petitioner “has an initial burden [] to compare the challenged claims with the disclosure in Thomas [which is not prior art unless it is entitled to priority to the Thomas Provisional].”); *see also Medtronic, Inc. v. Niazi Licensing Corp.*, IPR2018-00609, Paper 8, 11 (PTAB Aug. 20, 2018) (Determining that precedent requires “the Norlander provisional to support just one claim in the Norlander patent for the Norlander patent to be effective as prior art.”). Petitioner failed to carry that burden.

Contrary to Petitioner’s assertion, the Borden-575 provisional does not fully support even claim 1 of Borden-575, which recites a “semiconductor substrate.” Paper 3, 23-24; Ex. 1006, 10 at claim 1 (“an emitter layer formed on a semiconductor substrate”) (emphasis added). The Borden-575 Provisional separately discloses a “semiconductor device,” Ex. 1011, 8 at ¶1,” and “substrate,” *see, e.g., id.* at Abstract; *id.* at ¶¶6, 13, 16, 18, 20, 22, 23, 25, 26, 28]. But the Borden-575 Provisional does not disclose a “semiconductor substrate” in any of the portions Petitioner cited, or anywhere else. Paper 3, 24 (*citing* Ex. 1011 at Abstract; *id.* at ¶¶6, 13, 16-18; *id.* at Fig. 2; *id.* at claims 1-2).¹

2. *Petitioner Partially Relied on Disclosures in Borden-575 That Is Not Presented in the Borden Provisional*

At least the following relevant portions of Borden-575 are not disclosed in the Borden-575 Provisional and should not be considered as supporting Ground III and Ground IV (further modifying the proposed Froitzheim-Borden-575 combination). *Forescout*, IPR2021-01328, Paper 12, 9-10 (Holding that the petitioner “has an initial burden . . . to show that the subject matter that [the petitioner] relies on in Thomas is also found in the Thomas Provisional.”).

¹ Petitioner additionally cited its expert declaration, which merely copied the Petition. Paper 3, 23 (citing Ex. 1003, ¶112).

First, Borden-575 discloses a formula in paragraph 17 that is not supported in the Borden-575 Provisional:

[0017] The present inventors recognize that a point contact solar cell provides improved efficiency. This is because the current flow is concentrated into a small region, providing a higher current density. The open circuit voltage V_{OC} is given by the equation:

$$V_{OC} = kT/q \ln (J_L/J_0 + 1)$$

Ex. 1006, ¶17 (illustrating an equation).

[0014] The present inventors recognize that a point contact solar cell provides improved efficiency. This is because the current flow is concentrated into a small region, providing a higher current density. The open circuit voltage is given by the equation:

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Ex. 1011, ¶14 (displaying an error message instead of the equation).

Second, Borden-575 discloses that “contact holes 212 are provided in the insulating layer 212 to allow for photocurrent flow.” Ex. 1006, 5 at ¶19. This is not present in the Borden-575 Provisional and should not be considered as support for Petitioner’s argument. *See, e.g.*, Ex. 1011, ¶¶16-17.

Third, Borden-575 discloses an entire paragraph containing additional details on substrate 200 and contact holes. This paragraph is not included in the Borden-575 Provisional. *Compare* Ex. 1006, ¶20 *with* Ex. 1011, ¶¶16-17.

Fourth, as noted in the section above, Borden-575 added the disclosure that a thin tunnel oxide “[allows] for tunnel current flow.” *Compare* Ex. 1006, ¶22 (last sentence) *with* Ex. 1011, ¶18 (last sentence).

Petitioner and Petitioner’s expert expressly reference at least the third and fourth unsupported disclosures listed above. Paper 3, 59, 66, 68; Ex. 1003, ¶¶113, 139, 211, 228, 235, 239 n12. These references should not be considered—particularly in support of its motivation to combine arguments, where Petitioner cited Borden-575’s disclosure that its tunnel oxide provides “passivation between the substrate and the polysilicon, while allowing for tunnel current flow.” Paper 3, 66 (citing Ex. 1006, ¶22) (emphasis added). The underlined portion of Borden-575 should not be considered because Petitioner failed its initial burden to show that the subject matter that the Petitioner relies on in Borden-575 is also in the Borden-575 Provisional. *Forescout*, IPR2021-01328, Paper 12, 9-10 (Holding that the petitioner “has an initial burden . . . to show that the subject matter that [the petitioner] relies on in Thomas is also found in the Thomas Provisional.”).

To the extent Petitioner or its expert implicitly rely on any additional unsupported disclosures, those should also not be considered. *See, e.g.*, Paper 3 at

64, 65, 67, 70, 71, 73, 76, 78 (citing unsupported paragraphs in a range of paragraphs or for what appear to be unrelated disclosure); Ex. 1003, ¶¶223, 225, 231 (citing unsupported paragraphs in a range of paragraphs).

F. Li

Li (Ex. 1008) is directed to a “heterogeneous PN junction” created by “a layer of silicon thin film deposited on a back surface of an N-type” substrate. Ex. 1008, Abstract; *id.* at 4.

As its name implies, a heterogenous PN junction is a junction formed by two different materials on the two sides of the junction. Ex. 2027, ¶154. In Li’s case, those two different substances are a “N-type monocrystalline silicon substrate” and a “P-type silicon thin film.” Ex. 1008, Abstract; *see also id.* at 4 (“A layer of silicon thin film is deposited on a back surface of N-type monocrystalline silicon to form an emitting region.”).

Because the emitter layer is already of P-type, high anneal temperature (used to drive in/diffuse dopants) is not used in construction of Li’s heterogeneous PN junction structure. Ex. 2027, ¶155. Thus, Li teaches that its heterogeneous PN junction “is prepared by a low-temperature deposition method, which avoids a conventional diffusion process at 800-1000°C.” Ex. 1008, 4.

In contrast to the above-described structure on the back side of the substrate, Li describes on the front side of the substrate a conventional homogeneous PN

junction that “generally adopt P-type crystalline silicon to form an N-type emitting region through high-temperature diffusion.” Ex. 1008, Ex. 1008, 3; *see also id.* at Abstract (“[A] homogeneous PN junction prepared on a front surface of the cell by a conventional diffusion method.”). As its name implies, a homogeneous PN junction is a junction formed by the same materials on both sides of the junction. Ex. 2027, ¶151. Thus, for example, according to Li’s description, Froitzheim would have a homogeneous PN junction because its emitter layer is “a non-alloyed p-type doped region at the rear side of the body layer [substrate] and forming a p/n-junction therewith.” Ex. 1004, Abstract; Ex. 2027, ¶151.

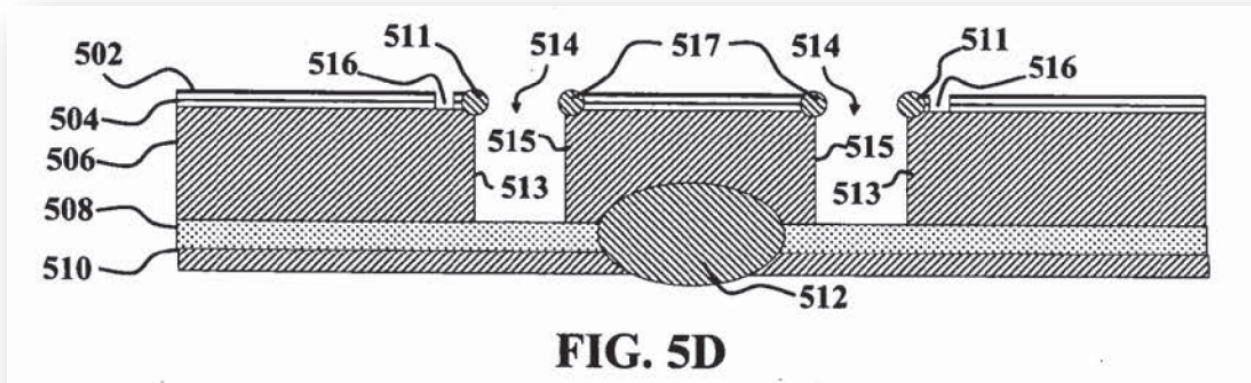
Because the emitter layer is formed on the substrate, a high anneal temperature is used in homogeneous PN junctions to drive in/diffuse dopants. *See, e.g.,* Ex. 1004, ¶¶40-42 (disclosing high anneal temperature to diffuse boron into “the rear surface of the body layer” to form a “p-type doped region”). According to Li, high-temperature diffusion in conventional homogeneous PN junction solar cells leads to defects and inefficiencies. Ex. 1008, 3 (“[Homogeneous PN junction solar cells] have the disadvantages that the high-temperature diffusion may cause more defects in silicon materials, and when pollution is caused in a high-temperature process, cell efficiency will be greatly reduced. Thus, higher requirements are put forward for both materials and a production environment.”); *see also id.* at 4 (“[H]igh-temperature process will cause more defects or

contamination in a silicon material, which will affect the improvement of cell efficiency.”).

G. Sheats

Sheats (Ex. 1012) is directed to improvements in optoelectronic device modules (multiple solar cells connected together) and the manufacturing thereof. Ex. 1012, Abstract; *see also id.* at ¶5 (explaining why “it is often necessary to electrically connect several devices . . . to obtain higher voltages.”); *id.* at ¶7 (addressing “problems associated with series interconnection of optoelectronic devices.”).

Sheats focuses on the drawbacks of solar cell arrays manufactured from a single substrate, where holes are cut into the substrate to form multiple solar cells. *See, e.g.*, Ex. 1012, ¶¶10-12; *see also id.* at Figs. 6A, 6B. Sheats’ purported solutions all relate to solar cell arrays. *See, e.g., id.* at ¶¶15, 18-20 (introducing Figs. 1-4A as arrays); *id.* at Fig. 1A (illustrating two solar cells); *id.* at ¶40 (discussing fabrication of the two solar cells). One of Sheats’ embodiments includes a single structure separated into multiple solar cells by a trench (514). *Id.* at Figs. 5A-I; *see also id.* at ¶¶56-60.



Ex. 1012, Fig. 5D.

In this embodiment, Sheats discusses, among other things, cutting an isolation trench 516 to prevent short circuit between the separated solar cells at points 511 and 517 during the formation of trench 514. Ex. 1012, ¶59.

IV. THE LEVEL OF ORDINARY SKILL

This Patent Owner Response (“POR”) applies the level of ordinary skill in the art proposed by Petitioner. Paper 3, 17; Ex. 2027, ¶¶99-100.

V. CLAIM CONSTRUCTION

This POR applies the “plain and ordinary meaning” to all claim terms, which Petitioner proposed. Paper 3, 18.

VI. PETITIONER FAILED TO DEMONSTRATE ANY REASONABLE LIKELIHOOD OF SUCCESS ON THE MERITS OF GROUNDS I TO V

All five grounds in the Petition fail.

Ground I (Froitzheim and Gan) fails because Gan and the Gan Thesis inform a POSITA that there was no reasonable expectation of consistently growing Gan’s

oxide layer in Froitzheim's solar cell. Further, there was no motivation to combine because Gan and the Gan Thesis establish that even if the thin oxide layer could have been reliably formed, using Froitzheim's anneal temperature would have eliminated any alleged benefit of the oxide layer.

Ground III (Froitzheim and Borden-575) fails because Petitioner failed to establish that Borden-575 is prior art and did not define whether the proposed combination would use Borden-575's tunnel oxide or buried oxide. In the former case (tunnel oxide), a POSITA would also not have been able to consistently grow Borden-575's tunnel oxide layer, while the latter (buried oxide) would have rendered the proposed combination inoperable.

Grounds II and IV (adding Sheats' trench cutting technique to Froitzheim and Gan/Borden-575) would not have remedied the shortcomings of Grounds I and III. Further, a POSITA would not have added Sheats because its benefits are superfluous to Froitzheim, and its trench cutting technique protects against short circuit between solar cells in an array, not a short circuit within a single solar cell such as the proposed Froitzheim-Gan/Borden-575 combination.

Ground V based on Li and Gan fails because Li teaches away from Gan.

Lastly, each Ground also fails to satisfy limitations of the claims against which they are asserted.

A. Ground I: Petitioner’s Challenge of Claims 1-4 and 6-12 Based on Froitzheim and Gan Fails

Petitioner’s proposed Froitzheim-Gan combination lacks both motivation to combine and reasonable expectation of success. The proposed combination also fails to meet at least one limitation recited in the independent claims and various limitations in the dependent claims.

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

A POSITA would not have been motivated to combine Froitzheim, a patent disclosing the structure and manufacturing of an actual solar cell, with Gan, a research paper disclosing the fabrication of test devices.

“The genius of invention is often a combination of known elements which in hindsight seems preordained.” *McGinley v. Franklin Sports, Inc.*, 262 F.3d 1339, 1351 (Fed. Cir. 2001). Further, “[w]hen the art in question is relatively simple, as is the case here, the opportunity to judge by hindsight is particularly tempting.” *Id.* By arguing that the proposed Froitzheim-Gan combination could be fabricated by “simply substituting one known element for another,” Paper 3, 32, Petitioner fell prey to impermissible hindsight reconstruction. In reality, a POSITA would have been dissuaded by the Gan Thesis’ documentation of repeated failure to reliably implement Gan’s structure in an actual solar cell. Ex. 2027, ¶¶173, 175.

a. The Gan Thesis Documents Gan's Failure to Reliably Implement an Interfacial Oxide Layer

The Gan Thesis (Ex. 2003), written by a co-author of the Gan reference (Ex. 1005), shows that Gan repeatedly attempted Petitioner's proposal—to implement Gan's polysilicon emitter and interfacial oxide structure on a real solar cell—but consistently failed. Thus, a POSITA would not have been motivated to attempt the proposed Froitzheim-Gan combination. *DePuy Spine, Inc. v. Medtronic Sofamor Danek, Inc.*, 567 F.3d 1314, 1326 (Fed. Cir. 2009) (“An inference of nonobviousness is especially strong where the prior art's teachings undermine the very reason being proffered as to why a person of ordinary skill would have combined the known elements.”)

The Gan Thesis was published and publicly available in the Stanford Library on April 10, 1991, which is prior to the priority date of the '516 patent. Ex. 2026, ¶23. Thus, a POSITA would have had knowledge of the information in Gan and the Gan Thesis before that priority date.

At best, the Gan Thesis posits that making a concentrator solar cell with polysilicon emitter and interfacial oxide is theoretically possible. For example, the Gan Thesis makes the following statements:

- “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.” Ex. 2003, 53 (emphasis added).

- “Theoretically, a model was proposed to make the polysilicon emitter with both low J_o ($\sim 3 \times 10^{-14} \text{ A/cm}^2$) and low contact resistance ($\rho_c \leq 1 \times 10^{-5} \Omega\text{-cm}^2$).” Ex. 2003, Abstract (emphasis added).
- “The polysilicon emitter with low J_o and ρ_c can be made with a very small fraction of interfacial oxide breakup.” Ex. 2003, 107 (emphasis added).
- “With 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 .” Ex. 2003, 69 (emphasis added).

A POSITA would recognize these musings in the Gan Thesis were theories that fell short of being reproducibly put into practice, and were deficient in supporting a reasonable expectation of success. Ex. 2027, ¶¶137, 173, 175. In fact, the Gan Thesis provides experimental data showing poor results when implementing his theories. *Id.* For example, 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. . .” Ex. 2003, 116-17 (emphasis added).

But the Gan Thesis documented its own failure to reliably implement the interfacial oxide structure in a real solar cell:

Later, in the real solar cell runs, the situation got even worse. The solar cells made in the experiment are the 15- μm -contact-line IBC which have been shown and simulated in Chapter 2. We found that, with the OCVD measurement, the total specific contact resistivity ($\rho_n + \rho_p$) was higher than $1 \times 10^{-3} \Omega\text{-cm}^2$. Although the ($J_{on} + J_{op}$) measured from those cells are between 8×10^{-14} and $4 \times 10^{-14} \text{ A/cm}^2$, the cell efficiency is greatly degraded by such a high emitter resistance. . .

As shown in the figure, the cell is in fact plagued by two things: the high surface recombination velocity ($S = 50 \text{ cm/sec}$), and high emitter resistance ($\rho_n + \rho_p = 1 \times 10^{-3} \Omega\text{-cm}^2$). . .

From the low emitter recombination and high emitter resistance, it is clear that the interfacial oxide did not break as we expected.

Ex. 2003, 110.

Further, the Gan Thesis showed that there was no known method for getting the oxide thickness reliably to obtain his best results:

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.

Ex. 2003, 119 (emphasis added).

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.

Ex. 2003, 107 (emphasis added); *see also id.* at 111 (“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.”); *id.* at 114 (“It becomes clear that the wide fluctuation of our results is mainly due to the poor control over the oxide thickness.”); *id.* at 114-17 (“[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.”) (emphasis added); *id.* at 56 (“With a window so narrow, it is not possible to have good control over the characteristics of a polysilicon SIS emitter.”).

Thus, a POSITA would not have had a reasonable expectation of success in attempting to achieve Gan's results by reliably implementing Gan's structure on Froitzheim's solar cell. Ex. 2027, ¶175; *see also Univ. of Strathclyde v. Clear-Vu Lighting LLC*, 17 F.4th 155, 165 (Fed. Cir. 2021) ("In this case, where the prior art evidences only failures to achieve that at which the inventors succeeded, no reasonable fact finder could find an expectation of success based on the teachings of that same prior art."); *OSI Pharms., LLC v. Apotex Inc.*, 939 F.3d 1375, 1385 (Fed. Cir. 2019) ("These references provide no more than hope—and hope . . . not enough to create a reasonable expectation of success in a highly unpredictable art such as this."); *Regents of Univ. of California v. Broad Inst., Inc.*, 903 F.3d 1286, 1293 (Fed. Cir. 2018) (affirming the Board's finding given "substantial evidence that skilled artisans believed many problems could arise in implementing the CRISPR-Cas9 system in eukaryotes, which the Board viewed as indicating that an ordinarily skilled artisan would have lacked a reasonable expectation of success.").

b. Polysilicon Emitters and Tunnel Oxide Layers Were Not Known Elements in Solar Cells

Petitioner's assertion that fabricating Froitzheim's solar cell with Gan's polysilicon emitters and interfacial oxide "was simply substituting one known element for another to obtain predictable results" is incurably infected with hindsight bias, mischaracterizations of the state of the art, and references that do not adequately support the assertion. Paper 3, 34. In fact, Petitioner identified no

reference that successfully combined a solar cell with polysilicon emitters and a tunnel oxide layer, and thus failed its burden of proof. *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 401 (2007) (“[A] patent composed of several elements is not proved obvious merely by demonstrating that each element was, independently, known in the prior art.”); *In re NuVasive, Inc.*, 842 F.3d 1376, 1381-82 (Fed. Cir. 2016) (cleaned up) (The “factual inquiry” into the reasons for “combin[ing] references must be thorough and searching,” and “the need for specificity pervades.”); *Trivascular, Inc. v. Samuels*, 812 F.3d 1056, 1066 (Fed. Cir. 2016) (“[T]he Board must still be careful not to allow hindsight reconstruction of references . . . without any explanation as to how or why the references would be combined to produce the claimed invention.”) (emphasis omitted).

Specifically, the references Petitioner cited in its “known element” argument do not, in fact, show a POSITA how to add an interfacial oxide layer (tunnel oxide)² to a solar cell. Paper 3, 34. First, Petitioner cites “Ex.1005-Gan, 246.” As

² In its argument, Petitioner blurs the line between generic “oxide layers” and tunnel oxide layers. Paper 3, 34. They are not the same. A tunnel oxide allows the majority carrier to pass through it by a quantum mechanical process called tunneling. See Ex. 1005, 249 (“When the interfacial oxide is intact, tunneling is the only process available for the majority carrier to pass through the interfacial

discussed in § III.B.2, Gan does not teach the fabrication of a solar cell, but rather, the fabrication of test devices.

Second, Petitioner cites “Ex.1006-Borden-575, [0026].” That paragraph disclose an optional tunnel oxide layer grown in Borden-575’s contact holes, which do not exist in the Froitzheim-Gan combination. *See* Paper 3, generally; *see also* Ex. 2029, 246:4-10. Importantly, Borden-575 admits solar cells with tunnel oxides “have not been commercially introduced, possibly because of the difficulty of reliably forming a thin tunnel oxide.” Ex. 1006, ¶5.

Third, Petitioner cites “Ex.1004-Froitzheim, [0030].” Neither this paragraph nor the rest of Froitzheim mentions interfacial or tunnel oxide. Instead, Froitzheim’s [0030] discloses a front surface passivation layer 18 that may be an oxide, which is not relevant to Petitioner’s argument.

Fourth, Petitioner cites “Ex.1015-Swanson, 2:50-53.” This portion of Swanson mentions adjusting the thickness of a back side tunnel oxide, but does not teach a POSITA how to add one to a solar cell.

oxide.”); Ex. 1042, ¶¶3-4 (discussing the tunneling mechanics of an interfacial oxide); *also* Ex. 1003, ¶83; Ex. 2027, ¶¶77-84 (both experts discuss the characteristics of a tunnel oxide layer).

Fifth, Petitioner cites the '516 patent itself, claiming its silence on how to manufacture a tunnel oxide layer suggests that a POSITA would have understood how to do so. Paper 3, 34-35. Petitioner's case law does not support this argument. *Id.* (citing *Uber Techs., Inc. v. X One, Inc.*, 957 F.3d 1334, 1339 (Fed. Cir. 2020)). In *Uber Technologies*, the court held that a specification's silence was on a choice between “a finite number of identified, predictable solutions’ to a design need,” and that the design choice was not related to “the alleged novelty” of the patent at issue. 957 F.3d at 1339. Here, the POSITA has no finite number of identified, predictable solutions to implement Gan's interfacial oxide layer or the tunnel oxide layer of the '516 patent. In fact, Petitioner identified no solution at all, and as discussed in § VI.A.1.a, the Gan Thesis confirms that no solution was available at the time.

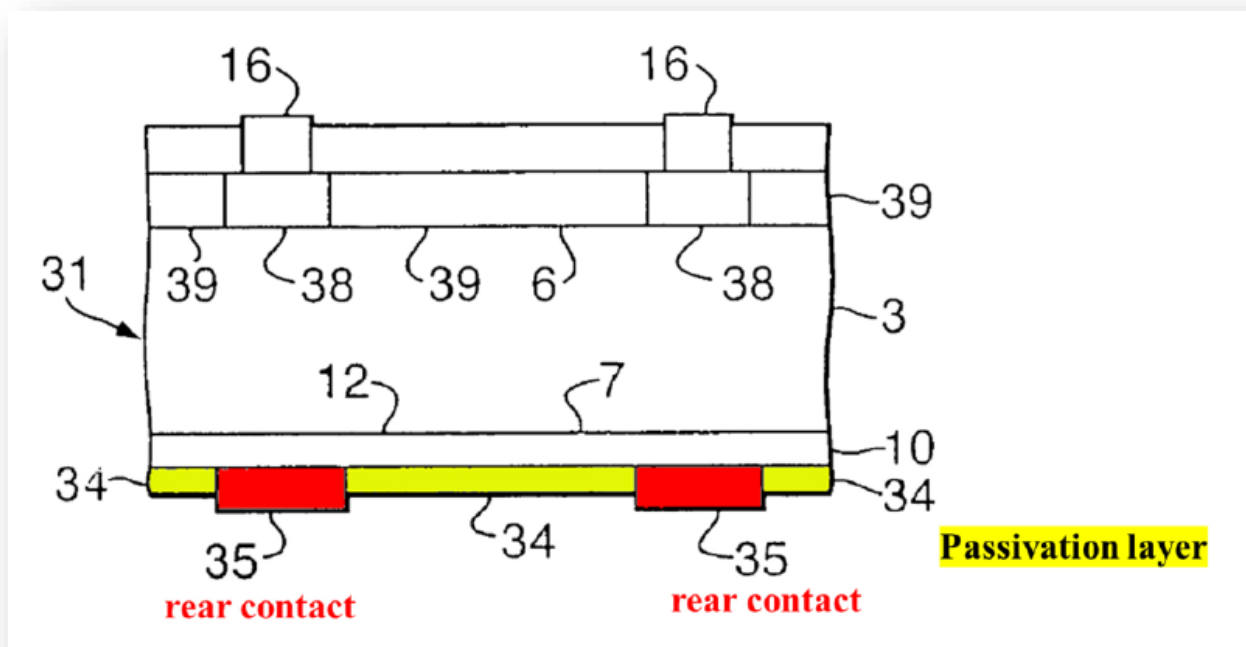
2. *The Proposed Froitzheim-Gan Combination Would Not Have Met the Limitation of Claim 12 of the '516 Patent*

The proposed Froitzheim-Gan combination does not include backside contacts with “silver formed over a layer of silicon dioxide,” as recited in claim 12 of the '516 patent.

Petitioner asserted that in Froitzheim, the passivation coating is applied before contact formation, and incorrectly concludes Froitzheim backside contact must be formed over the passivation layer. Paper 3, 51 (citing Ex. 1004 ¶50); see also *id.* at 59 (following citations of Ex. 1004, ¶50) (although Petitioner's

argument relates to formation of Froitzheim's frontside contacts, Froitzheim discloses that both contacts are formed in the same way, *see* Ex. 1004, ¶49). In reality, Froitzheim discloses forming metal contacts between the passivation layer. Ex. 2027, ¶183.

Froitzheim discloses that both its frontside and backside metal contacts are formed by screen printing and firing. Ex. 1004, ¶¶48-49. Froitzheim also discloses and illustrates that its passivation layer 34 is arranged “[b]etween the [rear contact 35] fingers.” *Id.* at ¶33.



Paper 3, 51 (citing Ex. 1004, Fig. 3) (annotations in Petition).

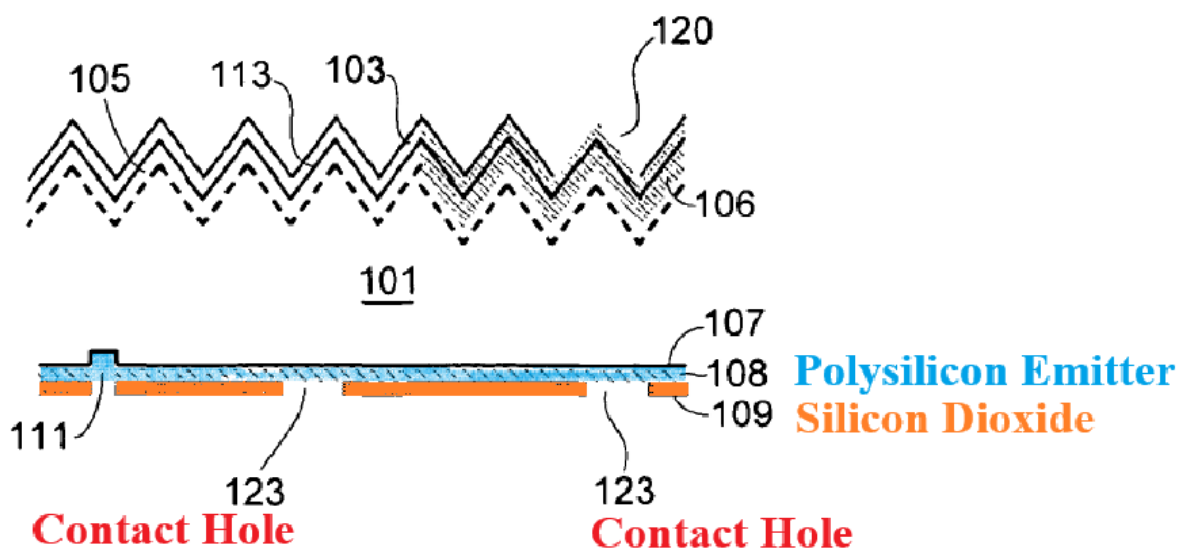
As shown above, the metal contacts (purple) are formed between the passivation layer (green), with no portion of the purple components being

positioned directly above (or below) the green components. Notably, Figure 3 illustrates the structure after firing, when the metal paste fires through the passivation layer. Before firing, the metal paste lies on top of the passivation layer. Ex. 2027, ¶186.

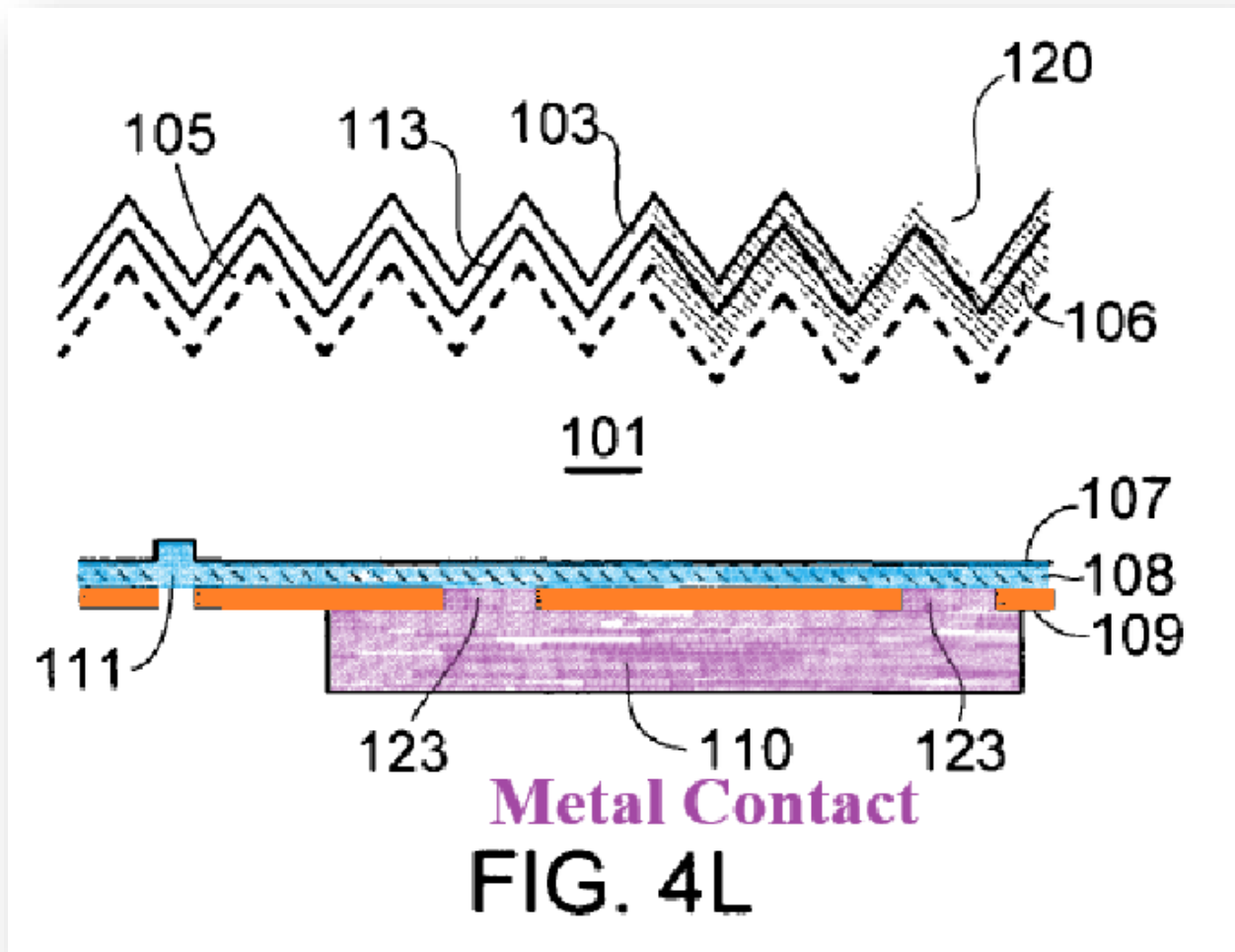
Thus, where Froitzheim's passivation is applied before contact formation, as Petitioner suggests, Paper 3, 51, a POSITA would have understood that a paste is fired through the passivation layer. Ex. 2027, ¶187.

In contrast, claim 12 requires that the backside contact be formed over a layer of silicon oxide. Ex. 1001, 6:63-65. Although the claim language speaks for itself, the '516 patent also provides a helpful description and illustration of the contact forming over the silicon dioxide layer, in contrast to Froitzheim.

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." Ex. 1001, 5:38-40.



Ex. 1001, Fig. 4K (annotated). 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.* at 5:48-50.



Ex. 1001, Fig. 4L (annotated). As shown, while parts of the metal contact 110 are formed over the silicon dioxide layer 109, the rest directly contacts the polysilicon emitter 108. The direct physical contact of the metal contact 110 and the polysilicon emitter 108 is needed to establish current flow. Ex. 2027, ¶191.

For this same reason, Froitzheim specifies that its squeegee paste is fired “to make electrical contact with the p region.” Ex. 1004, ¶49. Thus, in the proposed Froitzheim-Gan combination, the rear contact would not be formed on a silicon

dioxide passivating layer as Petitioner asserts. As a result, the proposed combination would not meet the limitation of “the second metal contact comprises silver formed over a layer of silicon dioxide” as recited in claim 12. Ex. 1001, 6:63-65.

B. Grounds II, IV: Petitioner’s Challenges of Claim 5 Based on Froitzheim, Gan/Borden-575, and Sheats Fail

Petitioner’s challenge of dependent claim 5 fails not only because Petitioner did not meet its burden with respect to independent claim 1 (see §§ VI.A.1, VI.C.1), but also because a POSITA would not have combined the proposed Froitzheim-Gan and Froitzheim-Borden-575 combinations with Sheats for at least three reasons. First, Petitioner’s alleged motivation to combine Froitzheim-Gan/Borden-575 with Sheats is superfluous. The alleged “edge isolation” that Sheats offers is both optional, and already provided in Froitzheim. Second, there are many techniques that achieve edge isolation, and the most common and popular technique is not trench cutting as taught by Sheats. Third, Sheats’ trench protects against short circuit between solar cells in an array, not a short circuit within a single solar cell such as the proposed Froitzheim-Gan/Borden-575.

Lastly, the patchwork of Froitzheim-Gan/Borden-575-Sheats, does not disclose all elements of claim 5 of the ’516 patent. Sheats’ trench is cut up “to” the substrate layer, not “into” the substrate as claim 5 recites.

1. *Edge Isolation Would Have Been Superfluous in Any Proposed Froitzheim Combinations*

Edge isolation is optional in Froitzheim's invention, and if one is needed, Froitzheim already discloses it. Ex. 1004, ¶47 ("If required after the formation of the n⁺ doped layer, a separation at the edge of the wafer may be performed, e.g. in a plasma."); Ex. 2029, 157:19-158:5 (Petitioner's expert testifying that paragraph 47 of Froitzheim "describes what is generally referred to as edge isolation."); Ex. 2027, ¶194.

Froitzheim's optional edge isolation is consistent with Petitioner's cited reference, Houser, teaching there are "several approaches to avoid" edge isolation. Paper 3, 62 (citing Ex. 1063); Ex. 1063, 1739 (proposing approaches such as "co diffusion," "diffusion by means of printing or silicon nitride (SiN)," and "one-sided emitter.>").

Thus, contrary to Petitioner's assertion, a POSITA would not "have been motivated to isolate the edge of Froitzheim's modified solar cell to prevent short circuits." Paper 3, 62. Indeed, if modifying Froitzheim's solar cell (in which edge isolation is optional) with Gan would cause short circuit concerns, a POSITA would not have combined the two references in the first place. Ex. 2027, ¶¶198-99. A POSITA would not have made an unnecessary modification that requires additional manufacturing steps (edge isolation) to resolve. *Id.* at ¶199.

2. *Even If Additional Edge Isolation Is Justified, a POSITA Would Not Have Used Trenches*

According to Petitioner’s own references, trenches are one of many edge isolation techniques, and not the most common one. For example, Houser repeatedly emphasizes that plasma etching of a wafer stack is “a common [edge isolation] technique in industry.” Ex. 1063, 1739; *see also id.* (“In industry the plasma etching of wafer stacks is very common); *id.* at 1742 (“In industry this [edge isolation] is mostly done by plasma etching of a wafer stack). Another one of Petitioner’s references, Wenham, agrees. Paper 3, 62 (citing Ex. 1066); Ex. 1066, 7:40-41 (“[Plasma etched edge isolation] is the technique believed to be used very effectively by several commercial enterprises.”). Notably, Froitzheim discloses plasma etching. Ex. 1004, ¶47 (“If required after the formation of the n+ doped layer, a separation at the edge of the wafer may be performed, e.g. in a plasma.”) (emphasis added); Ex. 2029, 159:14-20 (Petitioner’s expert agreeing that the last word of Froitzheim paragraph 47 refers to plasma etching).

Plasma etching aside, a POSITA would still have had several alternative edge isolation techniques. *See, e.g.,* Ex. 1063, 1739 (Houser identifying “the grinding of the wafer edge with sandpaper” as an edge isolation technique); Ex. 1066, 7:24-26 (Wenham disclosing “scribing the rear of the solar cell and then cleaving off the edges” as an edge isolation technique); Ex. 1020, Fig. 7.6 (Luque, cited in Paper 3, 62, illustrating “[a] typical processing sequence” for solar

fabrication based on screen printing, where the “edge isolation” step does not involve any trenches).

In sum, absent a hindsight reconstruction of claim 5, it is unlikely that a POSITA would select trenches over the common and popular plasma etching technique and the many other alternatives. Ex. 2027, ¶211; *see also Otsuka Pharm. Co. v. Sandoz, Inc.*, 678 F.3d 1280, 1296 (Fed. Cir. 2012) (“The inventor's own path itself never leads to a conclusion of obviousness; that is hindsight.”).

3. *A POSITA Would Not Have Looked to Sheats, Directed to Solar Arrays, for Edge Isolation for a Single Solar Cell*

To be clear, Petitioner claims a POSITA would want “to isolate the edge of Froitzheim’s modified solar cell to prevent short circuits.” Paper 3, 62. To do so, the POSITA would have modified Froitzheim to include a trench as taught by Sheats, specifically “‘an isolation trench 516’ formed through the transparent conductive layer and the active layer.” *Id.* at 60-61.

There is a gaping hole in Petitioner’s logic. In a single solar cell (such as Froitzheim/Gan and Froitzheim/Borden-575), edge isolation electrically isolates the front and rear surfaces of the solar cell, preventing unwanted current pathways or shunts that may cause short circuit within. Ex. 2027, ¶214. Sheat’s isolation trench 516, on the other hand, is to prevent short circuit between two or more solar cells in array formation. *Id.* at ¶215.

a. Sheats Is About Solar Cell Arrays

The distinction between the isolation trench 516 of Sheats and the edge isolation trench 111 of the '516 patent becomes apparent in the full context of Sheats.

Sheats addresses “problems associated with series interconnection of optoelectronic devices [solar cells].” Ex. 1012, ¶7. This is because “individual optoelectronic devices produce only a relatively small voltage” such that “it is often necessary to electrically connect several devices together in series in order to obtain higher voltages.” *Id.* at ¶5.

Sheats focuses on the drawbacks of solar cell arrays (*e.g.*, 600 below) manufactured from a single substrate (*e.g.*, 602 below), where holes (*e.g.*, 604, 608 below) are cut into the substrate to form multiple solar cells. *See, e.g.*, Ex. 1012, ¶¶10-12.

Prior Art Solar Cell Array

600

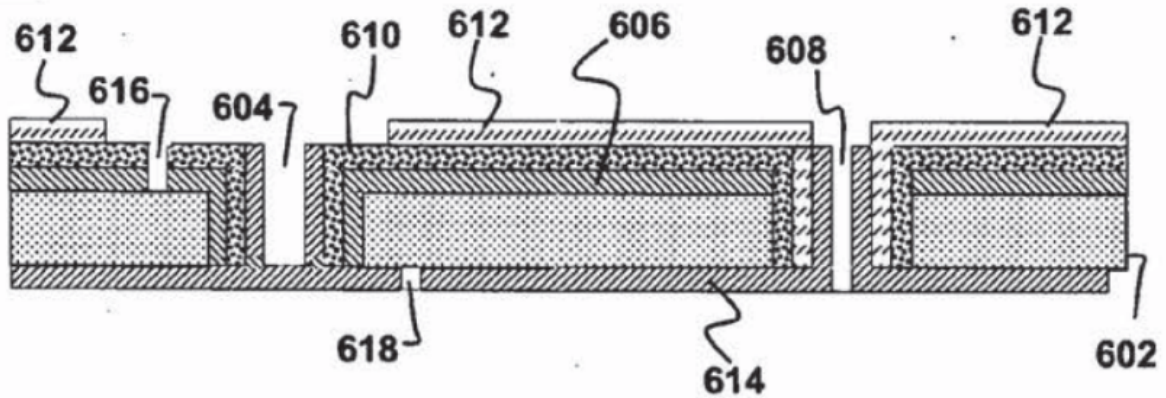
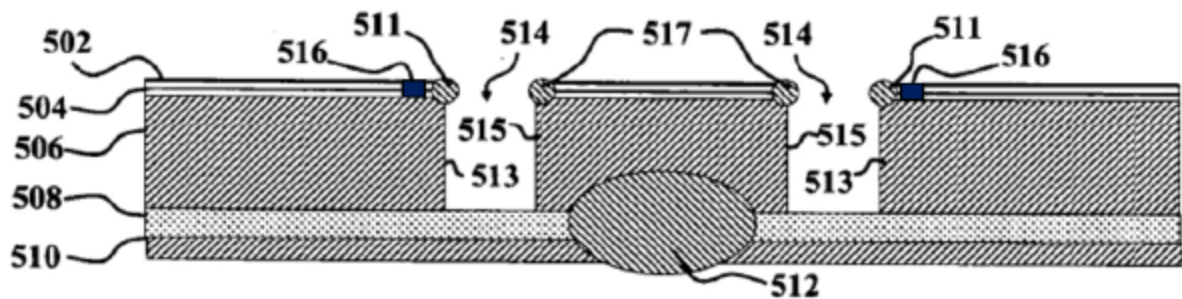


FIG. 6A

Ex. 1012, Fig. 6A (annotated); *see also id.* at Fig. 6B.

One of the embodiments of Sheats' purported solutions, which Petitioner relied on, similarly includes a single structure (500) separated into multiple solar cells.



Paper 3, 61 (citing Ex. 1012, ¶¶3-4, 58-59) (illustrating Ex. 1012, Fig. 5D).

Petitioner's expert agrees that Figure 5D illustrates multiple solar cells:

Q Figure 5D shows three rectangular blocks listed on top of layers 508 and 510. Right?

A Yes.

Q And the isolation trench 516 is illustrated in two of those three rectangular blocks. Right?

A That is correct.

Q Is it accurate to say that those three rectangular blocks represent three solar cells?

A I am turning to Sheats. Just give me one moment.
(Exhibit 1012, previously marked.)

A Yes, it would be appropriate to call each of the blocks a solar cell, and more particularly the layer identified as 504 is the intended absorber layer of the solar cell, going back to our previous discussion.

Ex. 2029, 240:1-18.

b. Sheats' Trench 516 Isolates Two Solar Cell Devices

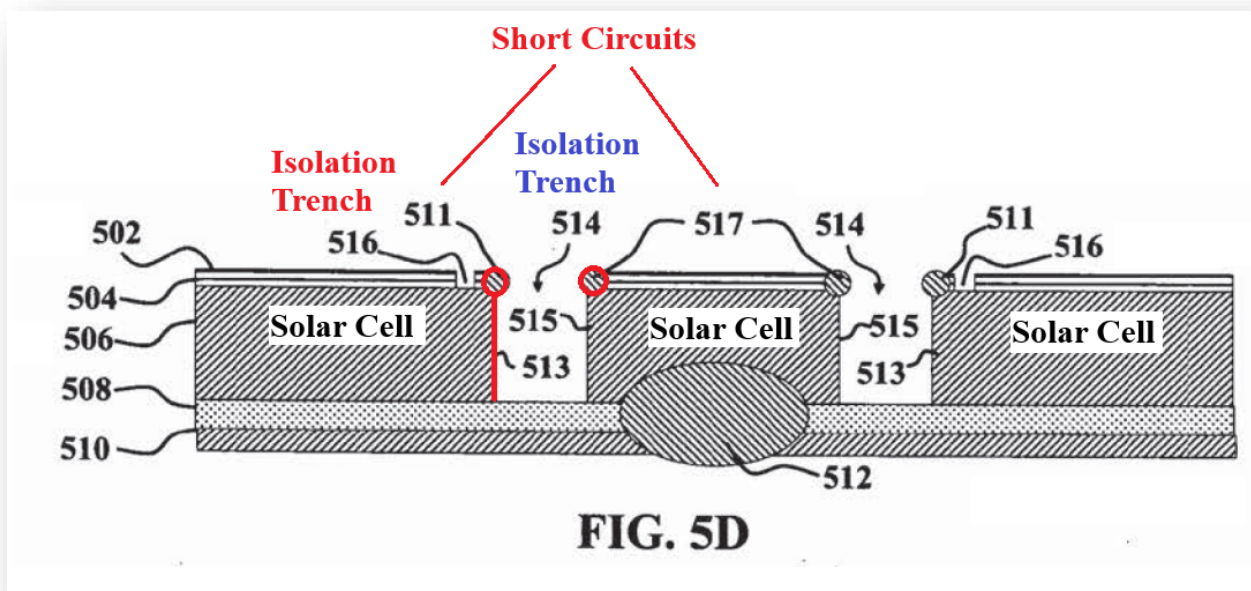
In the full context of Sheats, then, the function of isolation trench 516 becomes clear: to prevent short circuit between points 511 and 517 during the formation of trench 514.

The process of forming the isolation trench [514] may cause electrical short- circuits 511, 517 between the transparent conductive layer 502 and the bottom electrode 506. To electrically isolate undesirable short circuits 511 formed on an outside wall 513 of the trench 514 an

isolation trench 516 is formed through the transparent conductive layer and the active layer to the bottom electrode 506 as shown in FIG. 5D. **The isolation trench 516** surrounds the closed-loop trench 514 and electrically isolates the short circuits 511 on the outside wall 513 of the trench from the rest of the structure 500.

Ex. 1012, ¶¶59 (emphasis added).

In other words, the function of isolation trench 516 is to prevent short circuit between two solar cells in an array, during the formation of the gap (514) that separates these two solar cells:



Ex. 1012, Fig. 5D (annotated).

Thus, a POSITA modifying Froitzheim with a trench to prevent short circuit within the single solar cell, Paper 3, 62 (“A POSITA would have been motivated to isolate the edge of Froitzheim’s modified solar cell to prevent short circuits”),

would not have based their modification on Sheats disclosing a trench to prevent short circuit between two solar cells.

4. *Sheats' Involvement in the Prosecution History Is Not Relevant to Petitioner's Petition*

Petitioner's argument that the Examiner cited Sheats during prosecution of the '516 patent does not help Petitioner's wayward argument. Paper 3, 60-61 (*citing* Ex. 1002, 81-82; *id.* at 112). The applicant's lack of response to the Examiner's findings during an *ex parte* proceeding does not constitute waiver of, or estoppel to, Maxeon's ability to defend claim 5 in an adversarial proceeding such as the instant IPR Petition. *Medtronic Vascular, Inc. v. TMT Sys., Inc.*, IPR2021-01532, Paper 56 at 39-42 (PTAB Mar. 7, 2023) (Rejecting estoppel arguments because the same issues were not "actually litigated" during "[t]he prosecution of [a patent] application [which] is an *ex parte* proceeding, not an adversarial proceeding such as a district court litigation or *inter partes* review."); *see also Phillips v. AWH Corp.*, 415 F.3d 1303, 1317 (Fed. Cir. 2005) (recognizing, in the context of claim construction, that the "prosecution history represents an ongoing negotiation between the PTO and the applicant, rather than the final product of that negotiation").

C. Ground III: Petitioner’s Challenge of Claims 1-4 and 6-12 Based on Froitzheim and Borden-575 Fails

Petitioner failed to clearly define its proposed combination for this Ground. It is unclear whether Petitioner proposes implementing Froitzheim with Borden-575’s tunnel oxide or its buried oxide. But either implementation would fail, and either implementation (even if it could have been imagined) would also fail to meet at least one limitation recited in the independent claims.

1. Petitioner’s Proposed Froitzheim-Borden-575 Combination Is Impermissibly Vague

Petitioner’s proposal to implement “Borden-575’s polysilicon emitter and tunnel oxide layer to the backside configuration taught by Froitzheim” is impermissibly vague. Paper 3, 65; *but see* 37 C.F.R. § 42.104(b)(4) (requiring that petition “must specify where each element of the [challenged] claim is found in the prior art patents or printed publications relied upon”); 37 C.F.R. § 42.22(a)(2) (the Petition must include, among others, “a detailed explanation of the significance of the evidence.”); *Intelligent Bio-Systems, Inc. v. Illumina Cambridge Ltd.*, 821 F.3d 1359, 1369 (Fed. Cir. 2016) (“It is of the utmost importance that petitioners in the IPR proceedings adhere to the requirement that the initial petition identify ‘with particularity’ the ‘evidence that supports the grounds for the challenge to each claim.’”).

On the one hand, Petitioner appears to propose implementing Borden-575's tunnel oxide, which is not disclosed as a layer of any kind. *See, e.g.*, Paper 3, 65-66 (multiple references to a "tunnel oxide layer"). On the other hand, Petitioner repeatedly refers to a tunnel oxide "layer" and labels its proposed combination with an "oxide layer," *see, e.g., id.* at 65, 70, 71, 73, 76 (illustrating an "oxide layer"), while also referencing Borden-575's buried oxide in section X.C.2.c of the Petition (discussing claim limitation 9[c]), *id.* at 69 (highlighting "buried oxide" three times).

In fact, Petitioner's expert testified that Petitioner's illustration of the proposed Froitzheim-Borden-575 includes a label for "oxide layer" that is intentionally vague to represent both the tunnel oxide layer and the buried oxide layer:

Q On Page 146, above Paragraph 224, you illustrate this Froitzheim-Borden 575 combination. Right?

A Above Paragraph 226.

Q Yes.

A Yes.

Q And the orange line labeled as oxide layer is referring to the tunnel oxide layer as taught by Borden 575. Right?

A Borden teaches two oxide layers, and this oxide layer shown in the figure is purposefully labeled oxide layer. As I say in the text, we require Borden 575's tunnel oxide layer in order to make a functioning solar cell. But Borden teaches that its tunnel oxide layer

doesn't necessarily have to cover the entire wafer surface, and that its other oxide layer may also occupy some of the wafer surface. So this figure labeling the oxide layer as oxide layer recognizes that Borden's tunnel oxide layer is required, as described in the text, but doesn't limit Borden's teachings to his tunnel oxide layer.

Q So in the Froitzheim-Borden 575 combination are you incorporating Borden 575's other oxide layer as well?

A I -- I leave that possibility, as Borden teaches both. I am incorporating at least Borden's tunnel oxide layer.

Ex. 2029, 242:22-244:6.

Petitioner's intentional vagueness shifts the burden on the Patent Owner and the Board to guess which components would be included in proposed Froitzheim-Borden-575 combination. This is improper. *Parus Holdings, Inc. v. Google LLC*, 70 F4th 1365, 1372 (Fed. Cir. 2023) (internal quotations removed) (“[T]he Board should not be forced to play archaeologist with the record.”); *VIZIO, Inc. v. Nichia Corp.*, IPR2017-00551, Paper 9 at 9-12 (PTAB July 7, 2017) (“Petitioner leaves us to weave together these quotes in a manner that would have rendered the claim obvious. That, however, is not our role.”); *Ivantis, Inc. v. Glaukos Corp.*, IPR2018-01180, Paper 14 at 14 (PTAB Dec. 6, 2018) (citing 37 C.F.R. § 42.22(a)(2)) (“A patent owner should not have to guess what challenges a petitioner intends to make in a petition but did not.”).

2. *Petitioner Failed to Show Why a POSITA Would Have Used Borden-575's Buried Oxide*

To the extent Petitioner proposes implementing Borden-575's buried oxide, Petitioner is silent on why a POSITA would have been motivated to do so, and silent on whether a POSITA could have reasonably expected the implementation to be successful. Petitioner's expert also testified that his declaration did not discuss a POSITA's motivation to incorporate Borden's 575 buried oxide layer:

Q Do you discuss a POSITA's motivation to incorporate Borden's 575 buried oxide layer anywhere?

A I discuss a POSITA's motivation to incorporate the tunnel oxide layer taught by Borden. Because as I just mentioned, one requires Borden's tunnel oxide layer to make a working combination because the tunnel oxide layer allows current to flow. That is to say it has low contact resistivity, low C. But the combination doesn't have to necessarily be limited to Borden's tunnel oxide. Borden teaches a second oxide, a buried oxide, and it can – Borden's full teachings also results in a combination that meets the limitation of -- limitations of the claims.

Q But my question was, do you discuss a POSITA's motivation to incorporate Borden's buried oxide layer anywhere?

A I do not. I discuss a POSITA's motivation to include Borden's tunnel oxide layer, as it is the tunnel oxide layer that is necessary to make a working solar cell. I'm explaining why I have labeled in the figure this oxide layer, as opposed to tunnel oxide layer, because it is possible for a POSITA to take more than just Borden's tunnel oxide

layer because Borden teaches more than that, as I have acknowledged in the footnote on Page 155.

Ex. 2029, 244:12-245:17 (emphasis added).

Thus, Petitioner failed its burden to show obviousness based on a proposed Froitzheim-Borden-575 combination using Borden-575's buried oxide. *Elekta Ltd. v. ZAP Surgical Sys., Inc.*, 81 F.4th 1368, 1374-75 (Fed. Cir. 2023) (citation omitted) ("Obviousness requires, inter alia, a finding that a skilled artisan would have been motivated to combine the teachings of prior art in such a way that the combination discloses the claimed limitations. . . To be clear, an obviousness determination requires finding that a person of ordinary skill in the art would have had a reasonable expectation of success.").

3. *Petitioner Failed to Show Why a POSITA Would Have Been Motivated to Combine Froitzheim and Borden-575*

Regardless of whether the proposed Froitzheim-Borden-575 combination uses Borden-575's tunnel oxide, or buried oxide, or both, any of those combinations would be fatally flawed. Without the buried oxide, Burden-575's polysilicon emitter would not work. But with the buried oxide, Froitzheim's rear metal contacts would not receive current flow because Petitioner omitted contact holes from its proposed implementation. This is because "the cell structure includes an insulating (e.g. oxide) layer 214 under the doped region 210 and the

contact 202. The insulating layer 214 [the buried oxide layer] the contact 202 from the substrate 200.” Ex. 1006 at ¶19

a. Borden-575’s Tunnel Oxide Would Have Been Too Difficult to Implement

If Petitioner proposes implementing Borden-575’s tunnel oxide, then a POSITA would not have been motivated because the tunnel oxide would have been too difficult to reproduce with consistent and reliable thickness for the same reasons discussed in § VI.A.1.b. Ex. 2027, ¶231. The Gan Thesis discloses its struggle to control its oxide thickness to be between 15 to 20 Å, *see e.g.*, Ex. 2003, 119, yet Borden-575 requires its tunnel oxide to be even thinner, Ex. 1006, ¶22 (“[T]ypically 8 to 15Å thick.”). This is perhaps why the tunnel oxide is optional in Borden-575: Borden-575 provides no answer to the unresolved mystery of the Gan Thesis—how to reliably grow the thin oxide—other than to suggest not using a tunnel oxide. *See, e.g.*, Ex. 1006, ¶19 (“[A tunnel oxide] is not necessary in all embodiments.”); *see also id.* at ¶26 (“Another embodiment does not use the tunnel oxide.”).

In fact, Borden-575 states outright that the same problems with the oxide layer in the Gan Thesis are present in Borden’s embodiment with the tunnel oxide layer:

Another method to passivate contacts is to place a thin tunnel oxide - typically 15Å thick – under the metal contacts. Such types of contacts

are also well known, and have been used commercially by Schott solar to manufacture MIS solar cells. However, such solar cells have not been commercially introduced, possibly because of the difficulty of reliably forming a thin tunnel oxide.

Ex. 1006, ¶ 5 (emphasis added). Therefore, a POSITA would not have been motivated to combine the tunnel oxide layer of Borden-575 with Froitzheim because the tunnel oxide layer is hard to reproduce consistently and reliably. Ex. 2027, ¶236.

Further, Borden-575 uses the same high temperatures that the Gan thesis warns about:

In embodiments, the doped region 210 is formed using polysilicon, which may be deposited at a temperature on the order of 630° C and is in-situ doped. A short anneal at 1050° C for 30 seconds after deposition activates the dopants. As mentioned above, in some embodiments a thin tunnel oxide may be included between the substrate 200 and the polysilicon 210 in the contact holes 212.

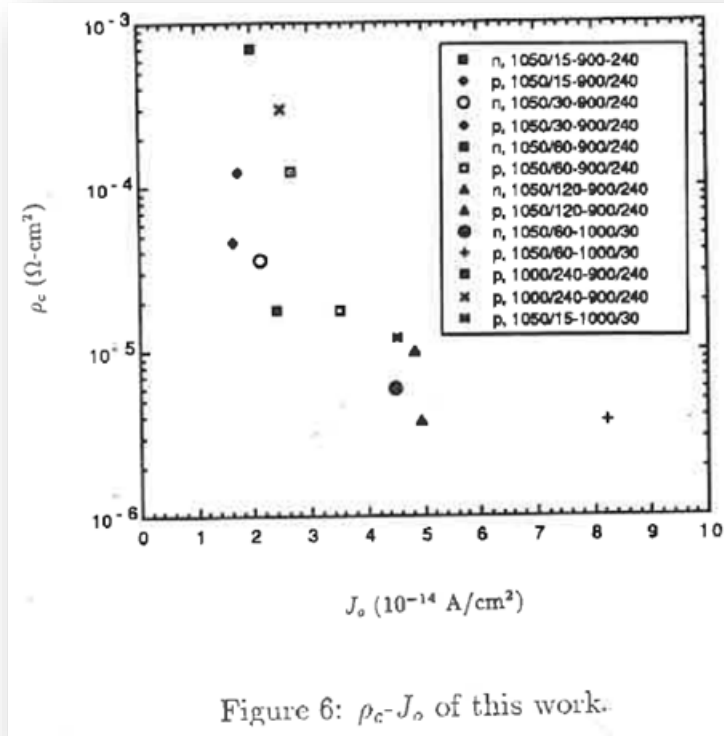
Ex. 1006, ¶ 22 (emphasis added). As discussed in § III.B.3, Gan teaches the higher the temperatures and time for the second step anneal, the worse the value of J_o :

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	

Ex. 1005, Table 1.

As shown below, Gan showed that a second step anneal at only 1000° C were the worst temperatures tested despite the fact that the high temperature second anneal lasted 1/8th as long as a lower temperature second anneal at 900°C.:



Ex. 1005, Fig. 6.

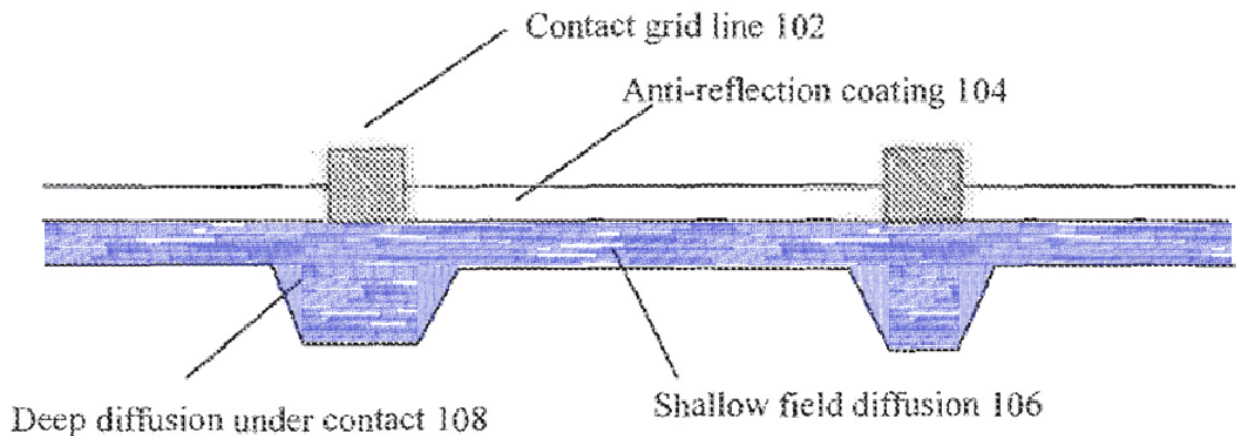
Although Borden-575 discloses a shorter anneal time than Gan, Gan is clear that using a temperature of 1000°C provided unsatisfactory results and Borden-575 teaches annealing at the even higher temperature of 1050°C. A POSITA with armed with the knowledge of the Gan Thesis would have rejected using Borden-575 because a tunnel oxide is not commercially viable if Borden-575 is followed. Ex.

1006, ¶ 5 (“[S]uch solar cells have not been commercially introduced, possibly because of the difficulty of reliably forming a thin tunnel oxide.”) (emphasis added). Therefore, a POSITA would not have been motivated to modify Froitzheim with the tunnel oxide layer or a combination of the tunnel oxide layer and buried oxide layer of Borden-575. Ex. 2027, ¶241.

b. A POSITA Would Not Have Implemented Borden-575’s Polysilicon Emitter Without Borden-575’s Buried Oxide

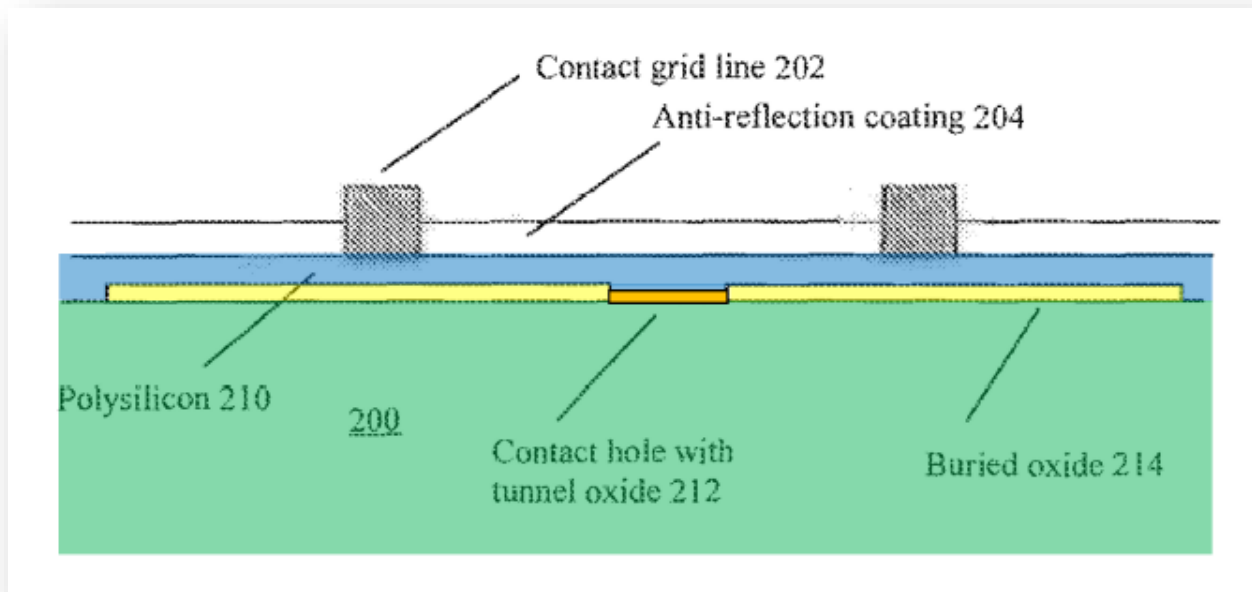
Even if undeterred by the travails revealed in the Gan Thesis, a POSITA would still not have implemented Borden-575’s polysilicon emitter in Froitzheim. In addition to Petitioner’s failure to show any motivation to combine or reasonable expectation of success (as discussed in § VI.C.2), there would have been no reasonable expectation of success from using Borden-575’s polysilicon emitter without its complimentary buried oxide. Ex. 2027, ¶242.

Borden-575 emphasizes the importance of isolating contacts in solar cells, Ex. 1006, ¶3 (“[C]ontact passivation is essential.”), and discusses prior art selective emitter structures that provide contact isolation. Below is the prior art selective emitter structures featuring deep diffusion 108 that “provide isolation so that the high recombination contact surfaces do not affect the cell performance.” Ex. 1006, ¶4.



Ex. 1006, Fig. 1 (annotated). Borden-575 notes the difficulty of forming selective emitters because “they require aligned patterning of the contact holes and the metal lines, as well as a several hour diffusion to obtain such a deep junction. Therefore, selective emitters are rarely used in commercial solar cells.”) *Id.* at ¶4.

Borden-575’s purported innovation thus collapses into a “buried oxide under the emitter of a polysilicon emitter solar cell.” Ex. 1006, Abstract. With this buried oxide providing “an excellent passivation layer” that “isolates the contacts from the substrate,” Borden-575 was able to use “a selective emitter structure without requiring deep diffusions.” *Id.*; see also *id.* at ¶16.



Paper 3, 68 (citing Ex. 1006, Fig. 2) (annotation in original).

Borden-575 explains that “if the insulating layer [buried oxide] 214 is made using a material that passivates silicon, such as thermal SiO₂, then the solar cell surface has very good passivation and a low surface recombination velocity, both in the field region 210 and under the contacts 202.” Ex. 1006, ¶19. The buried oxide may then combat the high surface recombination velocity of a metal contact, thereby achieving the essential contact passivation that Borden-575 emphasizes. *Id.* at ¶3.

Thus, it is important that the buried oxide be placed under each metal contact. Ex. 2027, ¶251. As Borden-575 notes, “the contact metal 202 is blocked from reaching the substrate 200 by the buried oxide 214. This enables contacting to the thin emitter without use of a sophisticated contact process.” Ex. 1006, ¶3.

In other words, polysilicon emitter 210 functions properly in Borden-575 because of buried oxide 214. Ex. 2027, ¶251.

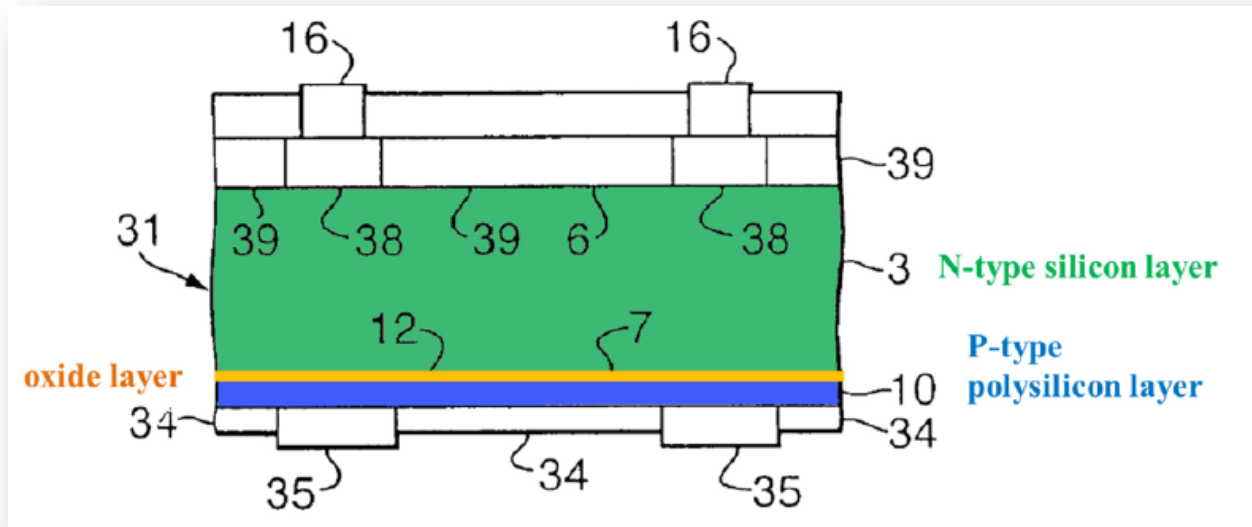
The buried oxide is not to be confused with an optional “thin tunnel oxide,” which Borden-575 separately discloses. *Compare* Ex. 1006, Abstract and ¶¶7, 16 (disclosing “buried oxide”) *with id.* at ¶¶19, 22 (disclosing a “thin tunnel oxide.”); *see also* Paper 3, 69 (separately coloring the two components).

This distinction is important because, at least in its motivation to combine section, Petitioner’s proposed Froitzheim-Borden-575 combination does not include consideration of the buried oxide. *See, e.g.*, Paper 3, 65-66 (multiple references to a “tunnel oxide layer”). Petitioner’s expert confirmed this omission. Ex. 2029, 244:12-245:17. Froitzheim’s own oxide layer is no suitable substitute because it is removed after doping. Ex. 1004, ¶¶44-45.

Without the buried oxide, Borden-575’s thin emitter would need “a sophisticated contact process,” such as the deep diffusion of prior art figure 1 of Borden-575, to reach the metal contact. Ex. 1006, ¶3. Froitzheim discloses no sophisticated contact process, and the Petition does not propose a solution to bridge this gap. Thus, a POSITA would not have reasonably expected to succeed in implementing Borden-575’s barebone emitter with Froitzheim. Ex. 2027, ¶254-55.

c. Borden-575's Buried Oxide Requires Contact Holes

To the extent Petitioner proposes to utilize Borden-575's buried oxide, there would still be no reasonable expectation of success because Petitioner's proposed combination omits contact holes



Paper 3, 70 (illustrating the Froitzheim-Borden-575 combination with an “oxide layer” but no contact holes).). Petitioner’s expert also testified that the proposed Froitzheim-Borden-575 combination did not include Borden-575’s contact holes. Ex. 2029, 245:18-246:15.

This omission is fatal. Ex. 2027, ¶¶256-58. Borden-575 defined the term “contact hole” broadly to include many types of openings, Ex. 1006, ¶20, but Borden-575 does not once contemplate the possibility of there being no opening at all. This is because contact holes are a crucial feature; they “allow current flow”

between the emitter and the substrate. Ex. 1006, ¶¶8, 9; *see also id.* at ¶19

(“Contact holes 212 are provided in the insulating layer 212 [*sic*]³ to allow for photocurrent flow.”).

More specifically, this is because the buried oxide is an “insulating (*e.g.*, oxide) layer 214 under the doped region 210 and the contact 202.⁴ This insulating layer 214 isolates the contact 202 from the substrate 200.” Ex. 1006, ¶19. Thus, contact holes are needed to permit current flow from the substrate to reach the metal contacts. Ex. 2027, ¶262.

Without that current flow, the metal contacts would not withdraw photocurrent from the p/n junction. Ex. 2027, ¶263. As Froitzheim explains in its background section, the “emitter layer forms a p/n-junction with the p-doped base layer [substrate]. Front and rear side contacts are arranged to be in electrical connection with the n-doped layer and the p-doped base layer, respectively, to

³ The label “212” here appears to be an error. The “insulating layer” is labelled as “214” throughout Borden-575, Ex. 1006, ¶¶18-21, and appears to be used interchangeably with the term “buried oxide,” *id.* at Figs. 2, 3, ¶24.

⁴ For this reason, Borden-575’s buried oxide does not satisfy the claim limitation of “oxide layer” as recited in independent claims 1 and 9, which the specification describes as tunnel oxide layers.

withdraw a photocurrent from both sides of the p/n-junction.” Ex. 1004, ¶2. In Borden-575’s structure, then, if the buried oxide has no contact holes, then the metal contacts are rendered inoperable, and no power could be drawn out of the solar cell. Ex. 2027, ¶264.

Thus, to the extent Petitioner proposes implementing Borden-575’s buried oxide, Petitioner’s failure to identify contact holes would reduce a POSITA’s expectation of success to zero. Ex. 2027, ¶265.

d. The Alleged Motivation of “allowing for tunnel current flow” Is Not Prior Art

In support of its motivation to combine arguments, Petitioner cited Borden-575’s disclosure that its tunnel oxide provides “passivation between the substrate and the polysilicon, while allowing for tunnel current flow.” Paper 3, 66 (citing Ex. 1006, ¶22) (emphasis added). However, the underlined portion of Borden-575 should not be considered because it is not supported by the Borden-575 Provisional and therefore not prior art. *See* § III.E.2.

4. *The Proposed Froitzheim-Borden-575 Combination Would Not Have Met the Limitation of Claim 12 of the ’516 Patent*

With respect to claim 12, Petitioner “incorporates Section X.C.2 [Petitioner’s argument from the Froitzheim-Gan combination]. The combination of Froitzheim-Borden-575 teaches this element for the reasons in Section X.A.5 [arguing that Froitzheim satisfies the limitation of claim 12].” Paper 3, 74. Thus,

Petitioner did not argue that aspects of Borden-575 would satisfy the limitation of claim 12.

As discussed in § VI.A.1.b, Froitzheim, and thus the proposed Froitzheim-Gan combination, fail to satisfy the limitation of having backside contacts with “silver formed over a layer of silicon dioxide” as recited in claim 12 of the ’516 patent. Replacing Gan with Borden-575 does not mitigate Froitzheim’s shortcoming in this regard. Ex. 2027, ¶¶266-67.

D. Ground V: Petitioner’s Challenge of Claims 1-2 and 8-11 Based on Li and Gan Fails

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

As discussed in § VI.A.1.a, a POSITA would not have been motivated to implement Gan’s polysilicon emitter and interfacial oxide structure in an actual solar cell because the Gan Thesis teaches that Gan’s interfacial oxide could not be reliably grown. Replacing Li with Froitzheim does not remedy those problems.

Further, because a POSITA would not have been motivated to combine Li and Gan for the same reasons discussed in § VI.A.1.a, Petitioner failed to show obviousness of the limitation of (1) forming “a P-type polysilicon emitter” (claim 1) or forming “an emitter layer” (claim 9) using Gan’s polysilicon emitter, and (2) forming “an oxide layer” (claims 1 and 9) using Gan’s interfacial oxide. Li does not disclose a polysilicon layer or an oxide layer at the specific location recited in

the claims. *Id.* Therefore, the proposed Li-Gan combination does not satisfy the independent claims of the '516 patent

2. *Li Teaches Away from Gan*

A POSITA would not have been motivated to modify Li using Gan's polysilicon emitter and oxide layer, Paper 3, 79, because Li teaches away from Gan. *Arctic Cat Inc. v. Bombardier Recreational Prod. Inc.*, 876 F.3d 1350, 1360 (Fed. Cir. 2017) (“[A] reference may be found to teach away from a claimed combination.”); *In re Mouttet*, 686 F.3d at 1333 (holding that a “reference that properly teaches away can preclude a determination that the reference renders a claim obvious.”); *In re Urbanski*, 809 at 1244 (“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.”).

Li's purported invention is a solar cell with a “heterogeneous PN junction” that has certain advantages over a conventional solar cell with a “homogeneous PN junction.” One such advantage is that Li's heterogeneous PN junction solar cell “is prepared by a low-temperature deposition method, which avoids a conventional diffusion process at 800-1000°C.” Ex. 1008, 4.

Compared to high-temperature diffusion, low-temperature diffusion results in fewer defects and contamination in silicon materials, improved efficiency, and

reduced manufacturing cost. Ex. 1008, 3 (“[Homogeneous PN junction solar] cells have the disadvantages that the high-temperature diffusion may cause more defects in silicon materials, and when pollution is caused by a high-temperature process, cell efficiency will be greatly reduced.”); *id.* (“[A] deposition [of amorphous silicon] temperature is low (200°C”), and a process is relatively simple, such that a high-temperature process is avoided, and the manufacturing cost of the cell is reduced.”); *id.* at 4 (“[Conventional diffusion process at 800-1000°C] will cause more defects or contamination in a silicon material, which will affect the improvement of cell efficiency.”).

In the context of Li’s disclosure, then, a POSITA would not have been motivated to implement Gan’s polysilicon emitter and oxide layer. Ex. 2027, ¶274. Construction of Gan’s polysilicon emitter and oxide layer would repeatedly require the kind of high temperature processes that Li teaches should be avoided. Specifically, in Gan’s 12-step process to construct its experimental device, step 3 is “[t]hin thermal oxide growth at 800 °C,” step 4 is “[p]olysilicon deposition (6000 Å) and first-step anneal at 1050 °C,” and step 10 is “[dopant d]rive-in; 900-1000 °C.” Ex. 1005, 246; *see also* Ex. 2029, 238:4-239:7 (testifying that the proposed Li-Gan combination uses Gan’s polysilicon emitter and oxide layer); *id.* at 236:16-20 (testifying that Gan’s step 3 discloses the formation of an oxide layer); *id.* at

237:13-18 (testifying that Gan’s steps 4, 9, and 10 disclose the formation of a polysilicon emitter).

Thus, Li teaches away from Gan, and a POSITA would not have combined the two references. Ex. 2027, ¶280; *see also Arctic Cat*, 876 F.3d at 1360 (quoting *Allergan, Inc. v. Sandoz Inc.*, 796 F.3d 1293, 1305 (Fed. Cir. 2015)) (“Prior art teaches 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.’”); *Trivascular, Inc. v. Samuels*, 812 F.3d 1056, 1068 (Fed. Cir. 2016) (affirming the Board’s finding that a reference taught away from substituting a feature because that feature was “the primary objective of the reference.”).

VII. CONCLUSION

For the foregoing reasons, claims 1-12 of the ’516 patent are patentable.

Respectfully submitted,

Date: May 22, 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, and certificate of word count, and list of exhibits, includes 13,420 words. Pursuant to 37 C.F.R. § 42.24(d), Patent Owner has relied on the word count feature of the word-processing system used to prepare this paper.

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CERTIFICATE OF SERVICE

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