

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 IPR2024-01199
U.S. Patent No. 8,878,053

PATENT OWNER 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

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

II. OVERVIEW OF THE '053 PATENT

A. The '053 Patent

The '053 patent discloses and claims a novel front contact solar cell with formed emitter. Ex. 1001, Title.

The patent describes, with reference to Figure 1, a cross-section of a solar cell in accordance with an embodiment of the present invention. Ex. 1001, 2:6-7.

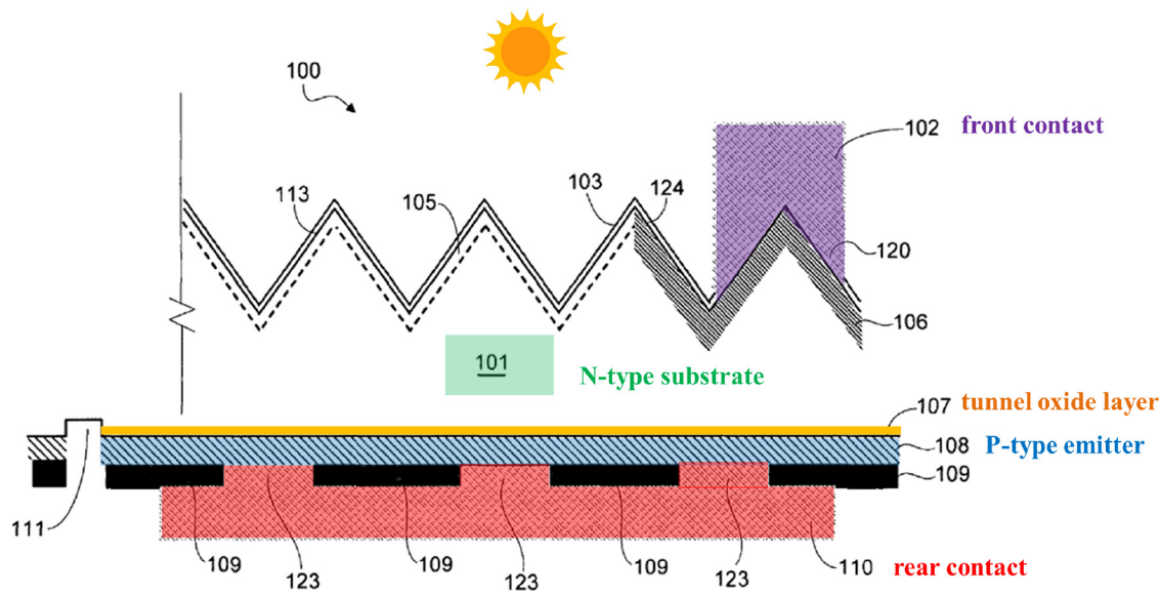


FIG. 1

Paper 3, 14 (citing Ex. 1001, Fig. 1) (annotation in Petition).

In this exemplary embodiment, an N-type silicon substrate 101 is formed from a silicon wafer, is etched to remove damaged surfaces. Ex. 1001, 3:59-64. The front side of the substrate is located at the top of Figure 1 and faces the sun; the back side of the substrate is at the bottom of Figure 1 and faces away from the sun. *Id.* at 2:33-34. A tunnel oxide 107, which can be silicon dioxide, is provided on the back surface of the substrate 101. *Id.* at 4:4-8.

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, 4:9-11. A dopant source layer 461 (not shown in Figure 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 layer during a drive-in step. *Id.* at 4:14-27. A capping layer 462 (not shown in Figure 1) is formed over this dopant layer to keep the dopants from escaping during the dopant drive in process. *Id.* at 4:18-21. 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 4:28-35.

Exposed surfaces of the substrate 101 (on the front side) are etched to form pyramid like structures 113. Ex. 1001, 4:36-41. 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

4:42-46. 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). This forms a heterojunction, referred to in claims 9 and 16 as a “backside junction.” *Id.* at 2:43-45, 4:60-5:1.

The drive in step may be formed in-situ, which the patent explains is “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.* at 5:9-16. 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 4:66-67, 2:43-45. A thin silicon dioxide layer 124 is provided as a passivation layer on the surface of the silicon substrate 101. *Id.* at 5:6-8.

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, 5:28-34. A front contact mask is then provided on the silicon nitride layer 103 to create a pattern for forming contact holes 102. *Id.* at 5:36-40. 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 5:46-55.

A back side metal contact 110 is formed on the silicon dioxide layer 109 to fill the contact holes 123 and to make electrical connection to the polysilicon emitter 108. Ex. 1001, 5:56-63. Finally, a front side metal contact 120 is formed on the silicon nitride layer 103 to fill contact holes and to make electrical connection to the substrate 101. *Id.* at 5:64-66.

While Figure 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, ¶95. This is shown in the below comparison of the independent claims 1, 9, and 16.

Claim 1	Claim 9	Claim 16
1. A method of fabricating 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 method comprising:	9. A method of fabricating a solar cell comprising:	16. A method of fabricating a solar cell comprising:
		forming an oxide layer over a back surface of a silicon substrate;
forming a layer of polysilicon over a back surface of an N-type silicon substrate on the back side of the solar cell;	forming a layer of polysilicon over a back surface of a silicon substrate;	forming a layer of polysilicon over the oxide layer;

Claim 1	Claim 9	Claim 16
forming a P-type dopant source over the layer of polysilicon;	forming a first dopant source layer over the layer of polysilicon;	
forming a capping layer over the P-type dopant source;		
diffusing P-type dopants from the P-type dopant source to the layer of polysilicon to form a backside junction with the N-type silicon substrate;	diffusing dopants from the first dopant source layer to the layer of polysilicon to form a backside junction with the silicon substrate;	diffusing dopants into the layer of polysilicon to form a backside junction with the silicon substrate;
diffusing N-type dopants into a front surface of the N-type silicon substrate; and	diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and	diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and
forming a metal contact on the front side of the solar cell, wherein the metal contact is electrically coupled to the N-type silicon substrate.	forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.	forming metal contacts on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.

Ex. 1001, claims 1 (6:13-29), 9 (6:52-65), and 16 (7:19-8:6) (emphasis added).

As is shown above, claim 1 is directed toward specific N-type and P-type dopants/dopant sources in the silicon and polysilicon layers, respectively. Claims 9 and 16, on the other hand, are silent with respect to the types of dopants/dopant sources used to dope the silicon substrate and the polysilicon layer. Therefore, considering the dopants/dopant sources, claims 9 and 16 are broader in scope than

claim 1. Claims 9 and 16 are not limited to N-type silicon and P-type polysilicon layers. Ex. 2027, ¶96.

B. Prosecution History of the '053 Patent

During prosecution of the '053 patent's parent application (*i.e.*, the '516 patent), the Examiner issued a restriction requirement between the claims “drawn to a solar cell” and those “drawn to a method of making a solar cell.” Ex. 2012, 61. The assignee, SunPower Corporation, elected the solar cell claims for the '516 patent and filed a divisional application to pursue the method claims issued in the '053 patent and challenged here. *Id.* at 70. The '053 patent issued after the Examiner determined that “[t]he prior art of record lacks the instantly claimed backside junction formed at the interface of a first material of a silicon substrate comprising one dopant type and a second material of a polysilicon layer of an opposite dopant type.” Ex. 1002, 250.

After allowance of the '053 patent, three continuations were filed seeking additional claims of varying scope:

- U.S. Patent Application No. 14/504,771 (the “’771 application”), filed October 2, 2014, claiming “a doped diffusion region in the substrate” and “a front electrode that is coupled to the doped diffusion region on the front surface of the substrate.” Ex. 1005, 470. This application was abandoned after an appeal of the Examiner’s decision to the Board. *Id.*, 506-520, 522.

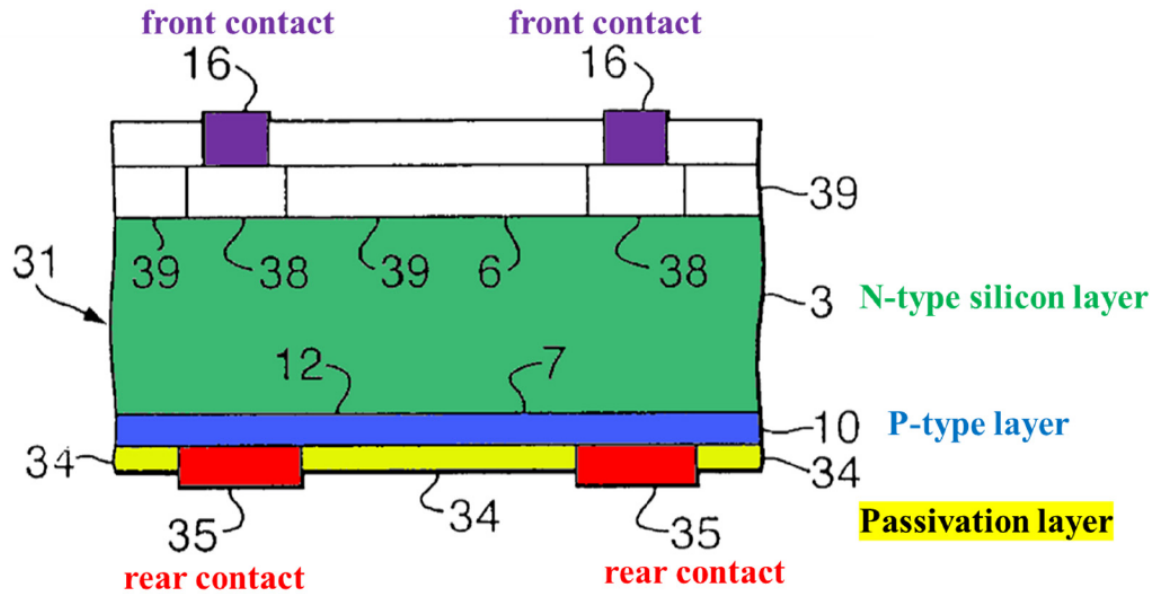
- U.S. Patent Application No., 16/460,035 (the “’035 application”), filed July 2, 2019, claiming “a plurality of dot-shaped N-type doped regions in the N-type silicon substrate under the antireflective layer, each of the plurality of dot-shaped doped regions having a dot shape as seen from a plan view of the solar cell” and “a first metal contact disposed on the front surface of the N-type silicon substrate, wherein the first metal contact is in electrical contact with the plurality of dot-shaped N-type doped regions.” Ex. 1018, 235. This application was abandoned after an appeal of the Examiner’s decision to the Board. *Id.*, 285-293, 295.
- U.S. Patent Application No. 17/870,268 (the “’268 application”), filed July 21, 2022, filed with claims directed towards a solar cell including a dielectric layer. Ex. 2013, 25-27. The ’268 application is currently under examination. *Id.*, 287-304 (a Final Rejection was issued September 16, 2024).

III. THE PRIOR ART

A. Froitzheim

Froitzheim 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).

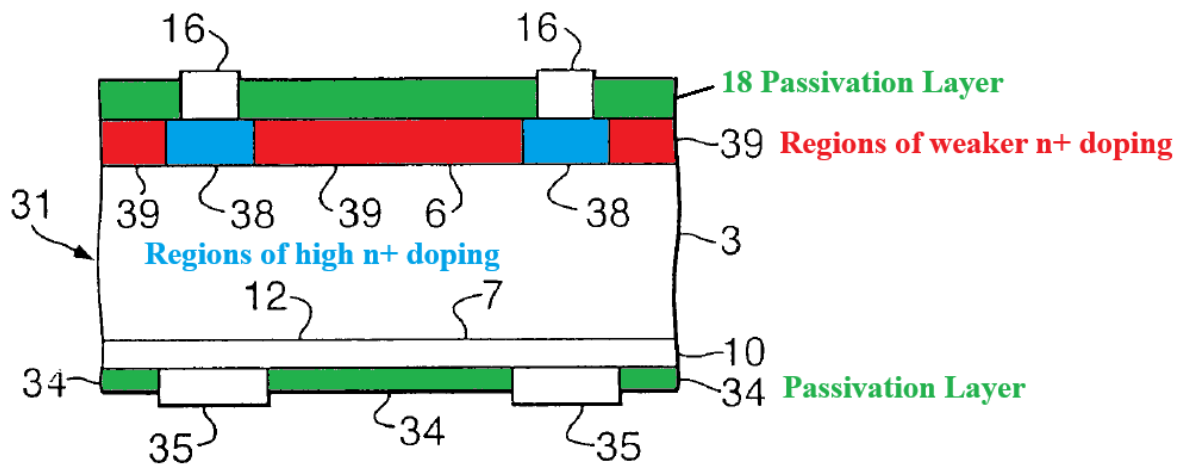
Below is the relevant embodiment Petitioner references:



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

Additional labels to Figure 3 of Froitzheim are shown below:

Fig.3.



Ex. 2027, ¶108 (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

There are two Gan publications relevant to the Petition. The first publication is Gan et al., “*Polysilicon Emitters for Silicon Concentrator Solar cells*,” Proceedings of the 21st IEEE-PVSC (1990) (“Gan”). Ex. 1005, 245. Gan is cited in the Petition and used in combination with Froitzheim, and separately, with Li. Paper 3, 24; *id.* at 73.

The second publication is Gan, “*Polysilicon emitters for silicon concentrator solar cells*,” a dissertation submitted to the Department of Material Science and Engineering and the Committee on Graduate Studies of Stanford University in 1990 (“Gan Thesis”). Ex. 2003, Cover. 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 ’053 patent. Ex. 2026, ¶23. Thus, a POSITA would have had knowledge of both of Gan and the Gan Thesis before that priority date. As explained below, the Gan Thesis is important for several reasons, including telling the complete story of why the technology disclosed in Gan was experimental, could not be reliably reproduced, and was not suitable for use in commercial concentrator cells.

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_o) [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 various 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 low J_o .

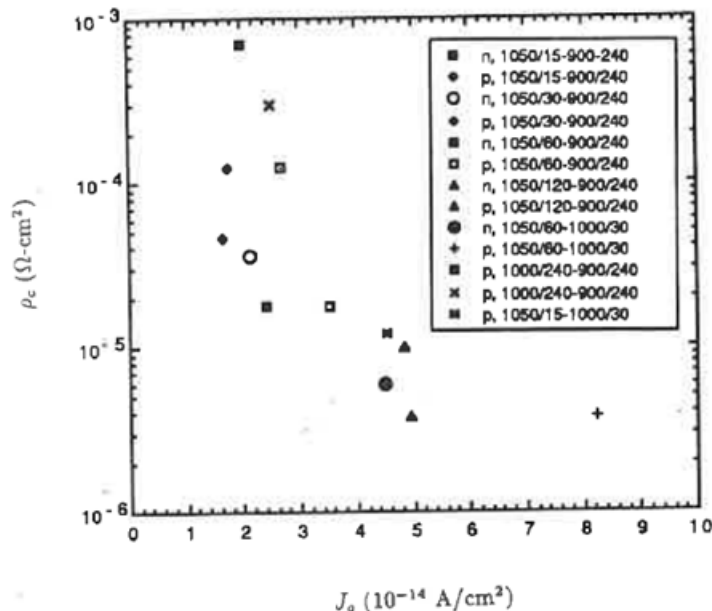


Figure 6: ρ_c - J_o of this work.

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, ¶125. Gan then discusses this figure and observes for regime 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, ¶129.

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 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 implementing 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 .

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- μ m-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 1×10^{-3} Ω -cm². 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. . .

As shown in the figure, the cell is in fact plagued by two things: the high surface recombination velocity ($S = 50$ 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. Smith

Unlike Froitzheim, which employs both front contacts 16 and back contacts 35 coupled to the substrate (*see*, Section III, A, *supra*), Smith has no front contacts, but relates to “a method of forming doped regions in a substrate of a back side contact solar cell.” Ex. 1007, Abstract. In back side contact solar cells, “the doped regions are coupled to metal contacts on the back side of the solar cell to allow an external electrical circuit to be coupled to and be powered by the solar cell.” *Id.* at 1:29-33.

Specifically, Smith discloses APCVD (atmospheric pressure chemical vapor deposition) to perform one-sided deposition where “a boron-doped silicon dioxide (SiO_2) (“BSG”) 104 is deposited on the back side of wafer 102 and “an undoped silicon dioxide 106 is deposited over [the] boron-doped silicon dioxide 104.” Ex. 1007, 2:44-55.

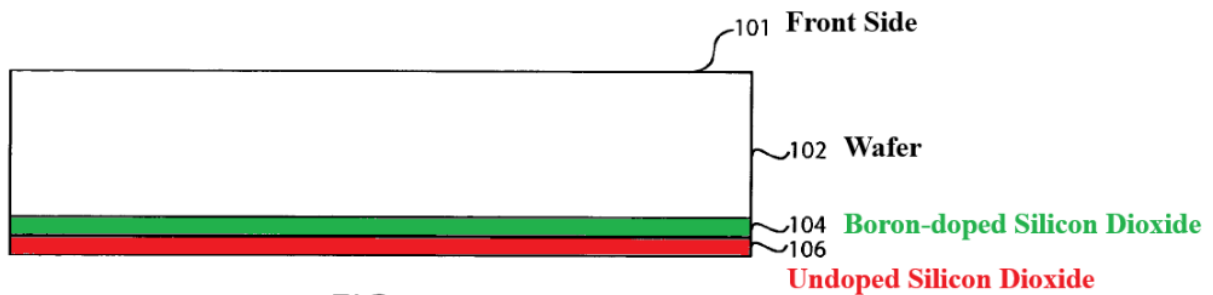


FIG. 2

Ex. 1007, Fig. 2 (annotated).

The silicon dioxide layers 104 and 106 are then patterned, and a phosphorus-doped silicon dioxide 501 and undoped silicon dioxide 502 are deposited over them. Ex. 1007, 2:65-3:22.

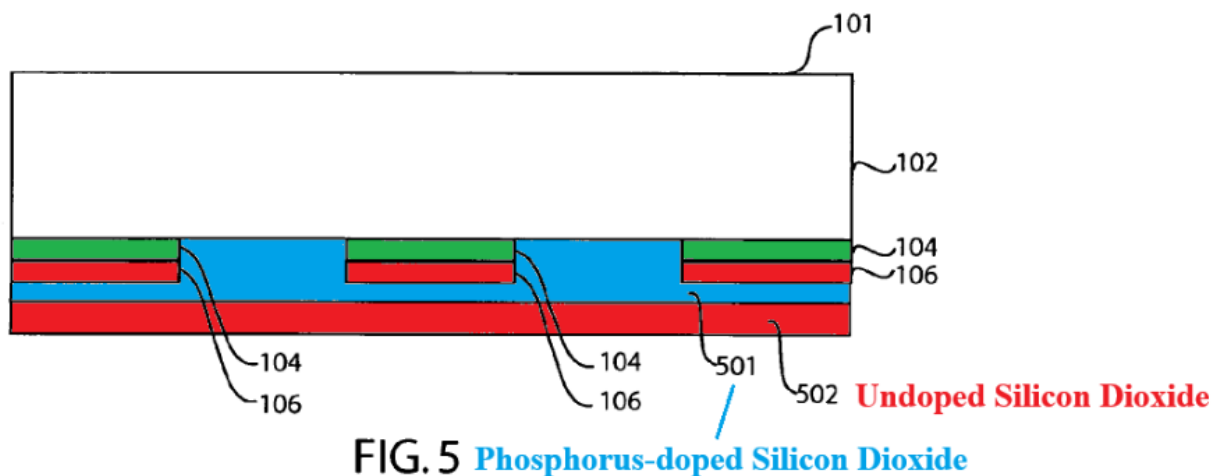


FIG. 5

Ex. 1007, Fig. 5 (annotated).

Smith discloses using “in-situ steps” to diffuse the dopants. In a first in-situ step, the wafer 102 is loaded into a wafer processing tool (such as a furnace), where the wafer 102 is “heated to about 1000° C[] for one hour” to diffuse dopants from the doped silicon dioxide 104, 501. “This results in the formation of P+ regions 702 (due to boron-doped silicon dioxide 104) and N+ regions 703 (due to phosphorus-doped silicon dioxide 501) in wafer 102.” Ex. 1007, 3:42-50.

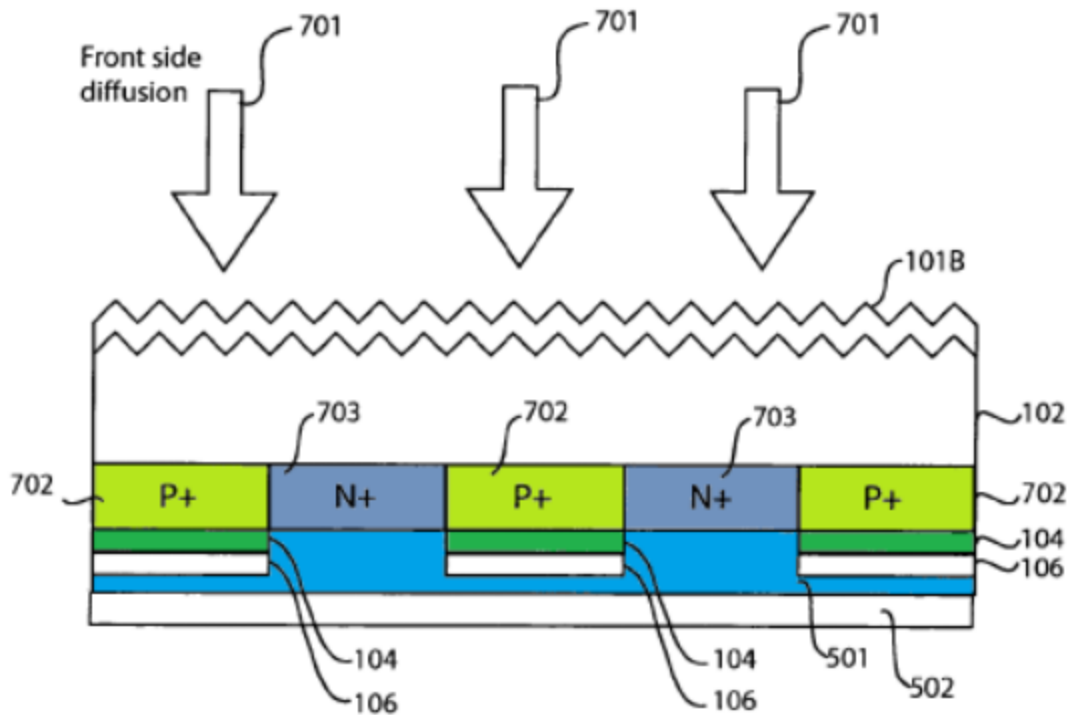


FIG. 7

Ex. 1007, Fig. 7 (annotated).

In a second in-situ step, the wafer 102 remains in the same furnace, where “the furnace conditions are changed to about 750° C. with an atmosphere

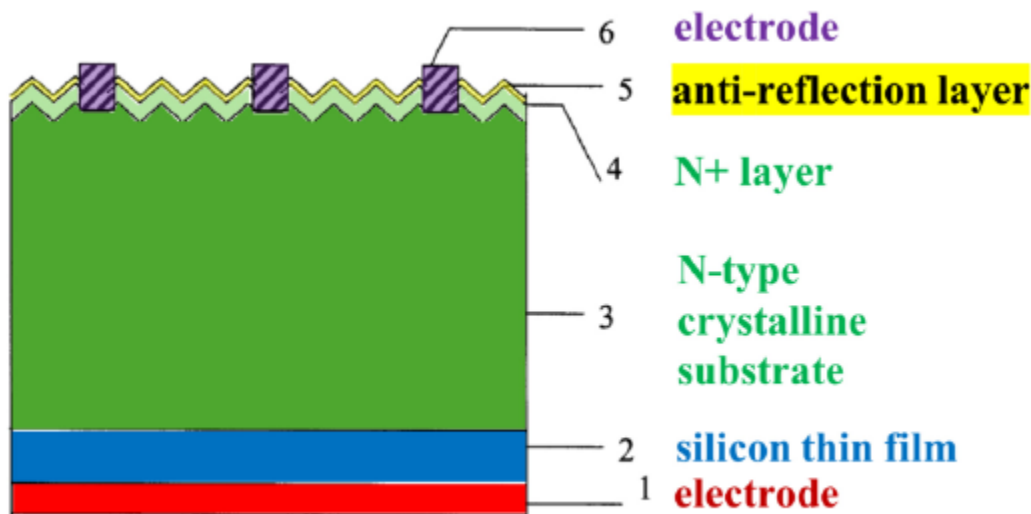
containing phosphorus oxychloride, then to about 975° C. with an atmosphere containing oxygen.” Ex. 1007, 3:56-59. This step diffuses “phosphorus as an N-type dopant into wafer 102 from its front side, and grow[s] a thin layer of silicon dioxide on both sides of wafer 102.” *Id.* at 3:59-61.

Finally, electrodes are formed and coupled to the P+ and N+ regions 702, 703 on the back side of the cell. Ex. 1007, 4:3-5.

E. Li

Li 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.

Li’s structure includes electrodes on the front and back side of the solar cell:



Paper 3, 23 (citing Ex. 1008, Fig. 1) (annotations in Petition).

Li describes conventional homogeneous PN junction solar cells as cells that “generally adopt P-type crystalline silicon to form an N-type emitting region through high-temperature diffusion.” 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.”).

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.”).

Li teaches that a PN junction is prepared by a low-temperature deposition method, which avoids a conventional diffusion process at 800-1000°C. Such high-temperature process will cause more defects or contamination in a silicon material, which will affect the improvement of cell efficiency.” *Id.* at p.3. This is in , Gan and Smith requiring, as discussed above, such high temperature diffusion of dopants.

IV. THE LEVEL OF ORDINARY SKILL

This Patent Owner Response (“POR”) applies the level of ordinary skill in the art Petitioner proposed. Paper 3, 4; Ex. 2027, ¶¶97-98.

V. CLAIM CONSTRUCTION

This POR adopts Petitioner’s proposal to apply the plain and ordinary meaning of the claims. Paper 3, 17.

VI. THE PETITION DOES NOT SHOW THAT ANY CHALLENGED CLAIM IS UNPATENTABLE

All three grounds in the Petition fail.

Ground I (Froitzheim and Gan) fails because a POSITA would not have had a reasonable expectation of success in combining Froitzheim’s solar cell Gan’s test device, which included an interfacial oxide that could not be reliably grown in solar cells at the time.

The addition of Smith to Froitzheim and Gan in Ground II does not remedy the failures of Ground I. Ground II also independently fails because a POSITA would not have applied Smith’s teaching of a one-sided deposition technique, which allegedly benefits solar cells having only back contacts. Froitzheim’s cell structure has both front side contacts and back side contacts, and would not benefit from using Smith’s one-sided deposition technique.

Ground III (Li, Gan, and Smith) fails because, like Froitzheim, Li is not a back contact solar cell. Li also teaches away from the high temperature diffusions required by both Gan and Smith.

A. Ground I: Claims 9-12, 14, and 16-20 Are Patentable Under Froitzheim and Gan

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’ repeated failure to implement Gan’s structure in an actual solar cell. Ex. 2027, ¶¶135, 158, 166, 168.

a. The Gan Thesis Failed to Reliably Implement Gan's
Interfacial Oxide Layer

The Gan Thesis (Ex. 2003), written by a co-author of the Gan reference (Ex. 1005), repeatedly attempted Petitioner's proposal—to implement Gan's polysilicon emitter and interfacial oxide structure on a real solar cell—and repeatedly 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 '053 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_0 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 fell even shorter of supporting a reasonable expectation of success. Ex. 2027, ¶¶135, 158, 166, 168. 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. *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, 32. 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)¹ to a solar cell. Paper 3, 32. First, Petitioner cites “Ex.1005-Gan, 246.” As

¹ In its argument, Petitioner blurs the line between generic “oxide layers” and tunnel oxide layers. Paper 3, 32. 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]-[0027].” Those two paragraphs disclose an optional tunnel oxide layer grown in Borden-575’s contact holes; contact holes do not exist in the Froitzheim-Gan combination. *See* Paper 3, generally; *see also* Ex. 2029, 246:4-10 (discussing an identical Froitzheim-Gan combination in Petitioner’s IPR2024-01203). 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, ¶¶78-85 (both experts discuss the characteristics of a tunnel oxide layer).

Fifth, Petitioner cites the '053 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, 32. 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 '053 patent. In fact, Petitioner identified no solution at all. Thus, *Uber Technologies* is far removed from the instant situation.

2. *A POSITA Would Not Have Been Able to Accomplish the Proposed Froitzheim-Gan Combination Without Undue Experimentation*

Undue experimentation is a matter of degree. *Chiron Corp. v. Genentech, Inc.*, 363 F.3d 1247, 1253 (Fed.Cir.2004). Even "a considerable amount of experimentation is permissible," as long as it is "merely routine" or the specification "provides a reasonable amount of guidance" regarding the direction of experimentation. *Johns Hopkins Univ. v. CellPro, Inc.*, 152 F.3d 1342, 1360-61 (Fed.Cir.1998) (internal quotation omitted). Yet, routine experimentation is "not

without bounds.” *Cephalon, Inc. v. Watson Pharm., Inc.*, 707 F.3d 1330, 1339 (Fed.Cir.2013).

To determine whether the amount of experimentation is undue, the Federal Circuit articulated in eight factors that can be considered in the analysis: (1) the quantity of experimentation necessary, (2) the amount of direction or guidance presented, (3) the presence or absence of working examples, (4) the nature of the invention, (5) the state of the prior art, (6) the relative skill of those in the art, (7) the predictability or unpredictability of the art, and (8) the breadth of the claims. *In re Wands*, 858 F.2d 731, 737 (Fed. Cir. 1988). The PTAB applies the *Wands* factors in IPRs. *See, e.g., Packers Plus Energy Servs. Inc. v. Baker Hughes Oilfield Operations, LLC*, IPR2016-01003, Paper 33, at 23-30 (PTAB Nov. 6, 2017) (analyzing the *Wands* factors and finding non-enablement).

On the other hand, not all factors must be considered and met in every case, and the consideration of other factors are not precluded if they are relevant to the inquiry. *See, e.g., Amgen, Inc. v. Chugai Pharm. Co., Ltd.*, 927 F.2d 1200, 1213 (Fed. Cir. 1991) (noting that the *Wands* factors “are illustrative, not mandatory. What is relevant depends on the facts.”).

In this case, several factors weigh in favor of finding that undue experimentation would be required. First, the state of the prior art (*Wands* factor 5) favor finding undue experimentation. As discussed in § VI.A.1.b, Petitioner has

not identified any prior art disclosing the ability to form a tunnel oxide layer successfully and consistently on polysilicon emitters in one-sun solar cells (because there was none at the time of the invention). *See, e.g.*, Ex. 1005 (Gan disclosing an interfacial oxide layer in concentrator cells); Ex. 1006, ¶5 (Borden-575 disclosing the “difficulty of reliably forming a thin tunnel oxide.”). As the Gan Thesis explains, this is due to the difficulty of controlling the thickness and degree of breakup of the interfacial oxide such that consistent and acceptable values of ρ_c and J_o are obtained. *See* § VI.A.1.a; Ex. 2027, ¶¶133-35, ¶¶160-68 (citing Ex. 1005, Abstract; *id.* at 53; *id.* at 56; *id.* at 69; *id.* at 107; *id.* at 110-12; *id.* at 114-17; *id.* at 119) (summarizing pertinent findings in Gan Thesis).

Second, the amount of direction or guidance presented (*Wands* factor 2), the absence of working examples (*Wands* factor 3), and the unpredictability of the art (*Wands* factor 7) favor finding the need for undue experimentation. As discussed in §III.B.2, Gan merely discloses steps to fabricate a polysilicon emitter and an interfacial oxide layer on test devices, and as discussed in § VI.A.1.a, the Gan Thesis discloses failures to incorporate Gan’s structure in an functioning solar cell. Thus, Petitioner has failed to provide any working examples of its proposed combinations.

Third, the relative skill of those in the art (*Wands* factor 6) favors finding undue experimentation. The author of Gan Thesis holds a Ph.D. degree from

Stanford University. Ex. 2003, 3 (cover). Thus, he exceeds Petitioner's proposed qualification of a POSITA, Paper 3, 16, but nevertheless Gan could not identify a solution to the problem of controlling the thickness and breakup of the interfacial oxide layer.

3. *Gan's Purported Benefits Only Apply When Gan's Polysilicon Emitter and Oxide Layer Are Both Implemented*

To the extent Petitioner proposes an alternative Froitzheim-Gan combination without Gan's oxide layer, 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. Thus, Petitioner failed its burden to show obviousness.

Specifically, in its discussion of the limitations of claims 9-12 and 14, Paper 3, 36-48, Petitioner appears to propose an alternative Froitzheim-Gan combination without Gan's oxide layer. Not only was Gan's reference layer not mentioned once, but Petitioner's expert repeatedly refused to answer whether Gan's oxide layer is part of its alternative Froitzheim-Gan combination:

Q So in Paragraph 148 [of Ex. 1003, in which Petitioner's expert argues that the proposed Froitzheim-Gan combination satisfies a limitation of claim 9] when you talk about the combination of Froitzheim and Gan, do you envision a combination that includes Gan's oxide layer?

MR. SELWYN: Objection. Form.

A A combination that includes Gan's oxide layer would also meet the limitation of the claim, as would one in which it was not omitted. Because in both cases the combined teachings of Froitzheim and Gan include forming a layer of polysilicon over a back surface of a silicon substrate.

Q Are you saying in this paragraph when you talk about the combination of Froitzheim and Gan you mean -- you could mean a combination that does not include Gan's oxide layer?

MR. SELWYN: Objection. Form.

A This claim, which is directed towards a method of manufacture of the structure, is about forming a layer of polysilicon over a back surface of a silicon substrate. And as I describe here, Gan teaches forming a layer over a polysilicon over a back surface of a silicon substrate, and the combination of Gan and Froitzheim teaches that. Gan also then teaches -- teaches an oxide layer. That oxide layer is not required to meet this claim limitation.

Q I'm just trying to understand what you mean by "the combination of Froitzheim and Gan" in Paragraph 148. This combination that you write about here, does it include Gan's oxide layer or not?

MR. SELWYN: Objection. Form.

A The combination of Froitzheim and Gan that combining the teachings of Froitzheim and Gan, Froitzheim -- excuse me, Gan teaches an oxide layer. Gan teaches a polysilicon layer. This claim requires a polysilicon layer. Gan teaches that. And if one combined the teachings of Gan and polysilicon, one has all of the elements of the claim limitation, in particular forming a layer of polysilicon over a back surface of a silicon substrate.

Ex. 2029, 187:13-189:12; *see also id.* at 189:13-193:17 (Petitioner’s expert continues to avoid committing to a definitive answer as to whether the proposed Froitzheim-Gan combination would include Gan’s oxide layer).

On the other hand, the Petitioner exclusively discussed a POSITA’s motivation to combine Froitzheim with both Gan’s polysilicon emitter and Gan’s oxide layer. *See, e.g.*, Paper 3, 24-35. At no point in the Petition did Petitioner ever attempt to explain why a POSITA may have been motivated to combine Froitzheim with only Gan’s polysilicon emitter.

The distinction between a Froitzheim-Gan combination with and without Gan’s oxide layer is important. The purported benefit of Gan, which allegedly would have motivated a POSITA to combine it with Froitzheim, is derived from the combination of Gan’s polysilicon emitter and oxide layer:

- “Gan’s published data demonstrates a polysilicon emitter and oxide layer structure would have improved performance over a diffused emitter.” Paper 3, 28 (emphasis added).
- “Gan also observes that the combination of a polysilicon emitter and oxide layer structure had lower recombination and contact resistance as compared to diffused-emitters [*sic*]. . .” Paper 3, 28 (emphasis added).

- “Based on this data, Gan concludes that a polysilicon emitter and oxide layer structure is ‘quite useful for silicon solar cells.’” Paper 3, 29 (emphasis added).
- “Gan broadly suggests that its polysilicon emitter and oxide layer structure are generally ‘useful for silicon solar cells.’” Paper 3, 29, n9 (emphasis added).
- “In view of Gan’s teachings, a POSITA would have been motivated to modify Froitzheim’s solar cell to incorporate a polysilicon emitter and oxide layer structure to obtain a more efficient cell.” Paper 3, 30 (emphasis added).
- “Gan specifically teaches that replacing a diffused emitter (as taught by Froitzheim) with a polysilicon emitter and oxide layer structure would improve the efficiency of a solar cell.” Paper 3, 30 (emphasis added).

Further, Petitioner’s expert testified that a POSITA would not have understood that Gan’s purported benefit could be derived from Gan’s polysilicon emitter alone:

Q On Page 83 in the middle of the paragraph you state, “Gan notes that this combination, polysilicon emitter and oxide layer on the wafer surface, has less recombination and lower contact resistance as compared to that of diffused emitters.” Do you see that?

A I do.

Q The result of less recombination and lower contact resistance, that is the benefit that Gan brings to the Froitzheim-Gan combination.

Right?

MR. SELWYN: Objection. Form.

A That is a benefit that Gan brings, that's correct, is this oxide polysilicon emitter structure has low recombination and low contact resistivity, and these things will lead to an enhancement, an increase in the efficiency of the solar cell.

Q And Gan achieves this benefit through a combination of polysilicon emitter and oxide layer. Right?

A That's correct. Gan's paper, his investigation is with the structure having both the oxide and the polysilicon.

Q And you're not claiming here that just implementing Gan's polysilicon emitter would lead to the same benefits. Right?

A I am not making that claim, as those experiments are not covered in Gan's paper. Gan doesn't show data for a polysilicon emitter without the oxide layer. There are other previous papers and publications that cover that structure. Gan focuses on the oxide layer and polysilicon emitter together.

Ex. 2029, 184:16-186:7.

It is improper for Petitioner and its expert' to stay intentionally vague on what Froitzheim-Gan combination they propose on pages 36 to 48 of the Petition. *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.”).

It is even more improper for Petitioner to introduce an alternative Froitzheim-Gan combination in an attempt to evade its burden of demonstrating motivation to combine and a reasonable expectation of success. *Elektro 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.”).

Thus, Petitioner’s arguments on whether the proposed Froitzheim-Gan combination satisfies the limitations of claims 9-12 and 14, Paper 3, 36-48, are improper and should be struck or at least ignored.

B. Ground II: Claims 1-20 Are Patentable Under Froitzheim, Gan, and Smith

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

As discussed in § VI.A, a POSITA would not have been motivated to combine Froitzheim and Gan because the Gan Thesis teaches that Gan's interfacial oxide could not be reliably grown. The proposed additions of Smith's manufacturing steps, Paper 3, 51-52, do not remedy those problems, *id.* at 51 (in its motivation to combine Froitzheim, Gan, and Smith section, Petitioner incorporates section X.A.1 of the Petition (motivation to combine Froitzheim and Gan)).

A POSITA would not have had a motivation to combine the oxide and polysilicon from Gan into Froitzhheim because, as discussed in § XI.A.1, the Gan Thesis teaches that the oxide layer growth is unreliable and inconsistent negating the benefits for combining Gan with Froitzheim. For the same reasons, a POSITA would not have had a motivation to combine Froitzheim, Gan, and Smith because Smith does not teach either an oxide layer or a polysilicon layer. The purpose of the proposed Smith combination is to add dopants.

Further, because a POSITA would not have been motivated to combine Froitzheim and Gan, Petitioner failed to show obviousness of the limitation of "forming a layer of polysilicon" as recited in independent claims 1, 9, and 16 using Gan's polysilicon emitter, and (2) the limitation of "forming an oxide layer over a

back surface of a silicon substrate” as recited in independent claim 1 using Gan’s interfacial oxide. The proposed additions of Smith’s manufacturing steps also do not remedy those problems. Neither Froitzheim nor Smith discloses a polysilicon layer. *See* Exs. 1004, 1007 generally; *see also* Paper 3, 17-18 (Petitioner’s description of Froitzheim), 20-22 (Petitioner’s description of Smith). Neither Froitzheim nor Smith discloses an oxide layer over a back surface of a silicon substrate. *Id.* Therefore, the proposed Froitzheim-Gan-Smith combination does not satisfy the limitations of the independent claims of the ’053 patent.

2. *A POSITA Would Not Have Been Motivated to Combine Froitzheim, Gan, and Smith*

Froitzheim’s structure (and therefore the structure of the proposed Froitzheim-Gan-Smith combination) differs from Smith’s back contact solar cell. Froitzheim has metal contacts on both sides of its cell, and thus, includes doped emitter layers on both sides of the substrate. This structure has no use for Smith’s teachings that focus on one-sided deposition (deposition of dopants on one side of the substrate).

a. A POSITA Would Not Have Used Smith’s One-Sided APCVD Deposition Because Its Purported Benefits Do Not Apply to Froitzheim’s Structure

Smith discloses that its one-sided APCVD deposition “is particularly useful in the manufacture of back side contact solar cells where only one side of the solar cell is textured.” Ex. 1007, 60-62. Ex. 1007, 60-62. The proposed Froitzheim-

Gan-Smith structure, using Froitzheim's solar cell, is not a back side contact solar cell.

Smith describes one-sided APCVD deposition as depositing both **boron-doped silicon dioxide 104** and **phosphorus-doped silicon dioxide 501** on the back side of the wafer. Ex. 1007, 2:45-49; *see also id.* at 3:19-20. Then, the wafer 102 is heated to diffuse the dopants from both silicon dioxides 104, 501 into the wafer 102, forming “**P+ regions 702** (due to boron-doped silicon dioxide 104) and **N+ regions 703** (due to phosphorus doped silicon dioxide 501).” *Id.* at 3:43-50.

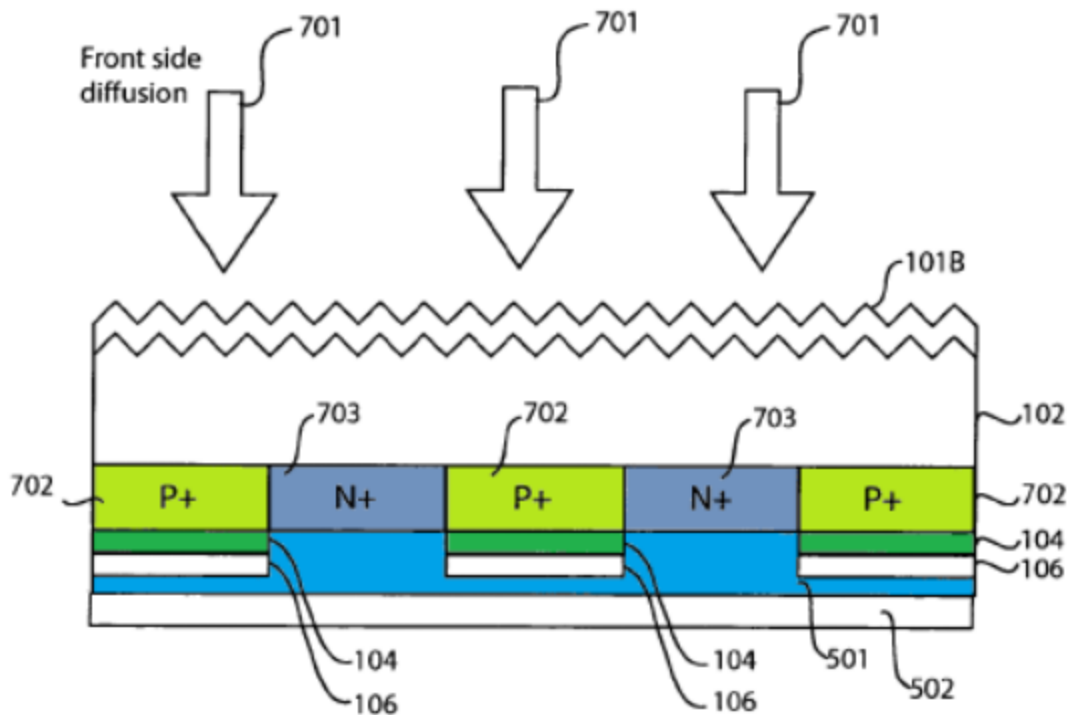
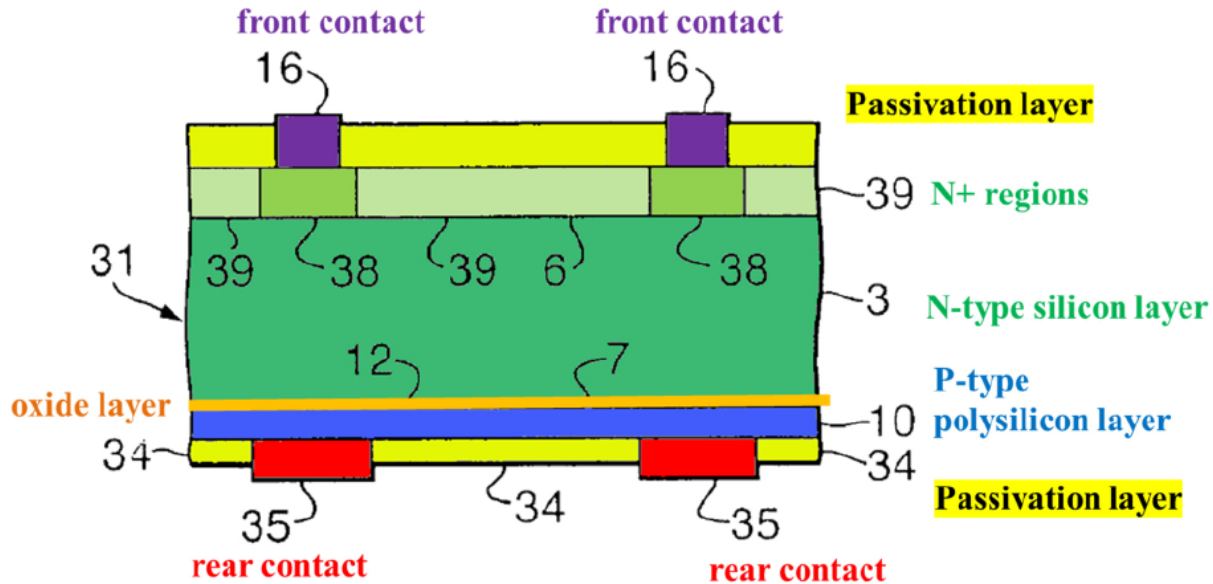


FIG. 7

Ex. 1007, Fig. 7 (annotated).

Using APCVD for one-sided deposition is compatible with Smith's solar cell, which is a back side contact cell. Ex. 2027, ¶179. According to Smith, "[i]n a back side contact solar cell, the doped regions are coupled to metal contacts on the back side of the solar cell to allow an external electrical circuit to be coupled to and be powered by the solar cell." Ex. 1007, 1:29-33. In this back contact structure, electrodes (metal contacts) are formed and coupled to the P⁺ and N⁺ regions 702, 703. *Id.* at 4:3-5; *see also* Ex. 1003, ¶66 (equating "metal contacts" to "electrodes"). Because both regions 702 and 703 are on the back side, all metal contacts are also on the back side. Ex. 2027, ¶179.

In contrast, Froitzheim's solar cell (and thus, the solar cell of the proposed Froitzheim-Gan-Smith combination) does not have both P⁺ and N⁺ regions on its back side, or all metal contacts on its backside. *See, e.g.*, Ex. 1004, Fig. 3; *see also id.* at ¶34 (discussing the front contact fingers of Figure 3). It is simply not a back contact solar cell. Ex. 2027, ¶180. Petitioner's own illustration of the proposed combination makes this clear:



Paper 3, 25 (citing Ex. 1004, Fig. 3; Ex. 1005, 245, 249) (annotations in Petition); *see also id.* at 51 (incorporating section X.A.1 of the Petition, which features the illustration above).

b. Petitioner Failed to Show How a POSITA Would Have Used Smith’s In-Situ Diffusion on Froitzheim’s Structure

Petitioner casually asserts a POSITA “would have been motivated to apply Smith’s ‘in-situ steps’ to the combination of Froitzheim and Gan to drive in the dopants to their target regions” without explaining how those “in-situ steps” would be applied to a different structure. Paper 3, 55. This leaves a gaping hole that neither Patent Owner nor the Board is responsible for filling.

Smith’s “in-situ steps” are used in Smith’s APCVD process. But as discussed in § VI.B.2.a, the proposed Froitzheim-Gan-Smith combination is not a back contact solar cell, and has no use for Smith’s one-sided APCVD deposition

process. Thus, Petitioner’s assertion that Smith’s “in-situ steps” is applicable to the proposed Froitzheim-Gan-Smith combination is unjustified.

Nor can Petitioner argue that justification is provided in its expert declaration, which Petitioner incorporated. *See, e.g.*, Paper 3, 55 (citing Ex. 1003, ¶209). The rules expressly prohibit the papers from incorporating arguments by reference. *See* 37 C.F.R. § 42.6(a)(3) (“Arguments must not be incorporated by reference from one document into another document.”) Thus, Petitioner failed to carry its burden of establishing that a POSITA could have applied Smith’s in-situ diffusion in the structure of Froitzheim and Gan. *Dominion Dealer Sols.*, IPR2013-00225, Paper 15 at 4 (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.”); *Wowza Media Sys., LLC v. Adobe Sys. Inc.*, IPR2013-00054, Paper 12 at 15 (PTAB Apr. 8, 2013) (“[A] Petition must specify where each element of a challenged claim is found in the prior art patents or printed publications.”).

Moreover, Petitioner’s incorporated argument of its expert is also meritless—it is equally silent on how Smith would have taught a POSITA to apply Smith’s in-situ diffusion of one-sided doping on the underlying Froitzheim-Gan structure, which does not use one-sided doping, and would only employ half of Smith’s APCVD process. Ex. 1003, ¶209. Instead, Petitioner’s expert relied on

other references to show that in-situ diffusion would have applied to diffusion on opposite sides of a wafer. *Id.* But Petitioner’s expert made no attempt to combine those other references with Froitzheim or Gan.

3. *Petitioner Improperly Relies on Smith to Satisfy Limitations in Claims 2-5 and 11-14 without Establishing Motivation to Combine*

Petitioner relies on various disclosures from Smith that Petitioner did not discuss in its motivation to combine section under Ground II. Thus, Petitioner cannot argue that those disclosures satisfy claim limitations.

Specifically, Petitioner’s proposed Froitzheim-Gan-Smith combination includes “Froitzheim’s back-junction solar cell,” “Gan’s polysilicon emitter and oxide layer,” and “Smith’s manufacturing steps.” Paper 3, 51. Petitioner cherry-picks the following alleged teachings of Smith in its motivation to combine: (1) “dopants can be deposited on the substrate using ‘APCVD,’” *id.* at 54 (citing Ex. 1007, 2:44-49); (2) “[a]fter APCVD, ‘an undoped silicon dioxide’ layer can be placed on the dopant source,” *id.* (citing Ex. 1007, 2:53-60); (3) using “Smith’s APCVD process to dope Gan’s polysilicon layer and the n+ layer on the frontside of Froitzheim’s substrate,” *id.* at 54-55; and/or (4) “apply Smith’s ‘in-situ’ steps to the combination of Froitzheim and Gan to drive in the dopants to their target regions,” *id.* at 55 (citing Ex. 1007, 3:40-42).

But absent from Petitioner's wish-list are the following components and techniques: (a) use of Smith's own dopant layers, Paper 3, 60 (asserting that Smith's first doped oxide layer 104 satisfies limitations in claim 11); *id.* at 61-62 (asserting that Smith's layer of glass with phosphorous dopants at the silicon surface satisfies limitations in claims 12 and 13), and (b) use of Smith's texturing technique, *id.* at 63 (asserting that Smith's wet etch process satisfies limitation in claim 14).

For items (a) and (b) listed above, Petitioner made no attempt to argue that a POSITA would have been motivated to combine them with Froitzheim's back-junction solar cell and Gan's polysilicon emitter and oxide layer. This renders Petitioner's arguments against claims 11-14 relying on Smith (arguments (1) to (4) listed further above) without support. Thus, the Board should ignore those arguments.

For the same reason, Petitioner's additional arguments against claims 2-5, incorporating arguments (1) to (4) listed above should also be ignored. Paper 3, 71 (Petitioner's argument against claim 2 incorporating section X.B.4 (argument against claim 11); Petitioner's argument against claim 3 incorporating section X.B.5 (argument against claim 12); and Petitioner's argument against claim 4 incorporating section X.B.6 (argument against claim 13)); *id.* at 72 (Petitioner's

argument against claim 5 incorporating section X.B.7 (argument against claim 14)).

C. Ground III: Claims 9-20 Are Patentable Under Li, Gan, and Smith

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

As discussed in § VI.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 Froitzheim with Li, or adding Smith's manufacturing steps, 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, Petitioner failed to show obviousness of the limitation of "forming a layer of polysilicon" as recited in independent claims 1, 9, and 16 using Gan's polysilicon emitter, and (2) the limitation of "forming an oxide layer over a back surface of a silicon substrate" as recited in independent claim 1 using Gan's interfacial oxide. The proposed additions of Smith's manufacturing steps do not remedy those problems. Neither Li nor Smith discloses a polysilicon layer. *See* Exs. 1007, 1008 generally; *see also* Paper 3, 20-24 (Petitioner's descriptions of Smith and Li). And neither Li nor Smith discloses an oxide layer over a back surface of a silicon substrate. *Id.*

Therefore, the proposed Li-Gan-Smith combination do not satisfy the independent claims of the '053 patent.

2. *Li Teaches Away from Gan and Smith*

A POSITA would not have been motivated to (1) modify “Li’s method of making a backside junction solar cell to incorporate Gan’s methods of using a polysilicon emitter and oxide layer structure,” Paper 3, 73, or (2) “to obtain the manufacturing efficiencies Smith teaches,” *id.* at 75. Regrettably for Petitioner, Li teaches away from both. *Arctic Cat*, 876 F.3d at 1360 (“[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, a POSITA would not have been motivated to implement Gan’s polysilicon emitter and oxide layer, and Smith’s in-situ diffusion because both necessitate high temperature diffusion. Construction of Gan’s polysilicon emitter and oxide layer would repeatedly require the kind of high temperature that Li seeks to avoid. Specifically, in Gan’s 12-step process to construct its test 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; Ex. 2029, 216:16-217:7

(testifying that the proposed Li-Gan-Smith combination would implement steps 3, 4, 9, and 10 from Gan’s 12 steps).

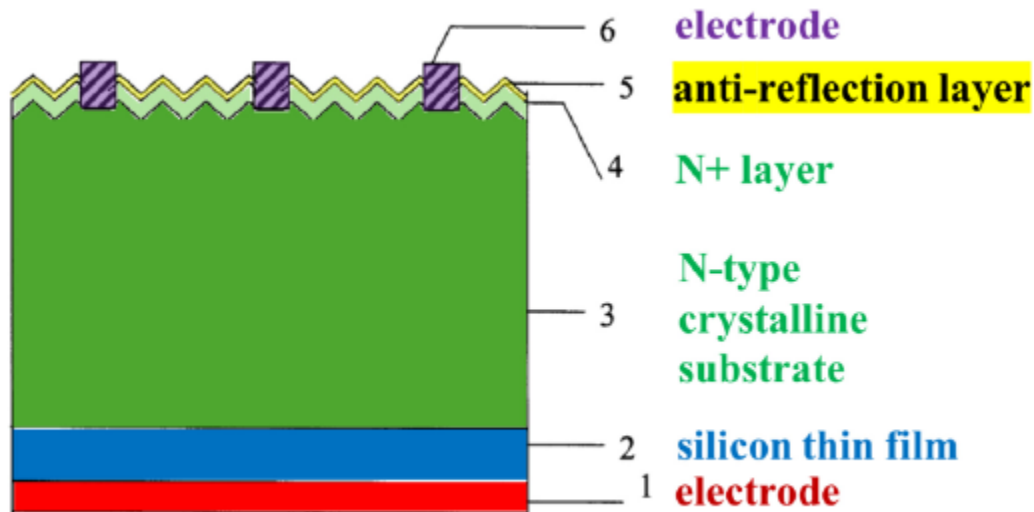
Similarly, a POSITA would not have been motivated to apply Smith’s “in-situ diffusion process,” Paper 3, 75, which also involves the kind of high temperature that Li seeks to avoid, Ex. 1007, 3:42-50 (disclosing a first in-situ step involving heating the wafer to 1000° C); *id.* at 3:59-61 (disclosing a second in-situ step involving furnace conditions of 750°C, then 975°C).

Thus, Li teaches away from both Gan and Smith, and a POSITA would not have combined the three references. Ex. 2027, ¶192; *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.”).

3. *A POSITA Would Not Have Been Motivated to Combine Li and Gan with Smith*

For the same reasons discussed in § VI.B.1, the proposed Li-Gan-Smith combination is not a back contact solar cell. As Petitioner illustrates below, Li’s

structure, like Froitzheim's structure, includes metal contacts on both sides of the solar cell:



Paper 3, 23 (citing Ex. 1008, Fig. 1) (annotations in Petition); *see also* Ex. 1003, ¶66 (equating “metal contacts” to “electrodes”). As a result, for the same reasons discussed in § VI.B.1, a POSITA would not have been motivated to combine Smith with Li and Gan. Ex. 2027, ¶¶193-94.

VII. CONCLUSION

For the foregoing reasons, claims 1-20 in the '053 patent are patentable.

Respectfully submitted,

Date: May 22, 2025

/Jeremy D. Peterson/

Jeremy D. Peterson (Reg. No. 52,115)

PV Law LLP

5335 Wisconsin Avenue, NW, Suite 440

Washington, DC 20015-2052

Telephone: 202.871.0140

Facsimile: 202.888.3163

*Counsel for Patent Owner Maxeon Solar
Pte. Ltd.*

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 11,055 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: May 22, 2025

/Jeremy D. Peterson/

Jeremy D. Peterson (Reg. No. 52,115)

*Counsel for Patent Owner Maxeon Solar
Pte. Ltd.*

CERTIFICATE OF SERVICE

I certify that the Patent Owner Response was served on Petitioner's counsel
of record by electronic notification through P-TACTS and email to:

David Cavanaugh (David.Cavanaugh@wilmerhale.com)
Mark Selwyn (Mark.Selwyn@wilmerhale.com)
John Hobgood (John.Hobgood@wilmerhale.com)
Gilbert Smolenski (Gilbert.Smolenski@wilmerhale.com)
Alex Nemtzow (Alex.Nemtzw@wilmerhale.com)
Bobby Hampton (Bobby.Hampton@wilmerhale.com)
Jungyeon Kim (John.Kim@wilmerhale.com)
WHMaxeonIPRService@wilmerhale.com

Respectfully submitted,

Date: May 22, 2025

/Jeremy D. Peterson/

Jeremy D. Peterson (Reg. No. 52,115)

*Counsel for Patent Owner Maxeon Solar
Pte. Ltd.*