

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

**REPLY DECLARATION OF DR. ZACHARY HOLMAN REGARDING
CLAIMS 1-12 OF U.S. PATENT NO. 8,222,516**

HANWHA v. MAXEON
IPR2024-01203
HANWHA 1077

Table of Contents

I.	INTRODUCTION	1
II.	MATERIALS CONSIDERED	2
III.	SUMMARY OF OPINIONS	3
IV.	QUALIFICATIONS AND EXPERIENCE	3
V.	LEGAL PRINCIPLES	3
VI.	PRIORITY DATE	4
VII.	LEVEL OF ORDINARY SKILL IN THE ART	4
VIII.	TECHNOLOGY BACKGROUND AND OVERVIEW OF THE '516 PATENT	5
IX.	CLAIM CONSTRUCTION	6
X.	OVERVIEW OF THE PRIOR ART	6
XI.	GROUND I: CLAIMS 1-4 AND 6-12 ARE INVALID AS OBVIOUS OVER FROITZHEIM AND GAN	7
A.	A POSITA Would Have Been Motivated To Combine Froitzheim And Gan With A Reasonable Expectation Of Success	8
1.	The Gan Thesis Supports The Combination Of Froitzheim And Gan And Corroborates Gan's Teachings	11
2.	Polysilicon Emitters And Tunnel Oxide Layers Were Known Features In Semiconductor Technology, Which Includes Solar Cells And Transistors	20
B.	The Combination Of Froitzheim And Gan Renders Claim 12 Obvious	23
XII.	GROUND III: CLAIMS 1-4 AND 6-12 ARE INVALID AS OBVIOUS OVER FROITZHEIM AND BORDEN-575	31
A.	Borden-575 Is Prior Art To The '516 Patent	32
B.	The Combination Of Froitzheim And Borden-575 Is Not Deficient Due To Borden-575's "Buried Oxide" Layer	36
C.	A POSITA Would Have Been Motivated To Combine Froitzheim And Borden-575 With A Reasonable Expectation Of Success	40

D.	The Froitzheim-Borden-575 Combination Discloses Claim 12	48
XIII.	GROUND V: CLAIMS 1-2 AND 8-11 ARE INVALID AS OBVIOUS OVER LI AND GAN	48
XIV.	FOUNDATIONS II & IV: CLAIM 5 IS INVALID AS OBVIOUS OVER FROITZHEIM, GAN, AND SHEATS (GROUND II) AND FROITZHEIM, BORDEN-575, AND SHEATS (GROUND IV)	52
XV.	AVAILABILITY FOR CROSS-EXAMINATION	57
XVI.	RIGHT TO SUPPLEMENT	58
XVII.	JURAT	59

I, Zachary Charles Holman, Ph.D., declare as follows:

I. INTRODUCTION

1. My name is Zachary Charles Holman.
2. I am making this declaration at the request of Hanwha Solutions Corporation (“HSC” or “Petitioner”) as an independent expert consultant in this proceeding before the United States Patent and Trademark Office and to address and respond to the arguments made in the Patent Owner’s Patent Owner Response (“POR”) and the declaration submitted by Dr. Douglas Ruby (Ex.2027) (“Ruby Declaration”) in support of the POR. I previously submitted a Declaration in support of the Petition, dated August 8, 2024 (Ex.1003) (“First Declaration”).
3. As stated in my First Declaration, I am being compensated for my work on this matter at my standard hourly consulting rate of \$500 per hour. My opinions are based on my own views and understanding of the prior art, the knowledge of a person of ordinary skill in the art, and the ’516 patent. My compensation is not dependent on and in no way affects the substance of my statements, opinions, or conclusions in this declaration, and it is also not dependent on any testimony I give or on the outcome of this proceeding.

4. As also stated in my First Declaration, I have no financial interest in Petitioner or Patent Owner. I similarly have no financial interest in the '516 patent, and I have had no contact with the named inventor of the '516 patent.

II. MATERIALS CONSIDERED

5. In forming my opinions, in addition to my knowledge and experience, I have considered the materials cited in my First Declaration and the documents cited herein, which are listed in **Appendix D**.¹

6. Since preparing my First Declaration, I have reviewed Patent Owner's Preliminary Response ("POPR"), the Board's Institution Decision ("ID"), the POR, and the Ruby Declaration. I have also reviewed and considered the documents cited by Dr. Ruby in his declaration, and the transcript of Dr. Ruby's deposition held on July 30, 2025 ("Ruby Deposition") (Ex.1075).²

¹ I also signed an errata with respect to the deposition transcript for my First Declaration. *See* Ex.1088.

² Similar to my First Declaration, various annotations have been added to the figures and diagrams in this report. All of these annotations are added unless noted otherwise.

III. SUMMARY OF OPINIONS

7. For the reasons discussed at length in my First Declaration, it is my opinion that there is nothing inventive about claims 1-12 of the '516 patent. As detailed herein, it remains my opinion that the prior art renders obvious claims 1-12 of the '516 patent.

8. Nothing in the POR, the Ruby Declaration, and the Ruby Deposition changes my opinions set forth in my First Declaration. As explained in my First Declaration and this Reply Declaration, I have interpreted the '516 patent and the prior art reference consistent with the knowledge and understanding of a POSITA without the use of hindsight. In this Reply Declaration, I respond to areas of dispute raised by Dr. Ruby.

IV. QUALIFICATIONS AND EXPERIENCE

9. In my First Declaration, I included a summary of my qualifications and experience, which I incorporate by reference here. Ex.1003-Decl., ¶¶3-16.

V. LEGAL PRINCIPLES

10. In my First Declaration, I set forth the applicable principles of patent law that counsel provided to me, which I incorporate by reference here. Ex.1003-Decl., ¶¶19-34. I have continued to apply those principles in providing my opinions in this Reply Declaration.

VI. PRIORITY DATE

11. As stated in my First Declaration, I have been informed that the priority date of the '516 patent is February 20, 2008. Dr. Ruby also applies a priority date of February 20, 2008. Ex.2027-Ruby-Decl., ¶13. I have formed the opinions set forth in my First Declaration and this Reply Declaration in reference to this priority date.

VII. LEVEL OF ORDINARY SKILL IN THE ART

12. As explained in my First Declaration, a person of ordinary skill in the art as of the claimed priority date of the '516 patent ("POSITA") would have had (1) an advanced degree in applied physics, chemistry, electrical engineering, materials science, mechanical engineering, or a related discipline and (2) at least one year of experience designing, developing, or researching the design and/or manufacture of solar cells or related technologies. Alternatively, a person of ordinary skill in the art would have had (1) a bachelor's degree in one of the aforementioned disciplines and (2) at least two years of experience designing, developing, or researching the design and/or manufacture of solar cells or related technologies. Additional work experience may compensate for less formal education, and vice versa. Dr. Ruby does not contest and applies my definition of a POSITA in his declaration. Ex.2027-Ruby-Decl., ¶¶14, 99-100. As also explained in my First Declaration, and as Dr. Ruby agrees (Ex.1075-Ruby-Tr., 162:21-163:2), I have the qualifications and

experience necessary to assess the '516 patent based on the perspective of a person of ordinary skill in the art, including as of the priority date for the '516 patent.

VIII. TECHNOLOGY BACKGROUND AND OVERVIEW OF THE '516 PATENT

13. In my First Declaration, I included a detailed overview of the technology background and the '516 patent (including the prosecution history of the '516 patent and related applications), which I incorporate by reference here. Ex.1003-Decl., ¶¶42-87.

14. Dr. Ruby includes a section in his declaration titled “Background of the '516 Patent and Related Technology” that describes the principles of solar cells and the state of the art. Ex.2027-Ruby-Decl., ¶¶22-85. Dr. Ruby also includes sections in his declaration titled “The '516 Patent” and “The '516 Patent Prosecution History and Related Applications.” Ex.2027-Ruby-Decl., ¶¶86-98. I disagree with several aspects of Dr. Ruby’s characterizations of the state of the art, the '516 patent, the '516 patent’s prosecution history, and the prosecution history of related applications. I address those points relevant to the issues before the Board in response to Dr. Ruby’s substantive arguments below.

15. I note, however, that many aspects of Dr. Ruby’s testimony confirm my opinions on the state of the art prior to the '516 patent. For example, Dr. Ruby agrees that the following goals, solar cell metrics, and features were known by 2008: the

goal of increasing efficiency was known (Ex.1075-Ruby-Tr., 69:6-13); the goal of reducing recombination was known (*id.*, 99:6-21); emitter saturation current density (“ J_0 ”) was a known metric (*id.*, 99:6-21); contact resistance (“ ρ_c ”) was a known metric, (*id.*, 57:5-9); oxide layers, including tunnel oxide layers, were known (*id.*, 106:5-19, 180:20-181:1); how to manufacture oxide layers was known (*id.*, 107:12-108:5); polysilicon emitters were known (*id.*, 109:1-9); modeling of solar cells was known (*id.*, 72:5-73:3); analyzing only portions of solar cells or test structures was known (*id.*, 103:17-104:11); design tradeoffs in optimizing cells were known (*id.*, 105:17-21); screen printing and metal contacts were known (*id.*, 116:7-118:3, 39:18-40:2); and trenches were known (*id.*, 46:3-5, 46:14-17).

IX. CLAIM CONSTRUCTION

16. As explained in my First Declaration, I applied the plain and ordinary meaning of the claim terms in my analysis. Ex.1003-Decl., ¶¶99-102. Dr. Ruby appears to agree that the plain and ordinary meaning of the claim terms should be applied in this IPR. Ex.2027-Ruby-Decl., ¶¶101-103.

X. OVERVIEW OF THE PRIOR ART

17. In my First Declaration, I included a detailed overview of the prior art, which I incorporate by reference here. Ex.1003-Decl., ¶¶103-119.

18. Dr. Ruby includes a section in his declaration titled “The Cited References and Other Prior Art.” Ex.2027-Ruby-Decl., ¶¶104-163. I disagree with

several aspects of Dr. Ruby's characterizations of the prior art references, including Froitzheim, Borden-575, Li, Gan, the Gan Thesis, Foglietti, and Sheats. I address those points relevant to the issues before the Board in response to Dr. Ruby's substantive arguments below.

19. I note, however, that many aspects of Dr. Ruby's testimony confirm my opinions on the disclosures of the references that I rely on in the invalidity grounds set forth in my First Declaration. For example, Dr. Ruby agrees that Gan teaches "an oxide layer formed between the back surface of the substrate and the emitter layer" (Ex.1075-Ruby-Tr., 180:20-181:1); Gan was studying "that the combination of a tunnel oxide and doped polycrystalline silicon layer provides excellent passivation and carrier selectivity on the N-type substrate" (*id.*, 109:1-9); Froitzheim teaches front and rear metal contacts that are formed by screen printing (Ex.1075-Ruby-Tr., 173:6-174:8); Sheats discloses a trench (*id.*, 196:18-22); Foglietti teaches a (tunnel) oxide layer for a transistor, which also applies to solar cells (Ex.2027-Ruby-Decl., ¶¶80-82); Froitzheim teaches a solar cell with a substrate and emitter (*id.*, ¶¶108-109); and Li teaches a solar cell with a substrate and emitter (*id.*, ¶149).

XI. GROUND I: CLAIMS 1-4 AND 6-12 ARE INVALID AS OBVIOUS OVER FROITZHEIM AND GAN

20. In my First Declaration, I explained that independent claims 1 and 9 of the '516 patent would have been obvious over the combination of Froitzheim and

Gan. Ex.1003-Holman-Decl., ¶¶121-172, 185-194. Dr. Ruby does not dispute that the combination of Froitzheim and Gan teaches every limitation of independent claims 1 and 9. Ex.2027-Ruby-Decl., ¶¶164-180. Dr. Ruby also does not dispute that a POSITA would have been motivated to combine the teachings of Froitzheim and Gan. Ex.2027-Ruby-Decl., ¶¶164-180. Dr. Ruby only disputes whether a POSITA would have had a reasonable expectation of success combining Froitzheim and Gan. I disagree with Dr. Ruby for the reasons in Section XI.A below.

21. The only dependent claim that Dr. Ruby addresses is claim 12. Ex.2027-Ruby-Decl., ¶¶181-193. I also disagree with Dr. Ruby's opinions regarding claim 12 for the reasons in Section XI.B below.

A. A POSITA Would Have Been Motivated To Combine Froitzheim And Gan With A Reasonable Expectation Of Success

22. As explained in my First Declaration, a POSITA would have been motivated to modify Froitzheim's solar cell to include an oxide layer and polysilicon emitter as taught by Gan with a reasonable expectation of success. Ex.1003-Holman-Decl., ¶¶121-145. In particular, a POSITA would have been motivated to implement Gan's teachings of an oxide layer and polysilicon emitter in Froitzheim's solar cell to increase the efficiency of Froitzheim's cell. Ex.1003-Holman-Decl., ¶¶121-145.

23. Dr. Ruby's testimony is consistent with my opinions. For example, Dr. Ruby agrees that Gan teaches "an oxide layer formed between the back surface of the substrate and the emitter layer." Ex.1075-Ruby-Tr., 180:20-181:1. Dr. Ruby also agrees that improving solar cell efficiency is, and long has been, a driving factor in solar cell design, and that improving solar cell efficiency by even "one-tenth" of a percent is "worthwhile" because "when you're producing millions of solar cells a year it adds up to a lot more electricity"—a point with which I agree. Ex.1075-Ruby-Tr., 69:6-13; Ex.2027-Ruby-Decl., ¶51 ("The overarching goal of the solar cell industry is to increase the efficiency of the solar cell[.]"). Dr. Ruby also agrees that recombination reduces solar cell efficiency, and that a POSITA would have understood that a "goal of effective solar cell design is to minimize this recombination by maximizing carrier lifetimes and diffusion lengths, thereby keeping J_o low." Ex.2027-Ruby-Decl., ¶¶52-53. He further agrees that contact resistance reduces solar cell efficiency, and that a POSITA would have understood that "[a] high ρ_c results in excessive loss of power and lower efficiency." Ex.2027-Ruby-Decl., ¶64.

24. Further, Dr. Ruby agrees that tunnel oxide layers and their benefits were well known by POSITAs. Ex.2027-Ruby-Decl., ¶¶77-84. He agrees that Gan was studying, and it was known in the art, "that the combination of a tunnel oxide and

doped polycrystalline layer provides excellent passivation and carrier selectivity on the N-type substrate....” Ex.1075-Ruby-Tr., 109:1-9. He also does not dispute Gan’s ultimate conclusion that an oxide layer and polysilicon emitter are beneficial for improving solar cell efficiency. Ex.2027-Ruby-Decl., ¶¶164-180; Ex.1075-Ruby-Tr., 109:1-9. Gan’s conclusion is consistent with the design goals that Dr. Ruby acknowledges—it is important to reduce J_o and ρ_c to improve solar cell efficiency. *See* Ex.1075-Ruby-Tr. 57:5-9 (agreeing that minimizing ρ_c was required to optimize performance), 99:6-21 (agreeing that a goal of effective solar cell design is to minimize recombination and J_o), 104:21-105:3 (agreeing that high ρ_c “results in excessive loss of power and lower efficiency”), 105:17-21 (agreeing that minimizing ρ_c may result in design tradeoffs), 106:5-19 (agreeing that tunnel oxides were known), 107:12-108:5 (agreeing that a POSITA would have known how to implement a tunnel oxide and tunnel oxides were compatible with solar cells). As a result, and as my First Declaration explains, a POSITA would have been motivated to apply Gan’s conclusion “that polysilicon emitters with low [J_o and ρ_c] can be obtained with a very small fraction of interfacial oxide breakup” to Froitzheim’s solar cell and would have understood that doing so was a straightforward application of the principles Dr. Ruby agrees were known by POSITAs. Ex.1005-Gan, 245, 249.

25. As detailed further below, I disagree with Dr. Ruby that a POSITA would not have had a reasonable expectation of success combining Froitzheim and Gan. Ex.2027-Ruby-Decl., ¶¶164-180. The Gan Thesis, which I have reviewed in its entirety, corroborates Gan's teachings and supports that a POSITA would have had a reasonable expectation of success combining the teachings of Froitzheim and Gan because it demonstrates that polysilicon emitters and oxide layers would be beneficial for increasing solar cell efficiency. Additionally, tunnel oxides and methods to reliably make them were well known in the art, and a POSITA would have readily understood how to successfully implement a tunnel oxide layer as taught by Gan in Froitzheim's solar cell.

1. The Gan Thesis Supports The Combination Of Froitzheim And Gan And Corroborates Gan's Teachings

26. Contrary to Dr. Ruby's declaration (Ex.2027-Ruby-Decl., ¶¶165-175), the Gan Thesis is consistent with Gan's teachings and supports that a POSITA would have been motivated to combine the teachings of Froitzheim and Gan with a reasonable expectation of success. Dr. Ruby's declaration quotes selected portions of the Gan Thesis to support his opinion that the Gan Thesis "documents consistent failures" and that "there was no known method for getting the oxide thickness sufficiently reliable to obtain acceptable results[.]" Ex.2027-Ruby-Decl., ¶¶164-175. I disagree with his statements. The Gan Thesis includes multiple sections that,

when considered in their entirety, teach that polysilicon emitters and oxide layers are beneficial for improving solar cell efficiency.

27. **First**, as my First Declaration explained, a POSITA would have been motivated to use an oxide layer between a polysilicon emitter and substrate because doing so was well known. Ex.1003-Decl., ¶122. Consistent with my First Declaration, the Gan Thesis would have motivated a POSITA to use an oxide layer and polysilicon emitter because the Gan Thesis describes the historical context for oxide layers and polysilicon emitters, explaining that each was previously used for solar cells and other semiconductor devices. Ex.2003-Gan-Thesis, 10 (“Chapter 3 starts a thorough review of the work done on the polysilicon emitter.”), 24-48 (Chapter 3). In particular, the Gan Thesis details historical studies about polysilicon emitters and interfacial oxide layers. For example, the Gan Thesis explains that “[t]he polysilicon-contacted emitter is now widely used in the silicon bipolar technology,” and “[t]he demand for polysilicon-contacted emitters stems from the down-scaling of bipolar transistors.” *Id.*, 24-25; *id.*, 31 (“The other proposed mechanism attributes the improvement of base current to the existence of a very thin oxide (interfacial oxide) sandwiched between the polysilicon and the substrate. This was first suggested by de Graaff and de Groot [9], and their reasoning is straightforward.”). The Gan Thesis explains that “[d]uring a high temperature

anneal, the breakup of the interfacial oxide has been reported by several authors....”

Id., 39. The Gan Thesis also acknowledges that polysilicon emitters and oxide layers stem from semiconductor devices such as bipolar transistors (*e.g.*, *id.*, 24-25, 39-41), which Dr. Ruby agrees are relevant to the field of solar cells. Ex.1075-Ruby-Tr., 27:13-22 (agreeing semiconductor physics includes solar cells), 109:1-7 (agreeing Gan was studying that a tunnel oxide and polysilicon emitter combination provide “excellent passivation and carrier selectivity”). Therefore, a POSITA would have been motivated to use an oxide layer and polysilicon emitter because the benefits of this technology were well developed and known, as recognized by the Gan Thesis.

28. **Second**, the Gan Thesis created theoretical models that study whether a polysilicon emitter and interfacial oxide layer combination had desirable characteristics (*e.g.*, desirable J_o and ρ_c values) and confirmed its models empirically. Ex.2003-Gan-Thesis, 10 (“Chapter 4 is dedicated to the derivations.... Chapter 5 is the demonstration of the experimental results.”), 49, 70. In particular, Chapter 4 of Gan describes theoretical models of an oxide layer and polysilicon emitter combination that concluded this combination would have “both low J_o and ρ_c .” Ex.2003-Gan-Thesis, 69; *see also id.*, 49-69. I disagree with Dr. Ruby’s assertion that these theoretical models are simply “musings” that a POSITA would have ignored. Ex.2027-Ruby-Decl., ¶135. By February 20, 2008, it was very common

(and, in fact, a best practice) in the solar cell industry and academia to consider the scientific theory behind a potential advancement, and to model it, just like the Gan Thesis (and Gan itself). Ex.2003-Gan-Thesis, 68 (“Figure 4.9: Simulated ρ_c versus J_o ”). Dr. Ruby also agrees that performing modeling on solar cell designs is important. He testified that he would use “computer modeling” when evaluating cell designs, and it was “always worthwhile” to perform computer modeling. Ex.1075-Ruby-Tr., 65:20-66:4, 73:22-74:2; *see also* Ex.1085-Ruby-2001 (publication from Dr. Ruby discussing modeling for solar cells). He also testified that computer modeling for solar cells has existed since 1985. Ex.1075-Ruby-Tr., 72:5-73:3.

29. Chapter 5 of the Gan Thesis discusses the testing that the author performed on polysilicon emitters and oxide layers that confirmed this combination of features would have low J_o and ρ_c . Ex.2003-Gan-Thesis, 10 (“The results shown in this chapter are very much like what are predicted in Chapter 4.”), 70 (“From the discussion in the previous chapter, there is a great chance to make a polysilicon SIS emitter with both low J_o and ρ_c by breaking a very small fraction of the interfacial oxide. In this chapter, we shall show, experimentally, that this is indeed the case.”). Based on the models and experiments, the Gan Thesis concludes that an oxide layer and polysilicon emitter combination can be made with desirable J_o and ρ_c values. Ex.2003-Gan-Thesis, 10 (“[A] polysilicon SIS emitter with low J_o and ρ_c can be

obtained by breaking a very small fraction of interfacial oxide.”), 53 (equations 4.8 and 4.11 establish that “[t]heoretically, it is possible to make a polysilicon SIS emitter with an intact interfacial oxide having low J_o and ‘acceptable’ ρ_c simultaneously”); *see also id.*, 10 (“Above all, obtaining small broken areal fraction of the interfacial oxide seems to be a very promising method for making polysilicon emitters....”). In view of the modeling and measurements described in the Gan Thesis that demonstrated an oxide layer and polysilicon emitter would successfully result in low J_o and ρ_c and thus increase a solar cell’s efficiency, a POSITA would have been motivated to use an oxide layer and polysilicon emitter in a solar cell.

30. **Third**, the challenges described by the Gan Thesis do not detract from its conclusion, supported by its models and measurements, that an oxide layer and polysilicon emitter are beneficial for solar cells. Dr. Ruby’s declaration selectively quotes portions of the Gan Thesis to support his argument that the Gan Thesis documents “consistent failures.” Ex.2027-Ruby-Decl., ¶¶167-174. It is important to consider these portions referenced by Dr. Ruby in the context of the entire Gan Thesis. It would have been clear to a POSITA reading the Gan Thesis in 2008 that Dr. Gan was explaining that, at his university, the furnace to which he had access provided insufficient control of the gases within it during oxide growth. For example, the Gan Thesis explains that the furnace and unintentional residual oxygen

in it led to quality control challenges with forming the interfacial oxide layer consistently. Ex.2003-Gan-Thesis, 112 (noting oxide growth, despite the furnace being filled “with pure argon” and noting that “[t]his may have to do with the oxygen residue in the furnace”).

31. In view of the furnace challenges, the Gan Thesis explains how to improve manufacturing methods for oxide layers. For example, the Gan Thesis explains that “the thin-oxide growth can be improved by performing the oxidation at lower temperature such that the oxidation rate can be controlled more precisely.” Ex.2003-Gan-Thesis, 112; *see also id.*, 10 (“In the final chapter, a summary of contributions of this study and suggestions for future work are given.”). That is, the author understood what caused the oxide layer challenge (inconsistent thickness because of poor control of oxygen in the university furnace) and he knew of at least one way to overcome it (adjusting furnace temperature). Thus, the Gan Thesis explains that a POSITA must utilize a furnace that is capable of adequately controlling the oxide layer thickness, rather than suggesting that the combination of an oxide layer and polysilicon emitter would be unsuccessful. As a result, in view of Gan’s teachings about the benefits of an oxide layer and polysilicon emitter, a POSITA would have been motivated to use an oxide layer and polysilicon emitter

in a solar cell even though the Gan Thesis described certain challenges with its furnace.

32. Even if Dr. Ruby were correct that the Gan Thesis indicates that Gan's described technique for forming an oxide layer was unreliable (Ex.2027-Ruby-Decl., ¶¶173, 175), Dr. Ruby ignores that a POSITA at the time of the '516 patent's priority date would have understood how to successfully manufacture an oxide layer.³ As my First Declaration explains, manufacturing techniques for oxide layers were well known by 2008. Ex.1003-Decl., ¶144. Dr. Ruby also agrees that a POSITA would have known how to manufacture a tunnel oxide layer for solar cells and transistors by 2008. Ex.1075-Ruby-Tr., 107:12-19; *see also id.*, 27:13-22 (agreeing that semiconductor physics applies to solar cells and a transistor is a semiconductor device), 109:1-7 (agreeing that the benefits of an oxide layer and polysilicon emitter were known by 2008). Additionally, in my First Declaration, I identified multiple prior art references that post-date the Gan Thesis and Gan that describe successfully

³ Dr. Ruby's opinion that Gan's technology was a "consistent failure" (Ex.2027-Ruby-Decl., ¶166) is also contradicted by the fact Dr. Ruby agrees that Gan teaches an oxide layer and polysilicon emitter (Ex.1075-Ruby-Tr., 180:20-181:1) and Gan successfully implemented an oxide layer. Ex.1005-Gan, 245, 249.

implementing oxide layers. *E.g.*, Ex.1003-Decl., ¶¶136, 138-139, 144-145; *see also* Ex.1078-Pulfrey, 1308 (describing tunnel oxides in early metal-insulator-semiconductor solar cells), 1310 (“Greater control over the oxide thickness and other properties has subsequently been achieved by a variety of deliberate oxidation processes....”), 1311; Ex.1079-Limiti, 1375 (describing a tunnel oxide and a polysilicon emitter for solar cells); Ex.1080-Metz-1997 (describing silicon solar cells having “a thin tunnel oxide”). For example, Dr. Ruby agrees that Foglietti teaches an oxide layer that was successfully implemented. Ex.1042-Foglietti, [0046]; Ex.2027-Ruby-Decl., ¶¶80-84. As a result, in view of the knowledge of a POSITA regarding oxide layers and the multiple prior art references describing oxide layers that post-date the Gan Thesis and Gan, a POSITA would have known how to successfully implement an oxide layer and polysilicon emitter.

33. Finally, I understand that the Patent Owner argues there was no motivation to combine Froitzheim and Gan “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.” POR, 28. I disagree. As my First Declaration (Ex.1003-Decl., ¶135) explains, Froitzheim and Gan each teach common manufacturing processes, such as diffusion from a dopant source to form the emitter, including overlapping

temperature ranges for said diffusion. Ex.1004-Froitzheim, [0042] (teaching a temperature range between 900 and 1200 °C); Ex.1005-Gan, 246 (teaching a temperature range between 900 and 1000 °C). To the extent that Froitzheim's temperature range required adjustment, a POSITA would have readily known how to do so. As I explained at my deposition, a POSITA would have understood that Fick's well-known laws govern the diffusion process, and would have understood how to apply those laws to adjust the diffusion temperature and time to achieve similar doping concentration while maintaining the integrity of the solar cell's layers. Ex.2029-Holman-Tr., 112:1-116:7. Dr. Ruby also agrees that a POSITA would have understood how to diffuse dopants by 2008 and provides no support in his declaration for Patent Owner's argument that the anneal temperature would have been detrimental. Ex.1075-Ruby-Tr., 46:22-47:16 (describing doping from his work at Sandia), 146:4-7. As a result, a POSITA would have readily understood how to adjust Froitzheim's processing temperatures as needed to manufacture a reliable solar cell while also implementing an oxide layer and polysilicon emitter as Gan teaches.

2. Polysilicon Emitters And Tunnel Oxide Layers Were Known Features In Semiconductor Technology, Which Includes Solar Cells And Transistors

34. As my First Declaration explains, a POSITA would have been motivated to implement a tunnel oxide layer and polysilicon emitter as taught by Gan in Froitzheim's solar cell because polysilicon emitters and tunnel oxide layers were well-known features in solar cells and transistors, which are each types of semiconductor devices. *E.g.*, Ex.1003-Decl., ¶¶136, 138-141. Despite the multiple references that I cite in my First Declaration, Dr. Ruby asserts in his declaration that "polysilicon emitters and tunnel oxide layers were not known elements in solar cells." Ex.2027-Ruby-Decl., ¶176. I disagree, and his deposition testimony is inconsistent with his declaration in this regard. In his deposition, Dr. Ruby agreed that "Gan teaches an oxide layer formed between the back surface of the substrate and emitter layer." Ex.1075-Ruby-Tr., 180:20-181:1. He also agreed that "by 2008, a [POSITA] of the ['516 patent] would have known how to add a tunnel oxide to a solar cell[.]" Ex.1075-Ruby-Tr., 107:12-108:5. He further agreed that transistors are semiconductor devices and transistor technologies are relevant to solar cells. *Id.*, 107:2-15. He also agreed that Foglietti teaches a tunnel oxide layer for a transistor. Ex.2027-Ruby-Decl., ¶81; Ex.1075-Ruby-Tr., 28:11-22. Dr. Ruby himself published an article in 1990 that describes multiple previous studies that used doped

polycrystalline silicon layers in solar cells (Ex.1086-Ruby-1990, 3), and he agreed at his deposition that polysilicon emitters were known in the prior art. Ex.1075-Ruby-Tr., 44:18-45:3. Thus, contrary to the Ruby Declaration, polysilicon emitters and tunnel oxide layers were known features of solar cells and related technology, and a POSITA would have been motivated to include these features in a solar cell to improve the cell's efficiency. *See also* Ex.1078-Pulfrey, 1308, 1310-11 (reviewing the state of the art in metal-insulator-semiconductor solar cells with tunnel oxide layers); Ex.1079-Limiti, 1375 (describing a tunnel oxide and a polysilicon emitter for solar cells); Ex.1080-Metz-1997 (describing silicon solar cells having “a thin tunnel oxide”).

35. I also disagree with Dr. Ruby's characterization of Gan, Borden-575, Froitzheim, and Swanson with regards to their teachings about oxide layers. Ex.2027-Ruby-Decl., ¶¶177-180. For example, Dr. Ruby states that “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....” Ex.2027-Ruby-Decl., ¶180 (citing Ex.1015-Swanson, 2:50-53). Dr. Ruby's analysis, however, does not consider the full scope of Swanson's teachings. In fact, Swanson specifically teaches a method of forming a tunnel oxide. Swanson explains that when the oxide layer “is formed on the back side [] of the wafer,” the oxide layer should be “about 7 to 20 Angstroms”

thick, and “may be formed using an ozone oxidation process, which involves dipping wafer 102 in a bath comprising ozone suspended in deionized water.” Ex.1015-Swanson, 3:35-57. Thus, Swanson directly teaches how to form a tunnel oxide, contrary to Dr. Ruby’s opinions.⁴

⁴ I also disagree with Dr. Ruby’s summary of Borden-575. Ex.2027-Ruby-Decl., ¶178. As explained in my First Declaration, Borden-575 teaches a tunnel oxide layer and polysilicon emitter (*e.g.*, Ex.1003-Decl., ¶224), and as Dr. Ruby acknowledges, a person of ordinary skill in the art would have understood how to successfully implement an oxide layer. Ex.1075-Ruby-Tr., 107:12-108:5. Dr. Ruby is incorrect that a POSITA would have limited Borden-575 teaching’s to “an optional tunnel oxide layer grown in Borden-575’s contact holes,” Ex.2027-Ruby-Decl., ¶178, for the reasons discussed herein. *See* Section XII.B–C (explaining that a POSITA would have understood that the fraction of the area covered by the tunnel oxide and the buried oxide in Borden-575 is a design tradeoff). Additionally, I disagree with Dr. Ruby’s summary of Froitzheim. I did not rely on Froitzheim’s disclosure of a silicon oxide passivation layer for teaching a tunnel oxide layer. *E.g.*, Ex.1003-Decl., ¶¶122, 136. Instead, I cited Froitzheim’s teachings to demonstrate that oxide layers were a known feature of solar cells. Ex.1003-Decl., ¶136.

36. Moreover, Dr. Ruby's statement that "Gan does not teach the fabrication of a solar cell, but rather, a test device that does not even have a PN junction" mischaracterizes Gan's teachings. Ex.2027-Ruby-Decl., ¶176. Dr. Ruby testified at his deposition that while he was employed at Sandia, he measured characteristics of an emitter—a solar cell component and not a full solar cell. Ex.1075-Ruby-Tr., 78:13-21. He also agreed that such measurements of a solar cell component or a test structure inform the expected performance of a solar cell. Ex.1075-Ruby-Tr., 103:17-104:11. Moreover, Dr. Ruby agreed that Gan's teachings are "directed to a concentrator [solar] cell." Ex.2027-Ruby-Decl., ¶59. Thus, the fact that Gan uses a "test device" does not indicate to a POSITA that Gan's teachings would be inapplicable to a full solar cell.

B. The Combination Of Froitzheim And Gan Renders Claim 12 Obvious

37. As my First Declaration explains, the combination of Froitzheim and Gan teaches claims 12. Ex.1003-Decl., ¶¶182-184. Dr. Ruby agrees that metal contacts and the screen-printing process to form metal contacts were known by 2008. Ex.1075-Ruby-Tr., 116:7-118:3, 39:18-40:2. Dr. Ruby also agrees that Froitzheim teaches a rear metal contact that is formed by screen printing. Ex.1075-Ruby-Tr., 173:6-174:8. Despite this agreement, Dr. Ruby contends that Froitzheim's screen printed contacts are "formed between the passivation layer" instead of being

“formed over a layer of silicon dioxide.” Ex.2027-Ruby-Decl., ¶¶181-193. I disagree.

38. As an initial matter, and as my First Declaration explains, claim 12 recites “wherein the second metal contact comprises silver formed over a layer of silicon dioxide.” Ex.1003-Decl., ¶¶182-184. Figure 4L of the ’516 patent, which only shows a portion of a solar cell rather than a complete solar cell, depicts an embodiment of a single, rear metal contact that penetrates through the silicon dioxide layer in two locations and contacts the emitter. Ex.1001-USP516, Fig. 4L, 5:48-55. The rear metal contact depicted in Figure 4L does not cover the entire backside of the solar cell, and because Figure 4L depicts only a portion of a solar cell, a POSITA would have understood that the rear side of the solar cell could include multiple metal contacts. *Id.* The ’516 patent also explains that the rear metal contact can be a “screen printed” metal contact. *Id.*, 5:60-64 (“Formation of the metal contacts 110 and 102 may be followed by a firing step. The firing step is applicable when using screen printed silver paste as metal contacts, but not when using other processes or metals.”).

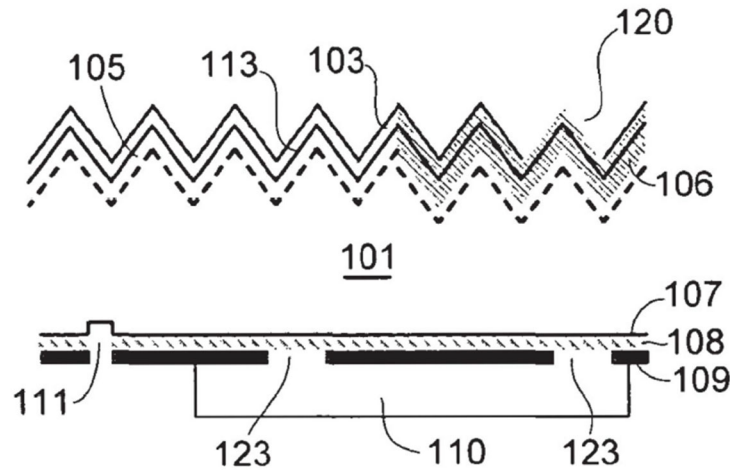
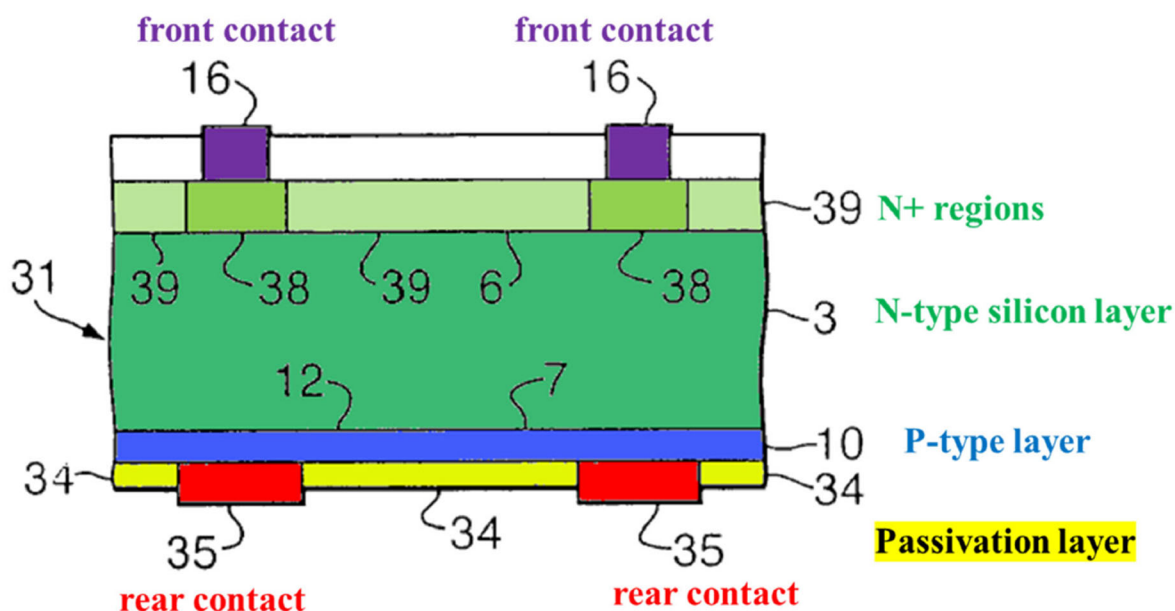


FIG. 4L

Id., Fig. 4L. Claim 12 does not recite the single, rear metal contact structure that Figure 4L depicts. Instead, claim 12 requires only that the metal contact is “formed over a layer of silicon dioxide.”

39. Additionally, for two reasons, I disagree with Dr. Ruby that Froitzheim fails to teach a second metal contact comprising silver “formed over a layer of silicon dioxide.” **First**, as my First Declaration explains and as Froitzheim’s Figure 3 shows, Froitzheim’s solar cell includes screen-printed “**rear side contacts 35**” “arranged in electrical connection with the **p-doped layer 10**.” Ex.1004-Froitzheim, [0027], [0033], [0048] (“Front and rear side contacts are preferably screen-printed in an industrial production process[.]”). Froitzheim also teaches that a “**passivation layer 34**” is created over the **p-doped layer 10**, and that the **passivation layer 34** can be made of silicon dioxide (SiO₂) or silicon nitride (SiN). Ex.1004-Froitzheim,

[0019], [0030], [0033]. Froitzheim teaches that this **passivation layer 34** can be applied **before** contact formation. The language in Froitzheim is that the “[p]assivation and antireflection coating **can be applied** using known methods, **before** or after contact formation.” Ex.1004-Froitzheim, [0050].



Ex.1004-Froitzheim, Fig.3. Significantly, the '516 patent states that its rear metal contact can be a “screen printed” metal contact. Ex.1001-USP516, 5:60-64. Thus, Froitzheim discloses the same rear contact described in the '516 patent: a rear metal contact that is created via screen printing.

40. Dr. Ruby agrees that Froitzheim teaches rear metal contacts that are formed by screen printing. Ex.1075-Ruby-Tr., 173:6-174:8. Dr. Ruby also agrees with the basic steps that are performed to screen print a metal contact. *Id.*, 40:12-

21, 116:7-118:3. Dr. Ruby agrees that “a screen is [first] placed over the solar cell and a metal paste is pushed through the screen to only lie on top of areas of the cell defined by the pattern in the screen.” *Id.*, 116:21-117:1. Dr. Ruby also testified that screen printing involves “depositing a metal paste on the surface of a solar cell which may have an anti-reflection coating on it[.]” *Id.*, 40:12-21. Antireflective coatings were well known and commonly also served as passivation layers. They were commonly implemented as a dielectric or layer stack made of silicon dioxide or silicon nitride. Ex.1003-Decl., ¶¶71-72; Ex.1075-Ruby-Tr., 54:2-6 (agreeing “silicon nitride” was used for antireflective layers). Dr. Ruby thus agrees that after metal paste is placed over a dielectric layer on the cell, the metal paste is heated to fire through the layer such that the metal paste penetrates the layer to become in contact with underlying layers to create an electrical connection. Ex.1075-Ruby-Tr., 40:12-21 (describing “firing through”), 117:9-22 (same). As a result, Dr. Ruby agrees that screen printing involves applying metal paste over a layer such as a silicon dioxide layer and then heating the metal paste such that it “fires through” the silicon dioxide layer to become in contact with underlying layers to create an electrical connection. Because Froitzheim teaches rear metal contacts that are created by screen printing the contacts over the layer of silicon dioxide (i.e., applying the metal paste over the layer of silicon dioxide and then heating the metal paste so

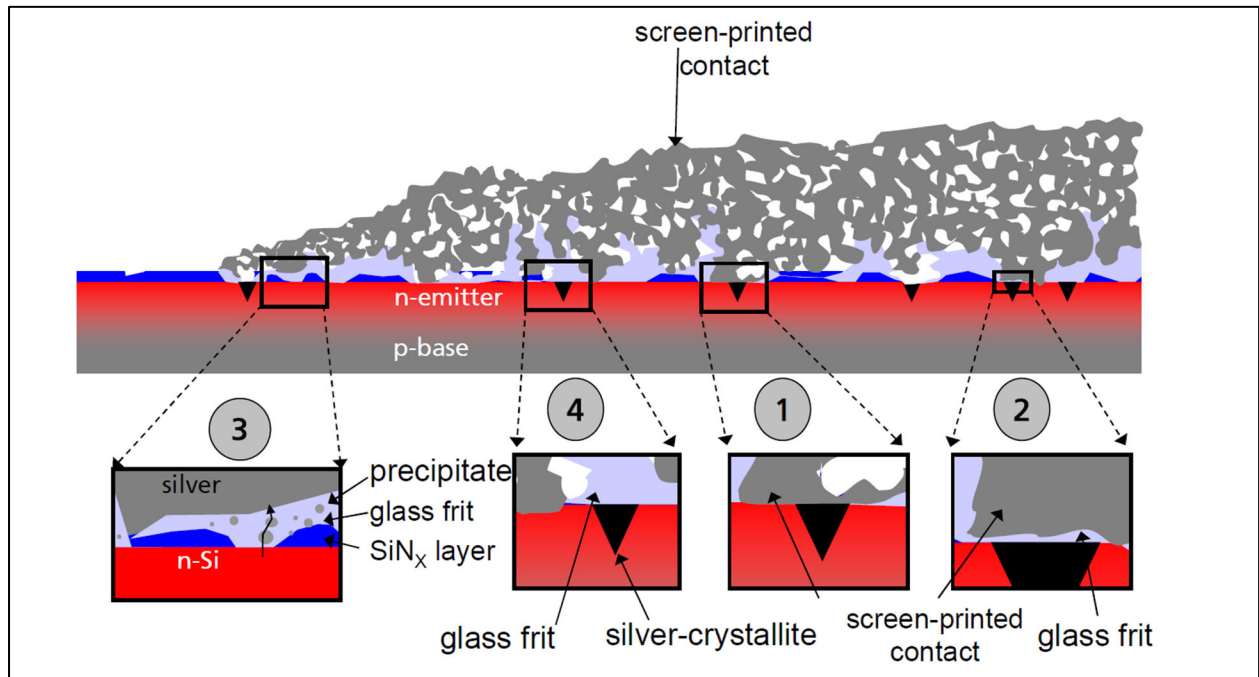
the metal comes into contact with the emitter of the cell)—which is the same process that the '516 patent describes for creating a rear contact (Ex.1001-USP516, 5:60-64)—Froitzheim teaches a metal contact *formed over a layer of silicon dioxide*.

41. **Second**, the analysis in Dr. Ruby's declaration mischaracterizes Froitzheim's disclosure of screen printing rear metal contacts. Ex.2027-Ruby-Decl., ¶¶185-187. Froitzheim's Figure 3 is a drawing in a patent document that is not drawn to scale. Contrary to Dr. Ruby's assertion, a POSITA would have understood that the metal paste that forms Froitzheim's rear contacts would not completely "fire through" the silicon dioxide layer. Instead, only a portion of the metal paste would "fire through" the silicon dioxide layer to create an electrical connection with the emitter, with most of the metal paste remaining over the silicon dioxide layer on which it was first applied.

42. As I explained at my deposition, a POSITA would have known screen printing involved placing silver (or other metal) paste onto a passivation layer, as Froitzheim teaches. Ex.2029-Holman-Tr., 84:13-85:16. The silver paste was then heated such that the metal was "fired through" the passivation layer to reach the emitter or substrate. Ex.2029-Holman-Tr., 84:13-85:16. "Firing through" did not result in the metal contact completely etching away the passivation layer so the metal contacts are "between" the passivation (e.g., silicon dioxide) layer. Ex.2029-

Holman-Tr., 84:13-85:16. The process instead results in metal “filaments” reaching through the passivation layer in some areas under the paste, but “most” of the metal would remain “on top of” or “over” the passivation layer. Ex.2029-Holman-Tr., 84:13-85:16. As discussed above, Dr. Ruby agrees that screen printing involves heating metal paste such that it “fires through” the passivation layer and creates an electrical connection with the underlying layer such as an emitter. Ex.1075-Ruby-Tr., 116:7-118:3. However, Dr. Ruby ignores that only a portion of the metal paste contacts the underlying layer to create an electrical connection.

43. This phenomenon is shown, for example, in Pysch (Ex.1081). The below cross-sectional schematic from Pysch accurately depicts screen printing and demonstrates how the metal contact would actually look on Froitzheim’s cell. As shown below, the metal “screen-printed contact” (grey) was fired through the passivation layer (blue) to reach the emitter (red). As seen, however, the firing-through process does not completely etch away the passivation layer. Instead, multiple portions of the passivation layer remain intact and therefore the metal contact remains “over” the passivation layer to a significant extent and not fully “between” the passivation layer, as Dr. Ruby asserts.



Ex.1081-Pysch, Fig. 14.⁵

⁵ Although the passivation layer shown in Pysch is SiN_x, the result would be similar for a passivation layer containing silicon dioxide, which Froitzheim teaches. By 2008, passivation stacks that contained silicon dioxide were known to survive high-temperature paste firing at least as well as silicon nitride alone. See Ex.1082-Schmidt, 167 (“The surface passivation provided by a thin oxide/nitride stack is slightly more effective than the best single-layer SiN passivation. However, even more important is the strongly improved thermal stability of the surface passivation

44. Therefore, Froitzheim's screen printing process to create its rear metal contacts results in metal paste being formed *over* the silicon dioxide layer even after firing, as only a portion of the metal will "fire through" the silicon dioxide layer to contact the emitter. *See also* Ex.1083-Liang, 105-106 (discussing "residual SiN_x" that is present after screen printing); Ex.1084-Cabrera, 110 ("Varying the glass frit content in the silver paste influences the opening of the SiN_x layer, the size and density of Ag crystallites formed, and the contact resistance."). For these reasons, Froitzheim teaches the limitations of claim 12.

XII. GROUND III: CLAIMS 1-4 AND 6-12 ARE INVALID AS OBVIOUS OVER FROITZHEIM AND BORDEN-575

45. As my First Declaration explains, a POSITA would have been motivated to modify Froitzheim to incorporate a polysilicon emitter and tunnel oxide layer as taught by Borden-575 with a reasonable expectation of success. Ex.1003-Decl., ¶¶223-231. As detailed below, I disagree with those portions of Dr. Ruby's

by the thin oxide/nitride stacks compared to the single-layer SiN passivation (see figure 8). This makes the stack passivation scheme particularly well suited for solar cell fabrication processes, where the surface passivation has to withstand a higher temperature (e.g. during the firing of screen-printed metal contacts).").

declaration where he suggests that a POSITA would not have been motivated to combine Froitzheim and Borden-575 with a reasonable expectation of success. Ex.2027-Ruby-Decl., ¶¶226-267.

A. Borden-575 Is Prior Art To The '516 Patent

46. I understand that Patent Owner argues that Borden-575 is not prior art. As I explained in my First Declaration, I have been informed and understand that a patent publication qualifies as prior art as of the filing date of its priority provisional application if the provisional application (1) supports at least one claim in the patent publication and (2) includes the relevant subject matter of the patent publication that is relied upon. Ex.1003-Decl., ¶110. My First Declaration explained how both requirements are satisfied by identifying (1) where all of Borden-575's claim 1 limitations are present in the Borden Provisional and (2) where all relevant portions of Borden-575's written description are present in the Borden Provisional. Ex.1003-Holman-Decl., ¶¶111-112. I understand that Patent Owner argues that claim 1 of Borden-575 is not supported by the Borden Provisional because the Borden Provisional does not disclose a "semiconductor substrate." POR, 20-21. I also understand that Patent Owner argues that the Borden Provisional does not provide written description support for certain portions of Borden-575's disclosure. POR, 21-24. As detailed below, I disagree that these are meaningful.

47. **First**, claim 1 of Borden-575 recites “[a] solar cell comprising: an emitter layer formed on a semiconductor substrate.” Ex.1006-Borden-575, claim 1. I understand that Patent Owner argues that the Borden Provisional does not disclose a “semiconductor substrate” because the Borden Provisional does not use the exact phrase “semiconductor substrate” and instead recites a “semiconductor device” and “substrate.” POR, 20-21. That is a distinction without a substantive difference. It was well known that solar cells like Borden-575’s (and the Borden Provisional’s) are “semiconductor devices” that include “substrates,” and that silicon is a semiconductor material. Dr. Ruby and I agree on this point, as he wrote in his declaration and testified in his deposition that solar cells are “semiconductor devices” that include “substrates.” See Ex.2027-Ruby-Decl., ¶24 (“One type of semiconductor uses a silicon (Si) substrate....”), 31 (explaining that a “junction” is a “solar cell structure” and is a “term for a region of a semiconductor device”), 46 (describing a solar cell as a type of “semiconductor device”); Ex.1075-Ruby-Tr., 27:6-9 (agreeing that “semiconductor physics include solar cells” and that “solar cells [are] a type of semiconductor device”), 89:20-22 (agreeing that a “generic prior art solar cell as of 2008 had a silicon substrate”). Therefore, contrary to Patent Owner’s argument, the Borden Provisional provides written description support for a “semiconductor substrate” because it discloses a “semiconductor device” that

includes a “substrate” of a semiconductor material (silicon), i.e., a “semiconductor substrate.”

48. ***Second***, Patent Owner contends that multiple portions of Borden-575 are not disclosed in the Borden Provisional. POR, 21-22. However, Patent Owner does not identify any portion of the Borden-575 reference that I rely on for my opinions that is missing from the Borden Provisional. Patent Owner argues that the Borden Provisional does not disclose a V_{oc} (open-circuit voltage) equation that is recited in Borden-575. POR, 21-22. However, I do not rely on the V_{oc} equation in Borden-575 for my opinions in the Froitzheim and Borden-575 ground. In any event, a POSITA would have understood how V_{oc} is defined, and the equation for V_{oc} was well known in the art. For example, Dr. Ruby has a patent from 1999 that studies the exact same metric— V_{oc} —that Borden-575 and the Borden Provisional discuss. *See* Ex.1076-Ruby-591 (Dr. Ruby’s patent from 1999 studying V_{oc}). Dr. Ruby also agreed at his deposition that V_{oc} was known and POSITAs would have known how to determine V_{oc} . Ex.1075-Ruby-Tr., 130:6-17, 132:2-12, 133:1-4. Thus, even though I do not rely on the equation for V_{oc} in my opinions, the Borden Provisional provides written description support for the V_{oc} equation because the V_{oc} equation was well known by POSITAs.

49. Patent Owner is similarly incorrect that the Borden Provisional insufficiently discloses “details on substrate 200 and contact holes” and “tunnel oxide.” POR, 22-24. The Borden Provisional and Borden-575 each disclose a “substrate,” “contact holes,” and “tunnel oxide.” See Ex.1011-Borden-575-Provisional, Fig.2, [0017] (“Photocurrent flows through **contact holes** patterned in the oxide layer.”), [0018] (“A **thin tunnel oxide** may be included between the **substrate** and the polysilicon in the contact holes. This oxide—typically 8 to 15 Å thick—provides passivation between the substrate and the polysilicon, as described in the prior art.”), [0019]-[0023]. Dr. Ruby agrees that a “substrate,” “contact holes,” and “tunnel oxide” were known features of solar cells by 2008. See, e.g., Ex.2027-Ruby-Decl., ¶71 (describing a prior art device that had “small holes...formed in this passivating oxide layer”), 77-84 (agreeing tunnel oxides and tunnel current flow were known). Moreover, Dr. Ruby agrees that a tunnel oxide permitted electrons to “tunnel” (i.e., current to flow) through the oxide layer. Ex.2027-Ruby-Decl., ¶¶77-83 (explaining the conditions that affect majority carrier movement across an oxide layer). Dr. Ruby also testified at his deposition that tunnel oxides were known (Ex.1075-Ruby-Tr., 106:5-19, 180:20-181:1), a POSITA would have known how to implement a tunnel oxide layer in a solar cell (Ex.1075-Ruby-Tr., 107:12-108:5), solar cells and tunnel oxides were compatible (Ex.1075-Ruby-Tr., 107:12-108:5),

and a POSITA would have known that a tunnel oxide provides excellent passivation and carrier selectivity, i.e., a tunnel oxide allows current to flow through it while also suppressing recombination at the silicon wafer surface. Ex.1075-Ruby-Tr., 109:1-9. Therefore, a POSITA would have understood that the Borden Provisional provides written description support for the relevant portions of Borden-575's disclosure that I rely on in the Froitzheim and Borden-575 ground.

B. The Combination Of Froitzheim And Borden-575 Is Not Deficient Due To Borden-575's "Buried Oxide" Layer

50. In my First Declaration, I explained in detail the reasons that a POSITA "would have been motivated to modify Froitzheim to incorporate a polysilicon emitter and *tunnel oxide layer* as taught by Borden-575 with a reasonable expectation of success." Ex.1003-Decl., ¶¶223-231. I explained that multiple references teach the benefits of polysilicon emitters and tunnel oxide layers, which would have motivated a POSITA to modify Froitzheim to incorporate a polysilicon emitter and *tunnel oxide layer* as Borden-575 teaches. *E.g.*, Ex.1003-Decl., ¶227. I also explained that Borden-575 itself provides additional motivations that a POSITA would have considered that further support the motivation to combine the teachings of Froitzheim and Borden-575. *E.g.*, Ex.1003-Decl., ¶228. While I believe my analysis was quite detailed, Dr. Ruby contends that the combination of

Froitzheim and Borden-575 is “vague.” Ex.2027-Ruby-Decl., ¶¶226-230. I disagree.

51. As my First Declaration explains, Borden-575’s “buried oxide” and “tunnel oxide” each meet the oxide limitations in the challenged claims. Ex.1003-Decl., ¶¶238-240. In fact, Borden-575 teaches the tunnel and buried oxides may have the same thicknesses. Ex.1006-Borden-575, claim 10 (buried oxide “layer is less than about 20 Å thick”), [0022] (tunnel oxide “typically 8 to 15 Å thick”). Dr. Ruby’s declaration does not contest that Borden-575’s “buried oxide” and “tunnel oxide” each meet the oxide limitations in the challenged claims. Ex.2027-Ruby-Decl., ¶¶226-230. In my First Declaration, I also specifically explained *why* a POSITA would have been motivated to implement a polysilicon emitter and ***tunnel oxide layer*** as taught by Borden-575 to Froitzheim’s solar cell, including because multiple references, including Borden-575, taught the benefits of this configuration. Ex.1003-Decl., ¶¶223-231. As I explained during my deposition, my analysis focused on Borden-575’s ***tunnel oxide*** because “Borden-575’s tunnel oxide layer” is required “in order to make a functioning solar cell.” Ex.2029-Holman-Tr., 243:9-17. Thus, my motivation to combine analysis was focused on applying Borden-575’s teaching of a ***tunnel oxide*** to Froitzheim’s solar cell and was not vague.

52. Moreover, I also explained during my deposition that Borden-575 “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.” Ex.2029-Holman-Tr., 243:9-17. As a result, consistent with my testimony from my deposition and my First Declaration, a POSITA would have understood that Borden-575’s *buried oxide layer* was not required (but could be included). That is, a POSITA would have understood that omitting Borden-575’s teachings of a buried oxide layer and instead only including Borden-575’s teachings of a tunnel oxide layer in Froitzheim’s solar cell was a design tradeoff made in balancing low-resistance current flow with surface recombination.

53. Consequently, I disagree with Dr. Ruby’s characterization of the buried oxide as “crucial” and the tunnel oxide as “optional.” Ex.2027-Ruby-Decl., ¶¶251-253. In my opinion, a POSITA would have understood that the tunnel oxide layer must cover at least some of the interface between the emitter and the substrate, or else no current would flow. Ex.2029-Holman-Tr., 243:9-17 (“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.”). A POSITA would also have known how to construct a cell in which the tunnel oxide covered the entire area, omitting the buried oxide layer (e.g., omitting steps S402 and S404 in Borden-575). And a POSITA would have understood that the fraction of the area covered by the tunnel oxide and the buried oxide in Borden-575 is a design tradeoff. *See* Ex.1006-Borden-575 (“Typical dimensions of the openings 212 can be 20 to 200 μm and spacing between openings 212 can be 1-5 mm. The ratio of the spacing to opening width provides the concentration, which is limited by series resistance due to current crowding at the contact holes. Concentration ratios on the order of 5 to 20 are typical. The openings can be lines parallel to the contact grid lines, or holes of shape such as rectangles or circles.”). Dr. Ruby agrees that designing solar cells involves “several tradeoffs and careful optimization” (Ex.2027-Ruby-Decl., ¶61), and he testified at his deposition that solar cell design involves “trade-offs.” Ex.1075-Ruby-Tr., 31:21-32:1, 105:4-21. As a result, implementing a tunnel oxide layer, as taught by Borden-575, to obtain the benefits of a tunnel oxide layer, which Dr. Ruby agrees were well known (e.g., Ex.2027-Ruby-Decl., ¶¶77-83; Ex.1075-Ruby-Tr., 106:5-19, 107:12-108:5, 109:1-9)—but omitting a buried oxide either in part or fully—was a simple design tradeoff like those that were commonly performed by

POSITAs. For these reasons, I disagree with Dr. Ruby that the combination of Froitzheim and Borden-575 is “vague.”

C. A POSITA Would Have Been Motivated To Combine Froitzheim And Borden-575 With A Reasonable Expectation Of Success

54. Dr. Ruby makes multiple arguments against the motivation to combine Froitzheim and Borden-575 with a reasonable expectation of success. Ex.2027-Ruby-Decl., ¶¶231-265. I disagree with Dr. Ruby’s opinions.

55. *First*, I disagree with Dr. Ruby that Borden-575 would have been “too difficult to implement.” Ex.2027-Ruby-Decl., ¶¶231-241. Borden-575 specifically teaches that tunnel oxides were “well known” (Ex.1006-Borden-575, [0005]), and, as explained in my First Declaration, a POSITA would have understood how to successfully implement a tunnel oxide layer, particularly since tunnel oxides and their fabrication were well described in literature. *E.g.*, Ex.1003-Decl., ¶227. While Dr. Ruby’s declaration states that Borden-575 would have been “too difficult to implement,” he testified in his deposition—oppositely, in my view—that tunnel oxides and their benefits were known (Ex.1075-Ruby-Tr., 106:5-19, 180:20-181:1), solar cells and tunnel oxides were compatible (Ex.1075-Ruby-Tr., 107:12-108:5), and a POSITA would have known that a tunnel oxide provides excellent passivation and carrier selectivity, i.e., a tunnel oxide allows for current flow while suppressing surface recombination. Ex.1075-Ruby-Tr., 109:1-9. Dr. Ruby’s assertion that

Borden-575 would have been “too difficult to implement” is also inconsistent with his deposition testimony where he admits that a POSITA would have known how to implement a tunnel oxide layer in a solar cell. Ex.1075-Ruby-Tr., 107:12-108:5; *see also* Ex.1078-Pulfrey, 1308, 1310-11 (describing “a variety of deliberate oxidation processes” to fabricate tunnel oxide layers in metal-insulator-semiconductor solar cells); Ex.1079-Limiti, 1375 (describing a tunnel oxide and a polysilicon emitter for solar cells); Ex.1080-Metz-1997 (describing silicon solar cells having “a thin tunnel oxide”). Thus, Dr. Ruby’s deposition testimony appears to support my opinion that a POSITA would have readily known how to successfully implement a tunnel oxide as taught by Borden-575 in Froitzheim’s solar cell.

56. The portion of Dr. Ruby’s declaration that asserts that Borden-575 would have been “too difficult to implement” references the Gan Thesis. *E.g.*, Ex.2027-Ruby-Decl., ¶¶234-235. For the same reasons I discussed in Section XI.A.1, the Gan Thesis supports that a POSITA would have been motivated to incorporate a tunnel oxide with a reasonable expectation of success. For example, the Gan Thesis specifically teaches that polysilicon emitters and tunnel oxides are beneficial. *E.g.*, Ex.2003-Gan-Thesis, 10 (“Above all, obtaining small broken areal fraction of the interfacial oxide seems to be a very promising method for making polysilicon emitters....”). Therefore, because the Gan Thesis teaches that tunnel

oxide layers are beneficial and a POSITA would have known how to successfully implement a tunnel oxide layer, the Gan Thesis further supports that a POSITA would have known how to successfully implement a tunnel oxide layer, as Borden-575 teaches, in Froitzheim's solar cell.

57. ***Second***, Dr. Ruby contends that Borden-575 would have been “too difficult to implement” because Borden-575’s background section indicates that “MIS solar cells” with a “tunnel oxide” “have not been commercially introduced....” Ex.1006-Borden-575, [0005]; Ex.2027-Ruby-Decl., ¶235. I disagree with this assessment too. Borden-575’s background section acknowledges that tunnel oxides were “well known, and have been used commercially by Schott solar to manufacture MIS solar cells” (Ex.1006-Borden-575, [0005]), and, as my First Declaration explains, a POSITA would have understood how to successfully implement a tunnel oxide layer, particularly since the literature describes tunnel oxides extensively. *E.g.*, Ex.1003-Decl., ¶227. For the same reasons I discussed above, Dr. Ruby’s argument is also at odds with his deposition testimony where he agreed that tunnel oxides and their benefits were known and a POSITA would have known how to implement a tunnel oxide layer in a solar cell. Ex.1075-Ruby-Tr., 106:5-19, 107:12-108:5, 109:1-9, 180:20-181:1; *see also* Ex.1078-Pulfrey, 1308, 1310-11; Ex.1079-Limiti, 1375; Ex.1080-Metz-1997. Thus, the fact that Borden-575’s background

section indicates that “MIS solar cells” with a “tunnel oxide” “have not been commercially introduced” does not detract from the fact that a POSITA would have known how to successfully implement a tunnel oxide layer, as Dr. Ruby acknowledges.

58. **Third**, Dr. Ruby incorrectly asserts that “Borden-575 uses the same high temperatures that the Gan thesis warns about....” Ex.2027-Ruby-Decl., ¶237. Gan and the Gan Thesis do not “warn about” using temperatures at or above 1000 °C. Borden-575 teaches that “[a] short anneal at 1050 °C for 30 seconds after deposition activates the dopants.” Ex.1006-Borden-575, [0022]. Both Gan and the Gan Thesis list device fabrication procedures, including: “4. Polysilicon deposition (6000 Å) and first-step anneal (1050 °C).” Ex.1005-Gan, 246; Ex.2003-Gan-Thesis, 92. Therefore, Gan and the Gan Thesis teach processing steps at the exact same temperature (1050 °C) that Borden-575 teaches. Furthermore, Gan and the Gan Thesis explain that a *tradeoff* exists when using higher and lower processing temperatures in a second-step anneal. For example, Gan and the Gan Thesis explain that at higher temperatures, J_o increases but ρ_c decreases. Ex.2003-Gan-Thesis, 106 (“The use of a thermally grown interfacial oxide is important in that it not only has a good quality interface to the substrate, but also is robust during high temperature anneals. This allows us to see the subtle relationship between the oxide breakup and

the ρ_c and J_o . Depending on the extent of the oxide breakup, various combinations of ρ_c and J_o have been obtained.”); Ex.1005-Gan, 245 (“When 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...and the J_o is high...[c]onversely, when both carriers are mostly blocked by the interfacial oxide, like for an intact chemical oxide...the ρ_c is high and the J_o is low.”). Since low J_o and low ρ_c are both desirable, a POSITA would not have been discouraged or “warned” from using processing at or above 1000 °C because Gan and the Gan Thesis teach higher temperatures in a second-step anneal result in a **better** ρ_c which is helpful for reaching higher solar cell efficiency. Ex.1075-Ruby-Tr., 57:5-9 (agreeing that lower ρ_c results in increased performance), 104:21-105:3 (agreeing that high ρ_c “results in excessive loss of power and lower efficiency”).

59. Additionally, even assuming Dr. Ruby is correct that an embodiment in Borden-575 teaches a higher preferred temperature than the Gan Thesis (or Gan itself), a POSITA would have known to adjust temperatures when manufacturing a solar cell. A POSITA would have readily understood how to adjust the process temperature ranges to successfully implement an oxide layer while maintaining the integrity of Gan’s solar cell, particularly because, as I explained in my First Declaration, manufacturing techniques for solar cells were well known by 2008.

E.g., Ex.1003-Decl., ¶227. POSITAs routinely considered design tradeoffs during the solar cell design process, and adjusting processing temperatures was a routine design consideration with which a POSITA would have been familiar by 2008. Dr. Ruby agrees that designing solar cells involves “several tradeoffs and careful optimization” (Ex.2027-Ruby-Decl., ¶64), and he testified at his deposition that solar cell design involves “trade-offs” (Ex.1075-Ruby-Tr., 31:21-32:1, 105:4-21). Dr. Ruby also agrees that a POSITA by 2008 would have understood how to successfully implement oxide layers. Ex.1075-Ruby-Tr., 107:12-108:5. He further agrees that dopant diffusion—a solar cell manufacturing step that requires heating the cell—was also known by 2008 and a POSITA would have known how to successfully “perform [dopant] diffusion.” Ex.1075-Ruby-Tr., 46:22-47:16, 146:4-7. Thus, a POSITA would have readily known how to adjust processing temperatures to successfully implement a tunnel oxide layer as taught by Borden-575 in Froitzheim’s solar cell while maintaining the solar cell’s integrity.

60. ***Fourth***, contrary to Dr. Ruby’s declaration (Ex.2027-Ruby-Decl., ¶¶242-265), a POSITA would have readily understood how to implement a tunnel oxide layer as taught by Borden-575, with or without a buried oxide or contact holes. As I explained in my First Declaration, a POSITA “would have been motivated to modify Froitzheim to incorporate a polysilicon emitter and ***tunnel oxide layer*** as

taught by Borden-575 with a reasonable expectation of success.” Ex.1003-Decl., ¶224. I did not discuss in my declaration whether a POSITA would have been motivated to incorporate Borden-575’s buried oxide or contact holes in Froitzheim’s solar cell. Moreover, as explained in my First Declaration and above, a POSITA would have been motivated to implement a tunnel oxide layer as taught by Borden-575 because the benefits of oxide layers were known and POSITAs would have known how to successfully implement oxide layers. *E.g.*, Ex.1003-Decl., ¶¶227-228; Ex.1006-Borden-575, [0022] (“a thin tunnel oxide may be included between the substrate 200 and the polysilicon 210 in the contact holes 212. This oxide—typically 8 to 15Å thick—provides passivation between the substrate and the polysilicon, while allowing for tunnel current flow.”). In his deposition testimony, Dr. Ruby agrees that tunnel oxides and their benefits were known and a POSITA would have known how to implement a tunnel oxide layer in a solar cell. Ex.1075-Ruby-Tr., 106:5-19, 107:12-108:5, 109:1-9, 180:20-181:1; *see also* Ex.1078-Pulfrey, 1308, 1310-11; Ex.1079-Limiti, 1375; Ex.1080-Metz-1997. Thus, a POSITA would have readily understood how to successfully implement a tunnel oxide layer as taught by Borden-575 in Froitzheim’s solar cell.

61. ***Finally***, I understand that Patent Owner argues that the Borden Provisional does not describe that Borden-575’s tunnel oxide “allow[s] for tunnel

current flow.” POR, 65 (quoting Ex.1006-Borden-575, [0022]). I disagree. The Borden Provisional specifically states that “[a] thin tunnel oxide may be included between the substrate and the polysilicon in the contact holes” and “[t]his oxide...provides passivation between the substrate and the polysilicon, *as described in the prior art.*” Ex.1011-Borden-Provisional, [0018]. In my opinion, this use of the term “*tunnel* oxide” in Borden-575 would have clearly indicated to a POSITA that the tunnel oxide allows tunnel current to flow, as this term is only used when tunneling is possible. The Borden Provisional also states that a thin tunnel oxide can be used “under a layer of polysilicon to form a high efficiency solar cell.” Ex.1011-Borden-Provisional, [0004]. Before 2008, it was known that tunnel oxides “allow[] for tunnel current flow.” *E.g.*, Ex.1003-Decl., ¶84. Dr. Ruby agrees that tunnel oxides were known by 2008 and that tunnel oxides allowed current to flow by electrons “tunneling” through an oxide layer. Ex.2027-Ruby-Decl., ¶¶77-83 (“Due to [the tunnel oxide’s] thinness, electrons can ‘tunnel’ through the oxide layer[.]”); Ex.1075-Ruby-Tr., 106:5-19 (agreeing tunnel oxides were known by 2008), 107:12-108:5 (agreeing POSITAs would have understood how to manufacture tunnel oxides), 109:1-9 (agreeing the benefits of tunnel oxides were known), 180:20-181:1 (agreeing Gan discloses a tunnel oxide). Therefore, I disagree with Patent Owner’s

assertion that the Borden Provisional does not disclose that a tunnel oxide “allow[s] for tunnel current flow.” POR, 23.

D. The Froitzheim-Borden-575 Combination Discloses Claim 12

62. As I explained in my First Declaration, the combination of Froitzheim and Gan discloses claim 12. Ex.1003-Decl., ¶¶249-250. I disagree with Dr. Ruby’s assertion that the Froitzheim-Borden-575 combination does not satisfy the limitation of claim 12. Ex.2027-Ruby-Decl., ¶¶266-267. Dr. Ruby makes the same arguments regarding claim 12 in the Froitzheim-Borden-575 combination as he does for the Froitzheim-Gan combination (POR, 65-66; Ex.2027-Ruby-Decl., ¶¶266-267), and these arguments fail for the same reasons I discussed in Section XI.B.

XIII. GROUND V: CLAIMS 1-2 AND 8-11 ARE INVALID AS OBVIOUS OVER LI AND GAN

63. As explained in my First Declaration, a POSITA would have been motivated to combine Li and Gan with a reasonable expectation of success, and this combination renders claims 1-2 and 8-11 obvious. Ex.1003-Decl., ¶¶269-310. Dr. Ruby does not dispute that the combination of Li and Gan teaches every limitation of independent claims 1 and 9 and dependent claims 2, 8, 10, and 11. Dr. Ruby’s declaration also does not contest that Li and Gan are analogous art or that a POSITA would have had a reasonable expectation of success at combining Li and Gan. Ex.2027-Ruby-Decl., ¶¶268-280. Dr. Ruby instead only disputes whether a

POSITA would have been motivated to modify Li in view of Gan's teachings "because Li and Gan's teachings are in conflict." Ex.2027-Ruby-Decl., ¶268. I disagree.

64. As a preliminary matter, I understand that Patent Owner argues that a POSITA would not have been motivated to combine Li and Gan for the same reasons that Patent Owner argued with respect to the combination of Froitzheim and Gan. POR, 66-67. Dr. Ruby does not offer any opinions about the Gan Thesis in his opposition to the Li and Gan ground. Ex.2027-Ruby-Decl., ¶¶268-280. I disagree with Patent Owner and incorporate my analysis from Section XI.A.1. For the reasons discussed in Section XI.A.1, Gan and the Gan Thesis teach that oxide layers and polysilicon emitters are beneficial, and a POSITA would have been motivated to implement an oxide layer and polysilicon emitter as taught by Gan in Li's solar cell with a reasonable expectation of success.

65. Moreover, contrary to Dr. Ruby's suggestion, Li's and Gan's teachings are not "in conflict." Ex.2027-Ruby-Decl., ¶268. As I explained in my First Declaration, Li and Gan teach similar and compatible solar cell structures. Ex.1003-Decl., ¶276. Dr. Ruby also agrees that Li and Gan teach similar solar cell structures. He agrees that Li teaches a back-junction solar cell that includes an emitter and substrate. Ex.2027-Ruby-Decl., ¶269 ("Li's purported invention is a solar cell with

a heterogeneous PN junction: ‘A layer of silicon thin film is deposited on a back surface of N-type monocrystalline silicon to form an emitting region....’”). He also agrees that Gan is directed to a solar cell that includes an oxide layer between an emitter and substrate. Ex.1075-Ruby-Tr., 180:20-181:1 (agreeing that “Gan teaches an oxide layer formed between the back surface of [a] substrate and [an] emitter layer”).

66. Nothing in Li would have dissuaded a POSITA from combining the teachings of Li and Gan. Dr. Ruby contends that “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.2027-Ruby-Decl., ¶270 (quoting Ex.1008-Li, 4). However, Li’s teachings are not limited to doping at a temperature range below 800-1000 °C. Most of Li’s disclosure, including the abstract, claims, figure, and bulk of the specification, concerns Li’s solar cell structure. For example, Li states that “[t]he purpose of the present invention is to overcome the disadvantages of *existing cell structures* so as to obtain a crystalline silicon solar cell having an *emitting region on a back surface* with high conversion efficiency and a simple manufacturing process.” Ex.1008-Li, 4. While Li indicates a preference to avoid diffusion “at 800-1000 °C,” (Ex.1008-Li, 4), Li does not suggest that its solar cell structure could not be manufactured at that temperature

range or at the temperature range disclosed by Gan. In fact, Li specifically states that “[t]he silicon thin film can be prepared by any deposition method,” which demonstrates that Li is not limited to a diffusion temperature range below 800-1000 °C. Ex.1008-Li, 4. Moreover, Li also teaches high-temperature diffusion as a step in fabricating its solar cell, stating that “[a]fter surfaces are cleaned and textured by a standard industrial process, a highly doped N⁺ layer (4) with a sheet resistance of 100–300 Ω/□ is first diffused on the front surface....” *Id.* A POSITA would have understood that this phosphorus diffusion step requires higher temperatures such as the temperature range disclosed by Gan. *E.g.*, Ex.1019-Krygowski, 20 (phosphorous diffusion at 1000 °C); Ex.1043-Kerr, 136 (phosphorous diffusion between 840 and 925 °C); Ex.1086-Ruby-1990, 4 (phosphorous diffusion at 800 °C). The fact that Li teaches diffusion at higher temperatures further demonstrates that Li is not limited to a temperature range below 800-1000 °C.

67. Additionally, Dr. Ruby does not dispute that Li’s structure could be manufactured using temperatures of 800-1000 °C or higher. He also agrees that a POSITA would have known how to successfully diffuse dopants. Ex.1075-Ruby-Tr., 46:22-47:16 (describing doping from his work at Sandia), 146:4-7 (agreeing a POSITA would have known how to perform diffusion). A POSITA would have understood that adjusting temperatures for diffusion was a standard and routine

consideration, and would have known there were many tradeoffs associated with creating a solar cell at higher or lower temperatures, such as processing time and diffusion depth. Ex.2027-Ruby-Decl., ¶64 (solar cell design involves “several tradeoffs and careful optimization”); Ex.1075-Ruby-Tr., 31:21-32:1 (agreeing solar cell design involves “trade-offs”), 105:4-21 (same). Thus, contrary to Dr. Ruby’s suggestion, a POSITA would have understood that Li’s and Gan’s disclosures are compatible and would have readily understood how to adjust Li’s manufacturing process, as necessary, to successfully implement an oxide layer and polysilicon emitter as taught by Gan.

**XIV. GROUNDS II & IV: CLAIM 5 IS INVALID AS OBVIOUS OVER
FROITZHEIM, GAN, AND SHEATS (GROUND II) AND
FROITZHEIM, BORDEN-575, AND SHEATS (GROUND IV)**

68. As detailed in my First Declaration, claim 5 is obvious over Froitzheim, Gan, and Sheats (Ground II) and Froitzheim, Borden-575, and Sheats (Ground IV). Ex.1003-Decl., ¶¶212-221, 265-268. Dr. Ruby’s arguments regarding Grounds II and IV are the same. Ex.2027-Ruby-Decl., ¶¶194-225. Therefore, my analysis below equally applies to Grounds II and IV.

69. As I explained in my First Declaration, a “trench” was a well-known feature of solar cells before 2008. *E.g.*, Ex.1003-Decl., ¶219. Sheats, like many other references, teaches a “trench” to prevent shorts, which are undesirable in solar

cells. Ex.1012-Sheats, [0003]-[0004], [0059], Fig.5D; Ex.1003-Decl., ¶¶214-215, 219. Dr. Ruby agrees that trenches were known by 2008 and it was known that trenches prevented short circuits. Dr. Ruby testified that (i) he was aware of solar cells with trenches when he was at Sandia (Ex.1075-Ruby-Tr., 46:3-5), (ii) trench-fabrication processes were common features in some commercial solar cell manufacturing lines (Ex.1075-Ruby-Tr., 46:14-17), (iii) a POSITA would have known by 2008 that trenches were one technique to prevent short circuits (Ex.1075-Ruby-Tr., 191:6-9), (iv) the '516 and '053 patents do not disclose any new technique to create a trench (Ex.1075-Ruby-Tr., 193:17-22), and (v) Sheats discloses trenches. Ex.1075-Ruby-Tr., 196:18-22. Thus, Dr. Ruby does not contest that Froitzheim, Gan, and Sheats (Ground II) and Froitzheim, Borden-575, and Sheats (Ground IV) disclose each limitation of claim 5.

70. I disagree with Dr. Ruby that a POSITA would not have been motivated to implement a trench as taught by Sheats in Froitzheim's solar cell. Ex.2027-Ruby-Decl., ¶¶194-225. **First**, I disagree with Dr. Ruby that a trench as taught by Sheats is "superfluous" in Froitzheim's solar cell because of Froitzheim's disclosure that "a separation at the edge of the wafer may be performed, e.g. in a plasma." Ex.2027-Ruby-Decl., ¶194 (citing Ex.1004-Froitzheim, [0047]). The paragraph in Froitzheim cited by Dr. Ruby generally discloses electrical isolation of one region

of a solar cell from another—commonly called “edge isolation” in silicon solar cells, as I discuss in my First Declaration (Ex.1003-Decl., ¶219)—to prevent short circuits. Ex.1004-Froitzheim, [0047]. As described in my First Declaration, a trench is an edge-isolation technique used to prevent shorts—that is its function. Ex.1003-Decl., ¶219. Dr. Ruby agrees that a trench is an edge isolation technique to prevent short circuits. Ex.1075-Ruby-Tr., 191:6-13. He also agrees that different ways to create a trench were “well known.” Ex.1075-Ruby-Tr., 194:1-4. Sheats specifically teaches a trench for isolation of one region of a solar cell from another. *See* Ex.1012-Sheats, [0059], Fig.5D; Ex.2029-Holman-Tr., 159:17-18. As a result, because Froitzheim acknowledges that edge isolation is applicable to its solar cell, a POSITA would have been motivated to incorporate a trench as taught by Sheats, as Sheats provides additional details regarding an edge isolation feature (i.e., a trench) that Froitzheim does not expressly disclose but were known by POSITAs.

71. **Second**, Dr. Ruby mistakenly contrasts plasma etching and trenches, and suggests that a POSITA would have to choose one over the other. Ex.2027-Ruby-Decl., ¶¶200-211. Plasma etching is a *method* of removing material—that is the meaning of “etching.” A trench is a *structure* that can be formed using different methods, one of which is plasma etching. Ex.1075-Ruby-Tr., 195:3-7 (“Q. As of 2008, could plasma etching be used to make a trench in a solar cell? A. Probably

so.”), 192:22-193:10; Ex.1012-Sheats, [0058] (“Techniques such as laser machining may be used to form the trench....”). A trench is a linear hole and can thus be formed by using plasma etching to remove material in a linear path (e.g., along the edge of a wafer). Trenches created via plasma etching were (and are) well known and routinely used in the semiconductor industry. And, even if Dr. Ruby is correct that plasma etching is different from forming a trench (Ex.2027-Decl., ¶211), a POSITA would have been motivated to incorporate a trench as taught by Sheats in Froitzheim’s solar cell. Froitzheim does not state that plasma etching is the only way to perform edge isolation. Rather, Froitzheim teaches that plasma etching is one potential technique for edge isolation. Ex.1004-Froitzheim, [0047] (“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.*”). Dr. Ruby agrees that that a POSITA would have been aware of different edge isolation techniques. *See, e.g.*, Ex.2027-Ruby-Decl., ¶197 (“Froitzheim’s optional edge isolation is consistent with Petitioner’s reference Houser, which teaches that there are ‘several approaches to avoid’ edge isolation.”); Ex.1075-Ruby-Tr., 191:6-9 (agreeing a POSITA “would have [known] that trenches were one technique to prevent short circuits”). As a result, a POSITA would have understood that a trench was a successful edge isolation technique and would have

been motivated to employ a trench as taught by Sheats in Froitzheim's solar cell to prevent short circuits.

72. **Third**, Dr. Ruby is incorrect that a POSITA would have considered Sheats' teachings to be limited to "solar cell arrays." Ex.2027-Ruby-Decl., ¶¶216-225. Dr. Ruby incorrectly assumes a POSITA would have limited Sheats' teachings to a particular example. However, a POSITA would have understood that Sheats' teachings regarding a trench were not limited to solar arrays. Dr. Ruby agrees that short circuits are a potential problem for both solar cells and solar arrays. Ex.1075-Ruby-Tr., 186:15-187:1, 188:10-13, 189:21-190:3. He also agrees that solar cells are connected together to form modules and arrays, and if a single solar cell short circuits, "it would reduce the output" of the solar cells to which it is connected. Ex.1075-Ruby-Tr., 187:2-18, 189:7-20. As a result, a POSITA would have understood that a trench is important not only to prevent a short circuit within a single solar cell but also to prevent a short circuit between connected cells. That is, a POSITA would have understood that a trench to prevent a short circuit in a single cell is physically and functionally similar to a trench for solar cells in an array because short circuits are a potential problem in either scenario. Therefore, a POSITA would have understood that Sheats' teachings of a trench to prevent short

circuits were not limited to solar arrays and would have been motivated to implement a trench as taught by Sheats in Froitzheim's solar cell to prevent short circuits.

73. **Finally**, I understand that Patent Owner argues that "Sheats' trench is cut up 'to' the substrate layer, not 'into' the substrate as claim 5 recites." POR, 42. I disagree because that is not what Sheats teaches. Sheats specifically teaches the trench is "formed through the transparent conductive layer and the active layer to the bottom electrode 506 as shown in FIG. 5D." Ex.1012-Sheats, [0059]. The "active" layer in Sheats' solar cell is the semiconductor light-absorbing layer and is therefore equivalent to the silicon wafer of the '516 patent, Froitzheim, Gan, and Borden-575.

XV. AVAILABILITY FOR CROSS-EXAMINATION

74. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

XVI. RIGHT TO SUPPLEMENT

75. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner raises and to take into account new information as it becomes available to me.

XVII.JURAT

76. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: August 14, 2025

A handwritten signature in black ink, appearing to read 'Zachary Holman', is written over a horizontal line.

Zachary C. Holman, Ph.D

Reply Declaration of Dr. Zachary Holman
Appendix D (Materials Considered)

APPENDIX D

Appendix D: Materials Considered

No.	Description
1001	U.S. Patent No. 8,222,516 B2 (“USP516”)
1002	File History for U.S. Patent No. 8,222,516 B2 (App. No. 12/070,742) (“FH516”)
1004	EP1732142A1 to Froitzheim (“Froitzheim”)
1005	Gan and Swanson, <i>Polysilicon Emitters for Silicon Concentrator Solar Cells</i> , <i>IEEE Conference on Photovoltaic Specialists</i> , Vol. 1, Pages 245-240 (1990) (“Gan”)
1006	WO 2009/094575 A2 (“Borden-575”)
1007	U.S. Patent No. 6,998,288 to Smith (“Smith”)
1008	CN 1949545A to Li (Translation) (“Li”)
1009	Translation Declaration for Li
1010	Zachary C. Holman, <i>Electron Transport in Amorphous Silicon</i> (May 2005) (Thesis Presented to The Division of Mathematics and Natural Sciences, Reed College) (“Holman-Thesis”)
1011	U.S. Provisional Appl. No. 61/023,354 (“Borden-Provisional”)
1012	U.S. Patent App. Pub. No. 2006/0157103 (“Sheats”)
1015	U.S. Patent No. 7,468,485 to Swanson (“Swanson”)
1016	R. J. Komp, <i>Practical Photovoltaics Electricity From Solar Cells</i> , 3rd Ed. (2002) (“Komp”)
1017	BP Solar Global Marketing, BP-MSX-120, 120-Watt Multicrystalline Photovoltaic Module (“BP-MSX-120”)
1018	J. Nelson, <i>The Physics of Solar Cells</i> , Imperial College Press (“Nelson”)
1019	T. Krygowski, A. Rohatgi, D. Ruby, <i>Simultaneous P and B Diffusion, In-Situ Surface Passivation, Impurity Filtering and Gettering for High-Frequency Silicon Solar Cells</i> , SAND-97-2620C; CONF-970953- (“Krygowski”)
1020	A. Luque, S. Hegedus, <i>Handbook of Photovoltaic Science and Engineering</i> , Wiley (2003) (“Luque”)
1021	J. Gordon, <i>Solar Energy the State of the Art</i> , ISES (2001) (“Gordon”)
1022	U.S. Patent No. 6,262,359 to Meier (“Meier”)

Reply Declaration of Dr. Zachary Holman
Appendix D (Materials Considered)

No.	Description
1023	U.S. Patent No. 4,525,593 to Yablonovitch (“Yablonovitch”)
1024	WO 2009/094578 A2 (“Borden-578”)
1025	U.S. Patent No. 4,665,277 to Sah (“Sah”)
1026	D. Chapin et al., <i>A New Silicon P-N Junction Photocell for Converting Solar Radiation into Electrical Power</i> , J. Appl. Phys. 25, 676 (1954) (“Chapin”)
1027	W. Shockley, H. J. Queisser, <i>Detailed Balance Limit of Efficiency of pn Junction Solar Cells</i> , J. Appl. Phys. 32, 510 (1961) (“Shockley”)
1028	A. Metz, R. Meyer, B. Kuhlmann, M. Grauvogl, R. Hezel, <i>18.5% Efficient First-Generation MIS Inversion-Layer Silicon Solar Cells</i> , 26th PVSC (1997) (“Metz”)
1029	D. De Ceuster, P. Cousins, D. Rose, D. Vicente, P. Tipones, W. Mulligan, <i>Low Cost, High Volume Production of >22% efficiency silicon solar cells</i> , 22nd European Photovoltaic Solar Energy Conference, 3-7 September 2007, Milan, Italy, pp. 816-819 (“De-Ceuster”)
1030	J. Benick, J. Rentsch, Ch. Schetter, C. Voyer, D. Biro, R. Preu, <i>PECVD PSG as a Dopant Source for Industrial Solar Cells, Presented at the 21st European Photovoltaic Solar Energy Conference</i> , September 4-8, 2006, Dresden (2CV.4.26) (“Benick”)
1031	JP07-106611 to Okayasu (Translation) (“Okayasu”)
1032	Translation Declaration for Okayasu
1033	Robert F. Pierret, <i>Semiconductor Device Fundamentals</i> , Addison Wesley Longman (Part I) (1996) (“Pierret”)
1034	A. I. A. Rahim, C. D. Marsh, P. Ashburn, G. R. Booker, <i>Impact of Ex-Situ and In-Situ Cleans on the Performance of Bipolar Transistors With Low Thermal Budget In-Situ Phosphorus-Doped Polysilicon Emitter Contacts</i> , IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. 48, NO. 11 (November 2001) (“Rahim”)
1035	N. S. Parekh, R. V. Taylor, D. O. Massetti, <i>A Simple Method to Control Bipolar Polysilicon Emitter Interfacial Oxide</i> , J. Electrochem. Soc., Vol. 141, No. 11, pp. 3167-3172 (1994) (“Parekh”)

Reply Declaration of Dr. Zachary Holman
Appendix D (Materials Considered)

No.	Description
1036	E. Yablonovitch, T. Gmitter, R. M. Swanson, Y. H. Kwark, <i>A 720 mV open circuit voltage SiO_x:c-Si:SiO_x double heterostructure solar cell</i> , Appl. Phys. Lett. 47, 1211–1213 (1985) (“Yablonovitch-1985”)
1037	U.S. Patent No. 8,878,053 B2 (“USP053”)
1038	File History for U.S. Patent No. 8,878,053 B2 (App. No. 13/495,577) (“FH053”)
1039	File History of U.S. Patent App. No. 14/504,771 (“771FH”)
1042	U.S. Patent Appl. Pub. No. 2002/0142500 A1 (“Foglietti”)
1043	Mark John Kerr, <i>Surface, Emitter and Bulk Recombination in Silicon and Development of Silicon Nitride Passivated Solar Cells</i> (2002) (Ph.D. Thesis, The Australian National University) (“Kerr”)
1045	M. Green, <i>Silicon Solar Cells Advanced Principles & Practice</i> , Centre for Photovoltaic Devices and Systems (1995) (“Green-1995”)
1046	Y. H. Kwark, R. M. Swanson, <i>N-Type Sipos and Poly-Silicon Emitters</i> , Solid-State Electronics Vol. 30, No. 11, pp. 1121-1125 (1987) (“Kwark”)
1047	G. R. Wolstenholme, N. Jorgensen, P. Ashburn, G. R. Booker, <i>An investigation of the thermal stability of the interfacial oxide in polycrystalline silicon emitter bipolar transistors by comparing device results with high-resolution electron microscopy observations</i> , J. Appl. Phys. 61, 225–233 (1987) (“Wolstenholme”)
1049	M. Green, <i>Solar Cells Operating Principles Technology and System Applications</i> (1986) (“Green-1986”)
1050	N. G. Tarr, <i>A polysilicon emitter solar cell</i> , IEEE Electron Device Letters, vol. 6, no. 12, pp. 655-658, Dec. 1985 (“Tarr”)
1051	R. M. Swanson, <i>Point Contact Solar Cells: Modeling and Experiment</i> , Solar Cells, 17, pp. 85-118 (1986) (“Swanson-1986”)
1054	U.S. Patent No. 7,144,751 to Gee (“Gee”)
1056	WO 2006/097303 A1 (“Agostinelli”)
1058	R. M. Swanson, R. A. Sinton, <i>High-Efficiency Silicon Solar Cells, Advances in Solar Energy: An Annual Review of</i>

Reply Declaration of Dr. Zachary Holman
Appendix D (Materials Considered)

No.	Description
	<i>Research and Development</i> , vol. 6. Chapter 4 (1990) (“Swanson-1990”)
1059	G. Lubberts, B. C. Burkey, F. Moser, E. A. Trabka, <i>Optical properties of phosphorus-doped polycrystalline silicon layers</i> , J. Appl. Phys. 52(11), (Nov. 1981) (“Lubberts”)
1060	U.S. Patent No. 6,352,876 to Bordogna (“Bordogna”)
1061	E. Centurioni, D. Iencinella, R. Rizzoli, F. Zignani, <i>Silicon Heterojunction Solar Cell: A New Buffer Layer Concept With Low-Temperature Epitaxial Silicon</i> , IEEE Transactions on Electron Devices, Vol. 51, No. 11 (November 2004) (“Centurioni”)
1062	M. Farrokh-Baroughi, H. El-Gohary, S. Sivoththaman, <i>Optical, Electrical, and Structural Properties of PECVD Quasi Epitaxial Phosphorous Doped Silicon Films on Crystalline Silicon Substrate</i> , Canadian Solar Buildings Conference (August 20-24, 2004) (“Farrokh-Baroughi”)
1063	A. Hauser, G. Hahn, M. Spiegel, H. Feist, O. Breitenstein, J.P. Rakotoniaina, P. Fath, E. Bucher, <i>Comparison of Different Techniques for Edge Isolation</i> , 17th European Photovoltaic Solar Energy Conference (October 2001) (“Hauser”)
1065	U.S. Patent No. 7,071,018 to Mason (“Mason”)
1066	U.S. Patent No. 4,748,130 to Wenham (“Wenham”)
1071	Deposition Transcript of Douglas S. Ruby, Ph.D., June 24, 2025, in <i>Canadian Solar, Inc. v. Maxeon Solar Pte, Ltd.</i> , IPR2024-01039, IPR20024-01040 (“Ruby-CSI-Dep.”)
1072	Sandia Report, Fundamental Understanding and Development of Lost-Cost, High-Efficiency Silicon Solar Cells, Annual Progress Report: Sept. 1998-Aug. 1999 (May 2000) (“Sandia-2000”)
1073	U.S. Patent Number 5,792,280 to Ruby (“Ruby-280”)
1074	D.S. Ruby, et al., Simplified processing for 23%-efficient silicon concentrator solar cells, Conference Record of the Twenty Third IEEE Photovoltaic Specialists Conference pp. 172-177 (1993) (“Ruby-1993”)
1075	Deposition Transcript of Douglas S. Ruby, Ph.D., July 31, 2025, in <i>Hanwha Solutions Corp. v. Maxeon Solar Pte, Ltd.</i> , IPR2024-01199, IPR20024-01203 (“Ruby-Tr.”)

Reply Declaration of Dr. Zachary Holman
Appendix D (Materials Considered)

No.	Description
1076	U.S. Patent No. 5,871,591 to Ruby (“Ruby-591”)
1078	David L. Pulfrey, MIS Solar Cells: A Review, IEEE Transactions on Electronic Devices, Vol ED-25, No. 11, Nov. 1978 (“Pulfrey”)
1079	M. Lemiti et al, Physical Properties of RT-LPCVD and LPCVD Polysilicon Thin Films: Application to Emitter Solar Cell (1994) (“Lemiti”)
1080	A. Metz et al., Record Efficiencies Above 21% for Mis-contacted Diffused Junction Silicon Solar Cells, 26th PVSC (Sept. 30 – Oct. 3, 1997) (“Metz-1997”)
1081	D. Pysch et al, Detailed Analysis of Fine Line Printed and Plated Solar Cell Contacts, 11nd European Photovoltaic Solar Energy Conference and Exhibition (2006) (“Pysch”)
1082	Jan Schmidt et al., Surface Passivation of Silicon Solar Cells Using Plasma-Enhanced Chemical-Vapour-Deposited SiN Films and Thin Thermal SiO ₂ /Plasma SiN Stacks (2001) (“Schmidt”)
1083	Z.G. Li, L. Liang, L.K. Cheng, Electron Microscopy Study of Front-Side Ag Contact in Crystalline Si Solar Cells, J. Appl. Phys. 105 (2009) (“Liang”)
1084	E. Cabrera et al., Experimental Evidence of Direct Contact Formation for the Current Transport in Silver Thick Film Metallized Silicon Emitters, J. Appl. Phys. 110 (2011) (“Cabrera”)
1085	SAND Report, SAND 2001-0833, History of the Crystalline Silicon Photovoltaic Cell Research Program at Sandia National Laboratories (April 2001) (“Ruby-2001”)
1086	D. S. Ruby & J. D. McBrayer, The Effects Of Different Diffusion Sources On Silicon Solar Cell Recombination Properties, Sandia Nat’l. Labs. (1990) (“Ruby-1990”)
1088	Errata from the May 8, 2025 Deposition of Dr. Zachary Holman