UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CANADIAN SOLAR INC.,
Petitioner,

v.

MAXEON SOLAR PTE. LTD.
Patent Owner

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

DECLARATION OF SANJAY BANERJEE REGARDING U.S. PATENT NO. 8,878,053

I, Sanjay Banerjee, do hereby declare and state, 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, under Section 1001 of Title 18 of the United States Code.

Executed on: June 24, 2024

Sanjay Banerjee

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I. INTRODUCTION

A. Engagement

1. I have been retained by counsel for Canadian Solar Inc. ("CSI" or "Petitioner") as an expert witness in the above-captioned proceeding. I have been asked to provide my opinions about the state of the art of the technology related to U.S. Patent No. 8,878,053 ("the 053 Patent") (EX1001) and on the patentability of claims 9-20 of this patent. The following is my written declaration on these topics.

B. Background and Qualifications

2. I currently serve as the Cockrell Family Regents Chair Professor of Electrical and Computer Engineering and Director of the Microelectronics Research Center at the University of Texas at Austin ("UT"). Prior to this position, I was first an Assistant Professor (September 1987 - August 1990) and later an Associate Professor (September 1990 - August 1993) at UT, before being named a Professor in September 1993. Prior to starting my academic work at UT, I was a member of the technical staff at Texas Instruments (Corporate R&D) from the time I completed my doctoral studies in 1983 until August 1987.

3. I received my Ph.D. in Electrical Engineering from the University of Illinois in 1983. I also received an M.S. in Electrical Engineering from the University of Illinois in 1981. I received a B. Tech. in Electronics from the Indian Institute of Technology at Kharagpur in 1979.

4. I have more than 40 years of experience in the field of electrical engineering, including extensive experience in semiconductor development and fabrication including that of solar cells, passivation, and dielectric materials. For example, I am a named author on 24 publications and conference proceedings relating to solar cells, as can be seen from my CV EX1004.

5. I am a Fellow of the Institute of Electrical and Electronics Engineers ("IEEE"), the American Physical Society ("APS"), and the American Association for the Advancement of Science ("AAAS"). I have served on numerous professional and government committees in the electrical engineering field, including chairing multiple IEEE committees, meetings, and programs, serving on Morgan & Claypool's editorial board, and serving as a member on the International Technology Roadmap for Semiconductors ("ITRS").

6. I have taught courses in Semiconductor Physics, Solid State Electronic Devices, and Microelectronic Device Fabrication at UT. In particular, I have taught an undergraduate course every year for 30 years on Semiconductor Devices out of a textbook, "Solid State Electronic Devices," by Ben Streetman and Sanjay Banerjee (ISBN 0-13-335603). Several of my lectures out of the textbook relate to solar cells. In addition, I have delivered many courses to industry professionals on Semiconductor Devices and Memory and Semiconductor

Processing. As a principal investigator, I have been the advisor to over 80 Doctoral and Masters students.

7. I am the co-author of several books and invited book chapters covering the area of electronic and semiconductor devices, including: Dopant Diffusion, Solid State Electronic Devices (three editions). I have authored or coauthored more than 1,000 papers and presentations in the areas of semiconductor devices and electronics development over the course of my career.

8. I have been the recipient of fifty grants to fund my research from a variety of funding agencies, including the National Science Foundation ("NSF"), DARPA, the Department of Energy, Semiconductor Research Corporation, the Department of Defense-Multidisciplinary University Research Initiative, and the Office of Naval Research. A number of the sponsored research grants on which I have been a principal or coinvestigator have related to solar cells and various deposition techniques for optoelectronic devices, including for example, "Optoelectronic Devices by Photo-enhanced Chemical Vapor Deposition," (National Science Foundation, August 1988-July 1993).

9. I have received numerous other awards recognizing my extensive work in the electrical engineering field. For example, I was on the Advisory Board, and the Silicon Solar Cell Thrust Lead for the Bay Area Photovoltaics

Consortium funded by the U.S. Department of Energy. This and other awards are described in more detail in my CV. EX1004.

C. Compensation and Prior Testimony

10. I am being compensated at a rate of $650.00 per hour for my time spent on this matter. I am also being reimbursed for reasonable and customary expenses associated with my work in this matter. My compensation is not contingent on the outcome of this matter or the specifics of my testimony.

11. I have previously submitted declarations in multiple IPR proceedings and have testified also as an expert witness in Federal Court and the ITC, as summarized in EX1004 at 1.

D. Information Considered

12. My opinions are based on my years of education, research and experience, as well as my investigation and study of relevant materials. In forming my opinions, I have considered the materials I identify in this declaration and those listed as exhibits in **Appendix B**, attached to this declaration.

13. I may rely upon these materials and/or additional materials to respond to arguments raised by the Patent Owner. I may also consider additional documents and information in forming any necessary opinions—including documents that may not yet have been provided to me.

14. My analysis of the materials produced in this investigation is ongoing and I will continue to review any new material as it is provided. This declaration represents only those opinions I have formed to date. I reserve the right to revise, supplement, and/or amend my opinions stated herein based on new information and on my continuing analysis of the materials already provided.

II. LEGAL STANDARDS FOR PATENTABILITY

15. I am not a lawyer and am not providing any legal opinions. In providing my opinions in this declaration, I am relying upon certain basic legal principles that have been explained to me by counsel and which I am summarizing below.

16. First, I understand that for an invention claimed in a patent to be found patentable, it must be, among other things, new and not obvious from what was known before the invention was made.

17. I understand the information that is used to evaluate whether an invention is new and not obvious is generally referred to as "prior art" and generally includes patents and printed publications (*e.g.*, books, journal publications, articles on websites, product manuals, *etc*.).

18. I understand that in this proceeding the Petitioner has the burden of proving that the claims are anticipated by or obvious from the prior art by a

preponderance of the evidence. I understand that "a preponderance of the evidence" is evidence sufficient to show that a fact is more likely true than it is not.

19. I understand that in this proceeding, the claims should be given their ordinary and accustomed meaning as understood by one of ordinary skill in the art in view of the patent and its file history. The claims after being construed in this manner are then to be compared to the information in the prior art.

20. I understand that in this proceeding, the information that may be evaluated is limited to patents and printed publications. My analysis below compares the claims to patents and printed publications that are prior art to the claims.

21. I understand that there are various ways in which prior art may render a patent claim unpatentable based on prior art patents and printed publications. First, the prior art can be shown to "anticipate" the claim. Second, the prior art can be shown to have made the claim "obvious" to a person of ordinary skill in the art. My understanding of the legal standards is set forth below.

A. <u>Anticipation</u>

22. I understand that the following standards govern the determination of whether a patent claim is "anticipated" by the prior art.

23. I have applied these standards in my evaluation of whether the claims would have been anticipated by the prior art.

24. I understand that the "prior art" includes patents and printed publications that existed before the earliest filing date (the "effective filing date") of the claim in the patent. I also understand that a patent will be prior art if it was filed before the effective filing date of the claimed invention, while a printed publication will be prior art if it was publicly available before that date.

25. I understand that, for a patent claim to be "anticipated" by the prior art, each and every requirement of the claim must be found, expressly or inherently, in a single prior art reference as recited in the claim. I understand that claim limitations that are not expressly described in a prior art reference may still be there if they are "inherent" to the thing or process being described in the prior art. I understand that a limitation can be "inherent" if that limitation is necessarily present in or the natural result of the elements explicitly disclosed by the prior art.

26. I understand that if a reference incorporates other documents by reference, the incorporating reference and the incorporated reference(s) should be treated as a single prior art reference for purposes of analyzing anticipation.

27. I understand that it is acceptable to consider evidence other than the information in a particular prior art document to determine if a feature is necessarily present in or inherently described by that reference.

B. <u>Obviousness</u>

28. I understand that a claimed invention is not patentable if it would have been obvious to a person of ordinary skill in the field of the invention at the time the invention was made.

29. I understand that the obviousness standard is defined in the patent statute (35 U.S.C. § 103(a)) as follows:

30. A patent may not be obtained though the invention is not identically disclosed or described if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

31. I understand that the following standards govern the determination of whether a claim in a patent is obvious. I have applied these standards in my evaluation of whether the claims would have been considered obvious as of the priority date of the patent.

32. I understand that to find a claim in a patent obvious, one must make certain findings regarding the claimed invention and the prior art. Specifically, I understand that the obviousness question requires consideration of four factors (although not necessarily in the following order):

- The scope and content of the prior art;
- The differences between the prior art and the claims at issue;
- The knowledge of a person of ordinary skill in the pertinent art; and
- Whatever objective factors indicating obviousness or non-obviousness may be present in any particular case.

33. In addition, I understand that the obviousness inquiry should not be done in hindsight, but must be done using the perspective of a person of ordinary skill in the relevant art as of the effective filing date of the patent claim.

34. I understand the objective factors indicating obviousness or non-obviousness may include: commercial success of products covered by the patent claims; a long-felt need for the invention; failed attempts by others to make the invention; copying of the invention by others in the field; unexpected results achieved by the invention; praise of the invention by those in the field; the taking of licenses under the patent by others; expressions of surprise by experts and those skilled in the art at the making of the invention; and the patentee proceeded contrary to the accepted wisdom of the prior art. I also understand that any of this evidence must be specifically connected to the invention rather than being associated with the prior art or with marketing or other efforts to promote an invention. I am not presently aware of any evidence of "objective factors" suggesting the claimed methods are not obvious, and reserve my right to address any such evidence if it is identified in the future.

35. I understand the combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. I understand that when the prior art does not expressly disclose a claim limitation, inherency may also supply a missing claim limitation in an obviousness analysis. I understand that inherency is established in the context of obviousness when the limitation at issue necessarily must be present, or the natural result of the combination of elements explicitly disclosed by the prior art. I also understand that an example of a solution in one field of endeavor may make that solution obvious in another related field. I also understand that market demands or design considerations may prompt variations of a prior art system or process, either in the same field or a different one, and that these variations will ordinarily be considered obvious variations of what has been described in the prior art.

36. I also understand that if a person of ordinary skill can implement a predictable variation, that variation would have been considered obvious. I understand that for similar reasons, if a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using that technique to improve the other device would have been obvious unless its actual application yields unexpected results or challenges in implementation.

37. I understand that the obviousness analysis need not seek out precise teachings directed to the specific subject matter of the challenged claim, but instead can take account of the "ordinary innovation" and experimentation that does no more than yield predictable results, which are inferences and creative steps that a person of ordinary skill in the art would employ.

38. I understand that sometimes it will be necessary to look to interrelated teachings of multiple patents/publications; the effects of demands known to the design community or present in the marketplace; and the background knowledge possessed by a person having ordinary skill in the art. I understand that all these issues may be considered to determine whether there was an apparent reason to combine the known elements in the fashion claimed by the patent at issue.

39. I understand that the obviousness analysis cannot be confined by a formalistic conception of the words "teaching, suggestion, and motivation." I understand that in 2007, the Supreme Court issued its decision in *KSR Int'l Co. v. Teleflex, Inc.,* 550 U.S. 398, 418 (2007), where the Court rejected the previous requirement of a "teaching, suggestion, or motivation to combine" known elements of prior art for purposes of an obviousness analysis as a precondition for finding obviousness. It is my understanding that *KSR* confirms that any motivation that would have been known to a person of skill in the art, including common sense, or

derived from the nature of the problem to be solved, is sufficient to explain why references would have been combined.

40. I understand that a person of ordinary skill attempting to solve a problem will not be led only to those elements of prior art designed to solve the same problem. I understand that under the *KSR* standard, steps suggested by common sense are important and should be considered. Common sense teaches that familiar items may have obvious uses beyond the particular application being described in a reference, that if something can be done once it is obvious to do it multiple times, and in many cases a person of ordinary skill will be able to fit the teachings of multiple patents/publications together like pieces of a puzzle. As such, the prior art considered can be directed to any need or problem known in the field of endeavor and can provide a reason for combining the elements of the prior art in the manner claimed. In other words, the prior art does not need to be directed towards solving the same problem that is addressed in the patent. Further, the individual prior art references themselves need not all be directed towards solving the same problem.

41. I understand that obviousness does not require that the features of a secondary reference be bodily incorporated into the structure of the primary reference. Rather, the test is what the combined teachings of those references would have suggested to a Skilled Artisan. The disclosures of the prior art

references need not be physically combinable. Combining the teachings of references should be the focus of the analysis.

42. I understand that an invention that might be considered an obvious variation or modification of the prior art may be considered non-obvious if one or more prior art references discourages or leads away from the line of inquiry disclosed in the reference(s). A reference does not "teach away" from an invention simply because the reference suggests that another embodiment of the invention is better or preferred. My understanding of the doctrine of teaching away requires a clear indication that the combination should not be attempted (*e.g.*, because it would not work or explicit statements saying the combination should not be made).

43. I understand that a person of ordinary skill is also a person of ordinary creativity.

44. I further understand that in many fields, it may be that there is little discussion of obvious techniques or combination, and it often may be the case that market demand, rather than scientific literature or knowledge, will drive design trends. When there is such a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within their technical grasp. If this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense. In that instance the fact that a

combination was obvious to try might show that it was obvious. The fact that a particular combination of prior art elements was "obvious to try" may indicate that the combination was obvious even if no one attempted the combination. If the combination was obvious to try (regardless of whether it was actually tried) or leads to anticipated success, then it is likely the result of ordinary skill and common sense rather than innovation.

III. THE 053 PATENT

A. The Person Of Ordinary Skill in the Art

45. I have reviewed the 053 Patent specification and its claims. Based on my experience in the field and the information disclosed in the 053 Patent that I discuss in this Declaration, I believe a person of ordinary skill in the art in the 053 Patent's field of solar cell design or manufacture in 2008 ("Skilled Artisan") would have been someone with an advanced degree in electrical engineering, applied physics, chemistry, or materials science, and at least two years of experience designing, developing, or researching in the field. Alternatively, that person would have had a bachelor's degree in electrical engineering, applied physics, or materials science, and at least three years of experience designing, developing, or researching in the field.

46. I was a Skilled Artisan before February 20, 2008 by this definition.

B. <u>053 Patent's Effective Filing Date</u>

47. The 053 Patent, titled "Front Contact Solar Cell with Formed Emitter," was filed on June 13, 2012. EX1001. Based on the information on the face of the 053 Patent, the 053 Patent is a divisional of, and claims priority to, U.S. Patent No. 8,222,516 filed on February 20, 2008. I have been asked by CSI's counsel to assume that the 053 Patent's effective filing date is February 20, 2008.

C. <u>053 Patent's Specification</u>

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

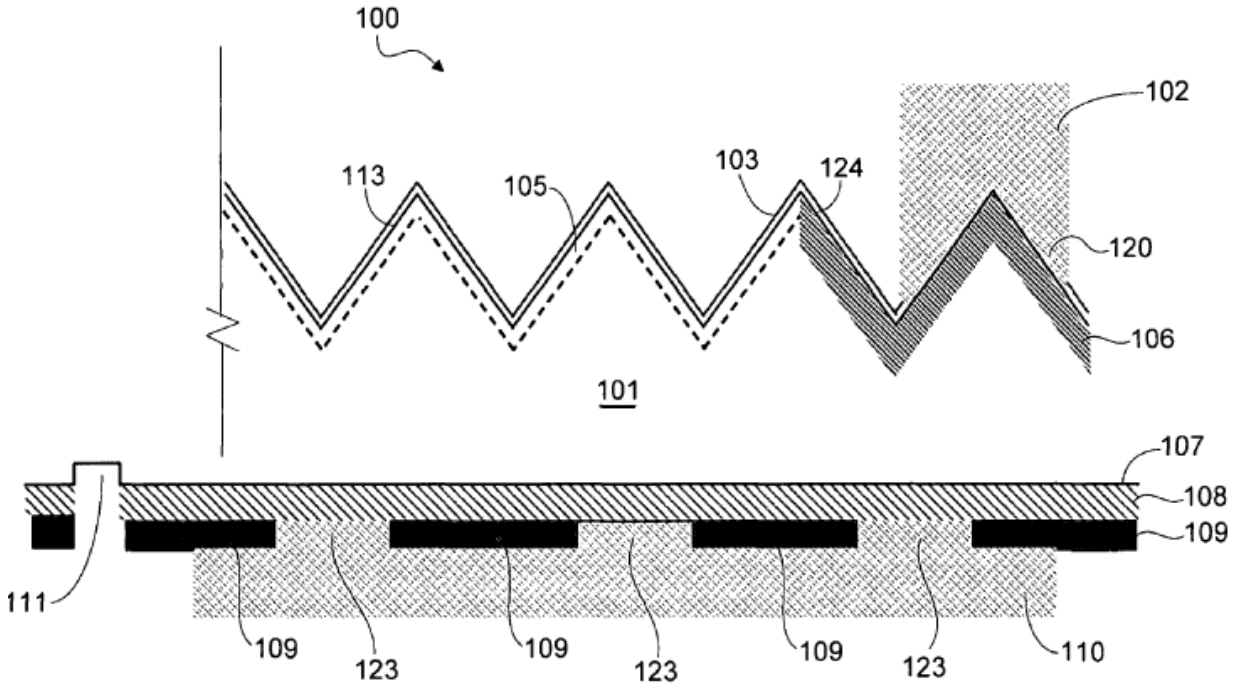


FIG. 1

49. Figure 1's solar cell 100 includes an N-type silicon substrate 101. EX1001, 2:35-38. According to the 053 Patent, a "backside junction" is formed by the N-type substrate 101 and the P-type doped polysilicon emitter 108 formed at

the solar cell's backside. EX1001, 2:35-38, 1:53-55. Between the polysilicon emitter 108 and the substrate 101 is a tunnel oxide layer 107, which "may comprise silicon oxide thermally grown" on the substrate's surface. EX1001, 2:64-3:6. Backside metal contact 110 connects with the emitter 108 through contact holes 123 in the silicon dioxide layer 109. EX1001, 3:6-18.

50. At the front, the solar cell's front side has a texture 113 and an antireflective coating 103 made of silicon nitride. EX1001, 2:29-34, 3:19-30, 4:36-41. Metal contact 102 at the front then connects with the substrate through holes in the antireflective coating 103. EX1001, 2:57-63.

51. Figures 4A-4M illustrate the solar cell manufacturing process. EX1001, 3:56-58. This summary focuses on steps relevant to the claim limitations in Claims 9-20.

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

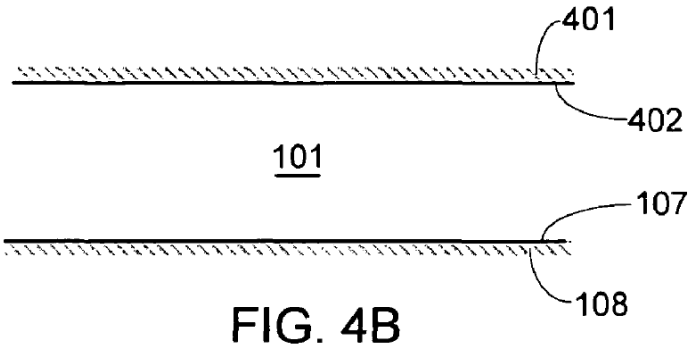


FIG. 4B

53. Subsequently, in preparation for doping the polysilicon layer 108, a p-type dopant source 461 such as BSG (borosilicate glass) is formed is formed by atmospheric pressure CVD ("APCVD") on the polysilicon layer 108 with an undoped silicon dioxide capping layer 462 as shown in Figure 4C. EX1001, 4:14-27.

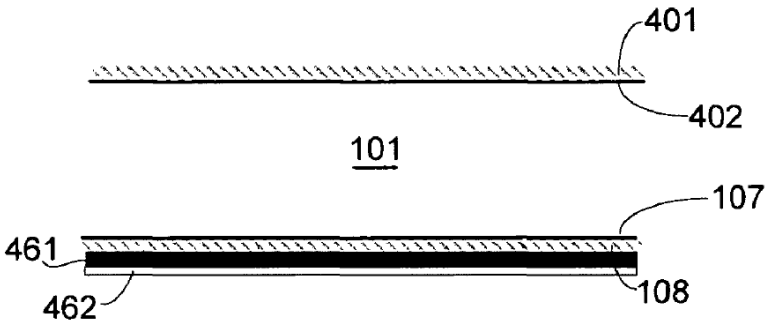


FIG. 4C

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

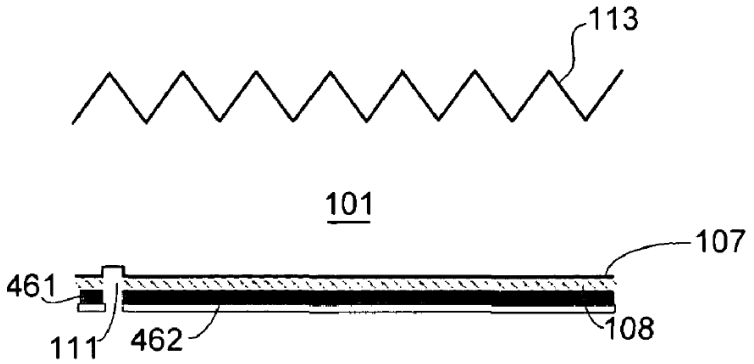


FIG. 4E

55. An N-type dopant source 412 is formed on the textured surface 113 as shown in Figure 4F. EX1001, 4:42-59. The N-type dopant source 412 can comprise "silicon dioxide doped with phosphorus." *Id.*, 4:51-52. Alternatively, this step can be omitted, and N-type doping can occur later through introduction of N-type dopant in the furnace during a drive-in step. EX1001, 5:19-27.

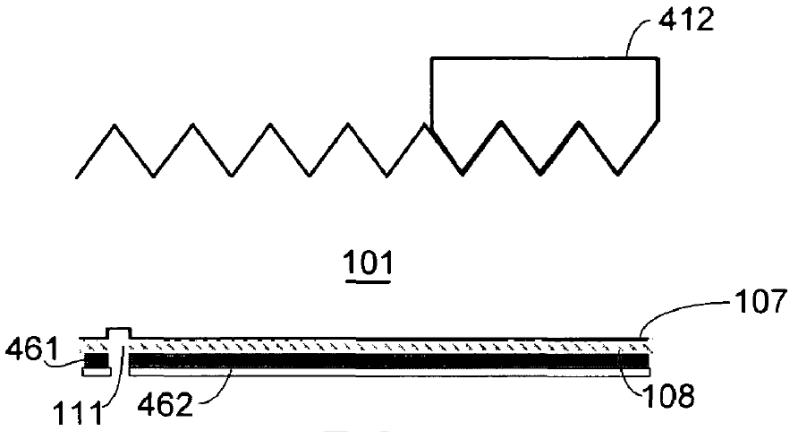


FIG. 4F

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

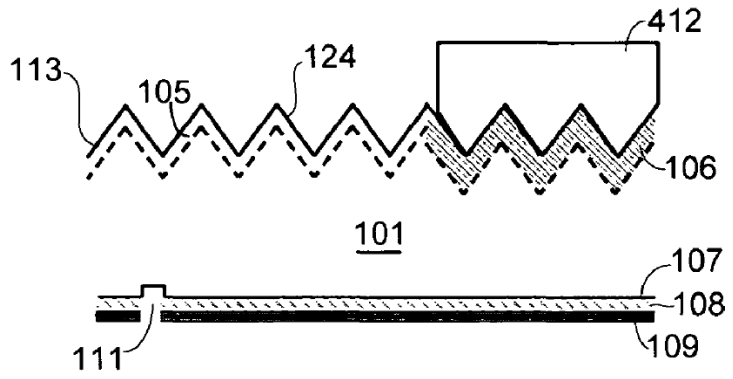


FIG. 4G

57. A silicon nitride antireflective coating 103 is then applied over the textured surface 113 after the N-type dopant source is removed, as seen in Figure 4H. EX1001, 5:28-35.

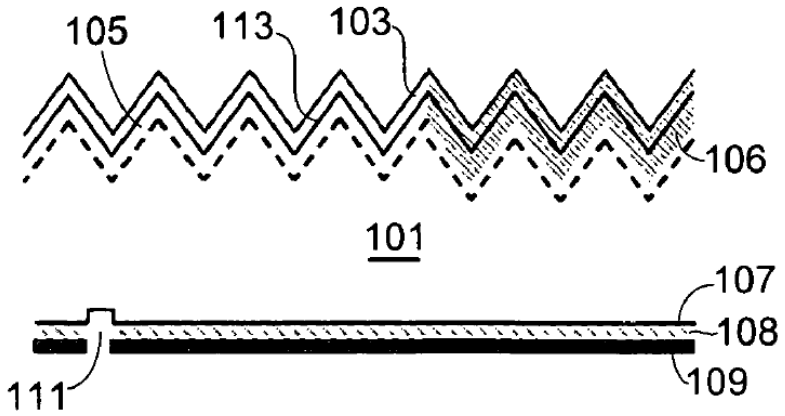


FIG. 4H

58. As shown in Figure 4M, this is followed by formation of the metal contacts 102 and 110, which includes creating contact holes 120/123 and then forming the contacts on the front and back side of the wafer over the contact holes. EX1001, 5:36-6:5. The metal contacts may be formed by screen-printing and firing. EX1001, 6:1-4.

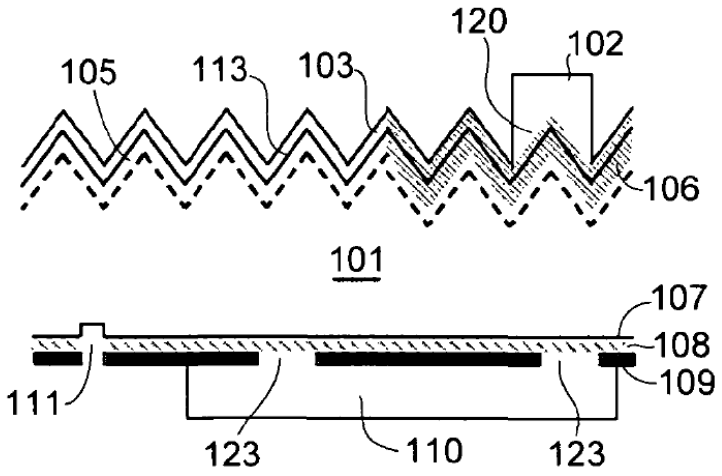


FIG. 4M

D. <u>053 Patent's Claims</u>

59. I understand that the Petitioner is challenging Claims 9-20 of the 053 Patent. These claims are reproduced below:

Claim Element	Claim Language
[9.a]	A method of fabricating a solar cell comprising:
[9.b]	forming a layer of polysilicon over a back surface of a silicon substrate;
[9.c]	forming a first dopant source layer over the layer of polysilicon;
[9.d]	diffusing dopants from the first dopant source layer to the layer of polysilicon to form a backside junction with the silicon substrate;
[9.e]	diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and

[9.f]	forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.
[10]	10. The method of claim 9 wherein the first dopant source layer comprises P-type dopants.
[11]	11. The method of claim 9 wherein the first dopant source layer comprises borosilicate glass.
[12]	12. The method of claim 9 wherein diffusing dopants into the front surface of the silicon substrate comprises forming a second dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate.
[14.a]	14. The method of claim 9 further comprising: texturing the front surface of the silicon substrate; and
[14.b]	forming an antireflective layer over the textured front surface of the silicon substrate.
[15]	The method of claim 9 wherein the diffusion of dopants from the first dopant source layer to the layer of polysilicon and the diffusion of dopants into the front surface of the silicon substrate are performed in situ.
[16.a]	A method of fabricating a solar cell comprising:
[16.b]	forming an oxide layer over a back surface of a silicon substrate;
[16.c]	forming a layer of polysilicon over the oxide layer;
[16.d]	diffusing dopants into the layer of polysilicon to form a backside junction with the silicon substrate;

[16.e]	diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and
[16.f]	forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.
[17]	17. The method of claim 16 wherein diffusing dopants into the layer of polysilicon to form the backside junction with the silicon substrate comprises: forming a first dopant source layer over the layer of polysilicon; and diffusing dopants from the first dopant source layer into the layer of polysilicon
[18]	18. The method of claim 16 wherein diffusing dopants into the front surface of the silicon substrate comprises forming a second dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate.
[19]	19. The method of claim 16 further comprising: texturing the front surface of the silicon substrate.
[20]	20. The method of claim 19 further comprising: forming an antireflective layer over the textured front surface of the silicon substrate.

E. The 053 Patent's Prosecution History

60. I have also reviewed the prosecution history of the 053 Patent to understand what the Examiner has considered during prosecution and the reasons for why the claims were allowed. I recite below a summary of the prosecution history of the 516 Patent.

61. The 053 Patent is what I understand is called a "divisional" of U.S. Patent No. 8,222,516. Issued independent claims 9 and 16 were numbered application claims 21 and 28 in prosecution. The original independent claims 9 and 16 (application claims 21 and 28 in prosecution) initially recited all the elements as issued except for "forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate." EX1002, 5.

62. The Examiner rejected the original application claim 21 over Meier (US6,262,359, EX1011) and Lindholm (EX1020), and original claims 21 and 28 over Smith288 (US6,998,288, EX1024) and Lindholm. EX1002, 89-91. Meier disclosed an "Aluminum Alloy Back Junction Solar Cell" with a p-type emitter layer on the backside of an n-type substrate and an n-type doped layer on the front side. EX1011, Title, Abstract, 4:27-43. Smith288 disclosed a "back side contact solar cell" with both p-typed doped and n-type doped regions on the backside of the solar cell and metal contacts formed over them. EX1024, Abstract, FIG. 7.

Lindholm disclosed "Heavily Doped Polysilicon-Contact Solar Cells" to "replace the conventional high-low junction or back surface-field (BSF) structure." EX1002, Abstract.

63. In response, the Applicant amended the claims to recite "forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate." EX1002, 125-29. The Applicant distinguished Smith288 as lacking "a metal contact on the front surface of the silicon substrate" because it is a backside contact solar cell, and "accordingly, Smith does not disclose a metal contact that connects to the substrate from the front side of the solar cell." EX1002, 131, 155-156. As to the Meier/Lindholm, the Applicant distinguished the combination as lacking a "diffusion of P-type dopants from the P-type dopant source to the layer of polysilicon" because "Meier teaches formation of a p+ layer 220 by epitaxial growth." EX1002, 130.

64. The Examiner then issued new rejections of application claim 21 over Silvestre (EX1021), Lindholm (EX1020), and Smith288 (EX1024); and of application claim 28 over Silvestre, Lindholm, and Swanson439 (EX1025). EX1002, 163-68. In response, Applicant relied on the limitations "diffusing dopants from the first dopant source layer to the ***layer of polysilicon to form a backside junction with the silicon substrate***" and "diffusing dopants into the ***layer***

of polysilicon to form a backside junction with the silicon substrate." EX1002, 217-219 (emphasis in original). Applicant distinguished the claimed backside junction from a back surface field (BSF). The Applicant said, "As is well known, ***a BSF has the same dopant type as the substrate***, but at a higher concentration to keep minority charge carriers away from the back surface." EX1002, 217 (emphasis in original). The Applicant then argued that the Examiner's prior art combinations of Silvestre, Lindholm, and Smith288 or Swanson439 disclosed that "the polysilicon forms a BSF with the substrate, as opposed to a backside junction with the substrate." EX1002, 218-219. After the Examiner maintained his rejection, a pre-appeal brief was filed by the Applicant urging similar arguments. EX1002, 229-30, 232-37. In a Notice of Panel Decision from Pre-Appeal Brief Review, the rejection was withdrawn and the claims issued, following Applicant's argument that a backside junction requires opposing dopant types and is distinct from a back surface field that uses the same dopant type (but at a different concentration). EX1002, 244.

F. <u>Known Technologies That the Examiner Did Not Consider</u>

65. While the Examiner of 053 Patent considered some prior art during prosecution, I do not believe that the Examiner had before him key pieces of prior art relevant to the 053 Patent, specifically with respect to back junction solar cells

and polysilicon emitters and associated oxide layer. I discussed these prior art references below.

66. During prosecution of the 053 Patent, the Applicant distinguished the back junction solar cell of Meier by arguing that its emitter layer was not formed by p-type dopant diffusion, but rather was formed by "epitaxial growth." EX1002, 130. But forming a backside emitter of a back junction solar cell by dopant diffusion was already known in the art before the 053 Patent, as was the backside junction/emitter that the Applicant used to argue Silvestre was distinguishable. For example, an European patent publication to Froitzheim in 2006 also disclosed a back junction solar cell with emitter that forms a backside junction with the substrate, and its emitter was formed by dopant diffusion. EX1006, ¶¶25-26, 40. Froitzheim was not considered by Examiner during prosecution. Froitzheim supplies the missing element of dopant diffusion that the Applicant used to overcome the back junction solar cell of Meier during prosecution. EX1002, 130. Froitzheim likewise supplies the "backside junction" element that the Applicant used to overcome Silvestre or Lindholm during prosecution.

67. Before the 053 Patent, those skilled in the art also recognized that replacing diffused in-substrate emitters (such as the emitter in Froitzheim) with deposited polysilicon emitters would improve both bipolar transistors and solar cell performance. Deposited polysilicon emitters with an interfacial oxide layer were

first used to improve the performance of bipolar transistors in 1984. EX1023 (Ashburn 1984). "Interfacial oxide layer" refers to a layer of silicon dioxide in between the substrate and the polysilicon emitter.

68. Around the same time, a number of publications suggested that this improvement with a polysilicon emitter can be achieved in solar cells as well. For example, Yablonovitch et al. published a paper in 1985 titled "A Study of n+-SIPOS:p-Si Heterojunction Emitters," in which the authors wrote:

> *There have been a considerable number of reports recently on improved bipolar transistor emitters made of polycrystalline silicon or of SIPOS (a mixture of microcrystalline silicon and silicon dioxide).* The improvement has come in the forward saturation current Jo, defined by J = Jo exp (qV/kT). For example, we have recently made SIPOS heterojunction emitters with Jo = 10 - l4 Amps/cm2 which is about two orders of magnitude smaller than in a conventional homojunction emitter…. ***Such heterojunctions are valuable not only for emitter efficiency in bipolar transistors, but also for solar cells.***

EX1016, 597 (emphasis added).

69. Likewise in around 1984, Kwark et al. published a paper titled "SIPOS Heterojunction Contacts to Silicon," in which the authors wrote: "Incorporation of these films into the emitter structure of an NPN bipolar transistor

had been found to reduce the emitter saturation current fifty fold; this translates into potential improvements of energy conversion efficiency for solar cells." EX1008, 742. Notably, Kwark et. al. did not just report on work with SIPOS, but the authors also reported "surprising" "good results" with pure polysilicon emitters, which they referred to as "POLY." EX1008, 742.

70. Subsequently in 1987, Sinton and Swanson published a paper titled "Design Criteria for Si Point-Contact Concentrator Solar Cells, where they noted that "[i]t is interesting to project what should be possible if the best available emitter technology were applied to point contact cells rather than the diffused emitters from the current process." EX1017, 2122. Sinton and Swanson modeled the projected efficiencies of what would be possible incorporating "SIPOS" emitters versus diffused emitters, and showed a more than one percent absolute increase in efficiency for the solar cell. EX1017, 2122. This is shown in Figure 9 of the paper and reproduced below:

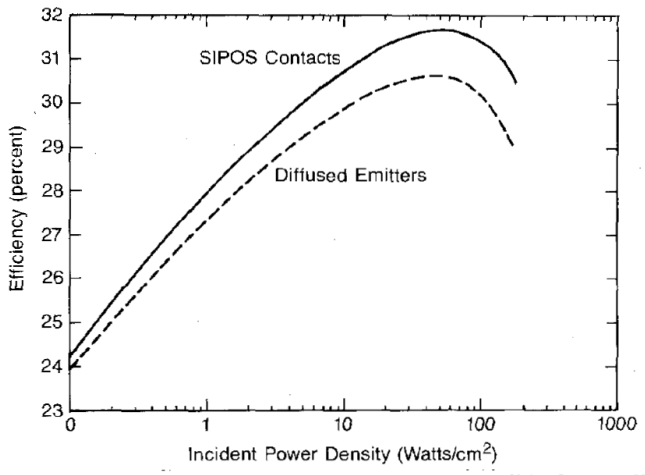


Fig. 9. A comparison of the projected efficiencies possible for a cell incorporating SIPOS emitters (solid curve), compared to projections for diffused emitters as used to date (dashed curve).

71. "SIPOS" refers to "semi-insulating polysilicon" which is formed by introducing a small amount of oxygen bearing species into the chemical vapor deposition of polysilicon. EX1008, 84. But as Kwark et. al. found in around 1984, even a pure polysilicon emitter layer with a chemically formed interfacial oxide layer led to "surprising" improvement. EX1008, 84. Following these suggestions, Gan and Swanson examined the use of deposited polysilicon emitters with an interfacial oxide layer in concentrator solar cells in 1990 and reported in their published paper, titled "Polysilicon Emitters for Silicon Concentrator Solar Cells," that the "cell performance can be improved if the diffused-emitter is replaced with the polysilicon emitter." EX1007, 245. Gan and Swanson also pointed to Sinton's earlier modeling showing one percent absolute increase in solar cell efficiency for a "backside contact solar cells." EX1007, 249. Backside contact solar cells or

back contact solar cells have their PN junction on the back of the solar cells, instead of the front as in a conventional solar cell.

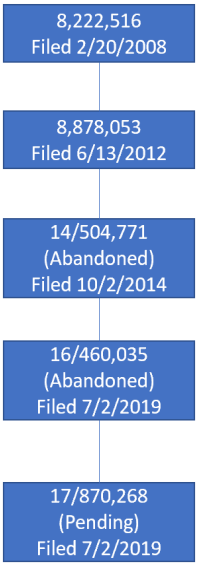
72. A month before the earliest possible effective filing date of the 053 Patent, Peter Borden from Applied Materials filed a provisional application, titled "Improved HIT Solar Cell Structure," in which he disclosed in the Abstract:

> The present invention relates to improved HIT type or polysilicon emitter solar cells. According to certain aspects, the invention includes ***forming a masking oxide layer on the front and back of the cell*** and then patterning holes in the masking oxide. A HIT cell structure or ***polysilicon emitter solar cell structure is then formed over the patterned oxide***,…. Benefits of the invention include that it provides a controlled interface for the HIT cell through insertion of a thin tunnel oxide. Moreover, the tunnel oxide prevents epitaxial growth of amorphous silicon, allowing it to remain amorphous for the optimum band structure. Still further, it provides a layer to protect the surface from plasma damage during deposition of the a-Si layer. Further, it may be used in conjunction with a point contact structure to further increase efficiency. EX1010, Abstract.

73. The same Abstract disclosure also appears in the PCT Publication filed by Borden about a year later. EX1009, Abstract.

74. None of these prior art references that I discussed above were before the 053 Patent Examiner.

G. PTAB's Unpatentability Decisions in Two Continuation Applications



75. I understand that there were a series of applications filed that claimed priority to the 053 Patent. I have also reviewed two of these continuation applications filed in the same family as the 053 Patent. These two applications that I reviewed are U.S. Application No. 14/504,771 ("771 Application") and 16/460,035 ("035 Application"). I have also reviewed their prosecution histories.

76. Based on my review, I believe that the 771 Application and the 035 Application presented device claims corresponding to and similar to the method claims of the 053 Patent discussed here, as seen in **Appendix A**.

77. In the 771 Application, I understand that the Examiner discovered polysilicon emitter and intervening oxide layer prior art references that he did not have when examining the 053 Patent or the earlier parent patent of the 053 Patent, US8,882,516. Based on the newly discovered prior art, the Examiner rejected the 771 Applications claims as obvious based on the combinations of (1) Meier in view of Okayasu, Borden, and Wenham and (2) Meier in view of Okayasu, Foglietti, Gan, and Wenham. EX1005, 447-455 (Final Office Action).

78. I understand that the Applicant appealed the rejections to the PTAB (EX1005, 458-499), which affirmed the rejections (EX1005, 507-520).

79. In the subsequent 035 Application, the Examiner again rejected as obvious the device claims presented that I believed correspond to and are similar to the method claims of the 053 Patent based on Meier in view of Okayasu, Borden, Wenham, Jordan, and Xi. EX1018, 208-223. Maxeon again appealed the rejection, which the PTAB again affirmed. EX1018, 227-270, 286-293.

80. I understand that Maxeon *did not* appeal either of the PTAB's decisions to the Federal Circuit, and notices of abandonment were issued by the US Patent Office. EX1005, 522; EX1018, 295.

IV. CLAIM CONSTRUCTION

81. For purposes of my opinions, I applied each claim term's ordinary and customary meaning to a Skilled Artisan read in light of the specification and prosecution history.

82. For the term "*in situ*" in dependent claim 15, I applied a definition provided in the specification. The 053 Patent explains the term "in-situ" as follows:

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

EX1001, 5:9-18. Thus, in the context of the 053 Patent, "in situ" refers to simultaneous processing that occurs after a single manual loading of the substrate into a furnace or other single chamber or multi-chamber processing tool. Therefore, in the context of claim 15's diffusion steps, the single, simultaneous drive-in/diffusion of the front and back dopants in a single furnace device would constitute "in situ" steps that satisfy the claim.

V. OVERVIEW OF THE PRIOR ART

83. Back junction solar cells and polysilicon emitters with interfacial oxides were well-known in the art before the 053 Patent. For example, Froitzheim (discussed below) disclosed a back junction solar cell and the process for making the cell. Gan, Kwark, and Borden (discussed below) all disclosed polysilicon emitters with interfacial oxides, and the process for making them. In my opinion, it would be obvious to combine the polysilicon emitter and interfacial oxide layer of Gan and Kwark with the back junction solar cell of Froitzheim as the prior art (e.g., Gan, Kwark, and Borden) taught to do so.

A. <u>Prior Art Status</u>

84. I understand from counsel for CSI that Froitzheim (EX1006), Gan (EX1007), Kwark (EX1008), Hartiti (EX1012), and Sivoththaman (EX1013) each qualifies as prior art, and I have been asked to assume them to be so. With respect to Borden (EX1009), I was also asked by counsel for CSI to review the U.S.

Provisional Patent Application No. 61/023,342 (EX1010) ("Borden Provisional") in addition to the corresponding PCT Application by Borden (WO2009/094578) and to determine whether claim 1 of the Borden PCT is supported by the disclosure in the Borden Provisional. Based on my review, my opinion is that claim 1 of the Borden PCT is supported by the Borden Provisional. I provide a table below to show the specific descriptions from the Borden Provisional that support claim 1 of the Borden PCT.

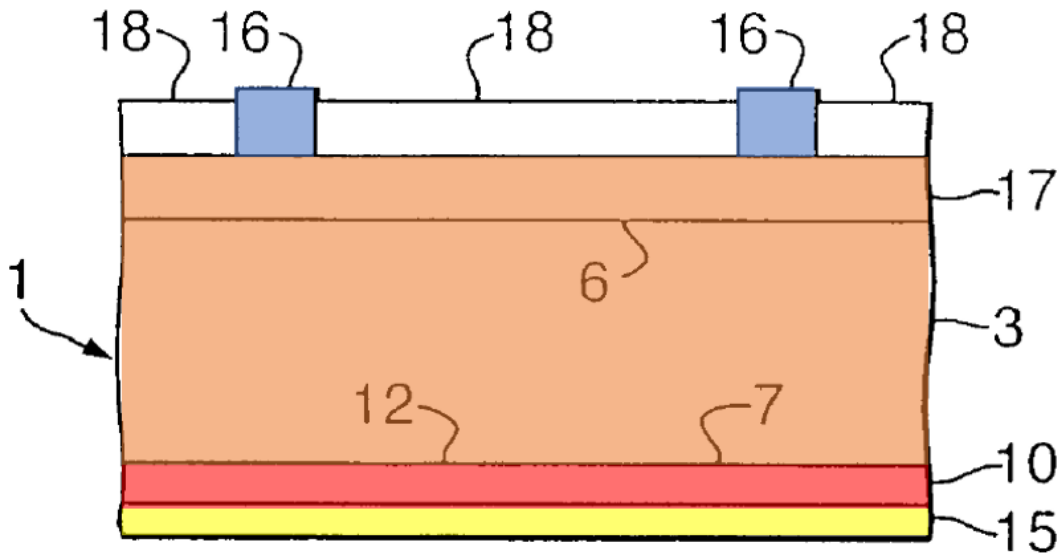
Borden PCT (EX1009) Claim 1	**Borden Provisional EX1010**
1. A solar cell comprising:	¶1, claim 1 ("A solar cell …")
an amorphous semiconductor layer formed over a substrate;	¶¶14-16, claim 1 ("A solar cell including a passivation structure consisting of a tunnel dielectric interposed between a substrate and a layer of an amorphous semiconductor"), Figs. 1-3
a dielectric layer interposed between the substrate and the amorphous semiconductor layer, wherein the dielectric layer is sufficiently thin so as to support a tunneling current therethrough.	¶14 ("The dielectric layer should be thin, on the order of 8-10A, in order to support a tunneling current.") ¶16 ("In another embodiment, the oxide is formed on both front and back at the same time. Next, the a-Si layers are deposited on the front surface."); claim 1 ("a tunnel dielectric interposed between a substrate and a layer of an amorphous semiconductor"), Figs. 1-3

85. The Borden Provisional also supports each disclosure of Borden cited in this Declaration.

Borden EX1009 Citation in Petition	Borden Provisional EX1010 Disclosure
Abstract	Abstract
¶8	¶6
¶16	¶13
¶24	¶16
Figure 1A	Figure 1

B. EP1732142A1 to Froitzheim (EX1006)

86. "Froitzheim" refers to EP1732142A1 (EX1006). It was published on December 13, 2006. EX1006, face. Froitzheim explained that in conventional solar cells, the emitter is placed at the front of the cell to form a PN junction with an oppositely doped p-type substrate. EX1006, ¶2. However, Froitzhem proposed to instead place the emitter/PN junction at the rear side of the solar cell, and thus forms a backside junction solar cell (just like Meier). EX1006, ¶8. Froitzheim's Figure 1, shown below, is a solar cell 1 having an N-type body layer or substrate 3 with a front side 6 and a rear side 7. EX1006, ¶24.



87. To fabricate this solar cell, Froitzheim started with an n-type silicon substrate and etched the front surface "to texture the surface in order to improve the geometry of incidence of light in order to prevent reflection." EX1006, ¶39. Froitzheim explicitly taught diffusion of boron, a p-type dopant, into the substrate's rear surface. EX1006, ¶40. This diffused p-type doped layer 10 forms a backside junction with the oppositely doped n-type substrate. The boron is diffused from a "diffusion source layer that contains boron" and is "applied e.g., spun, only onto the back of the n-doped silicon wafer." EX1006, ¶41. Froitzheim differed from the Meier reference that was distinguished during the 053 Patent prosecution based on Applicant's argument that "Meier teaches formation of a p+ layer 220 by epitaxial growth." EX1002, 130. Froitzheim forms the p+ layer by diffusion of boron, and not epitaxial growth.

88. Moreover, as was well known in the art, the spun on boron diffusion source referred to in Froitzheim forms a borosilicate glass (BSG) from which the boron is thermally driven into the silicon. EX1006, ¶42; EX1030 (Nolan). For example, Nolan describes investigations of borosilicate glass that is created by spinning on borosilicate gel and forms borosilicate glass upon heating. EX1030, Abstract ("A borosilicate gel was spun into a silicon wafer and the layer was rapid thermally processed to convert it to a borosilicate glass.").

89. Returning to Froitzheim, on the front side, phosphorus (an n-type dopant) is diffused onto the front surface of the substrate to create a front surface field. EX1006, ¶¶43-44. Afterwards, passivation and anti-reflection coating are applied "using known methods," and front and rear contacts are screen-printed and fired. EX1006, ¶48-50, 60.

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

90. "Gan" refers to EX1007, J.Y. Gan et al., "Polysilicon Emitters for Silicon Concentrator Solar cells," Proceedings of the 21st IEEE-PVSC ("Gan"). I understand from counsel that Gan is prior art.

91. Gan examined "polysilicon emitters with a thermally grown interfacial oxide" for solar cells in "great detail." EX1007, 245. Gan disclosed that "a very thin oxide (interfacial oxide)" "always exists" between the polysilicon emitter and substrate, "which can be as a by-product of the cleaning process or is

grown intentionally." EX1007, 245. Gan explicitly suggested that solar "cell performance can be improved if the diffused-emitter [*i.e.*, an emitter doped into the substrate, as in Froitzheim] is replaced with the polysilicon emitter,…." EX1007, 245. Before depositing the polysilicon layer, Gan first formed an oxide layer on the silicon substrate. EX1007, 246 (Steps 1-3). Gan experimented with thin interfacial oxides typically less than 20 Angstroms. EX1007, 246. Gan also tested both n- and p-type emitters. *E.g.*, EX1007, Figs. 4-5, 248.

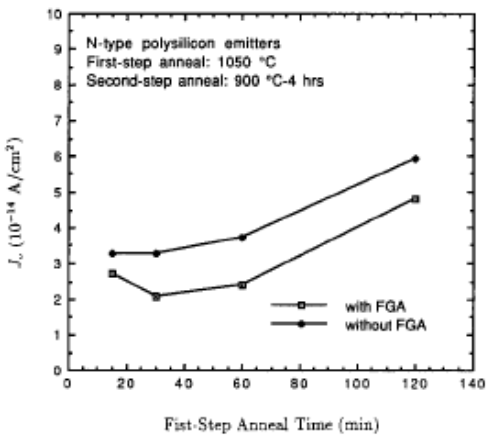


Figure 4: The J_o versus the first-step anneal time for n-type polysilicon emitters.

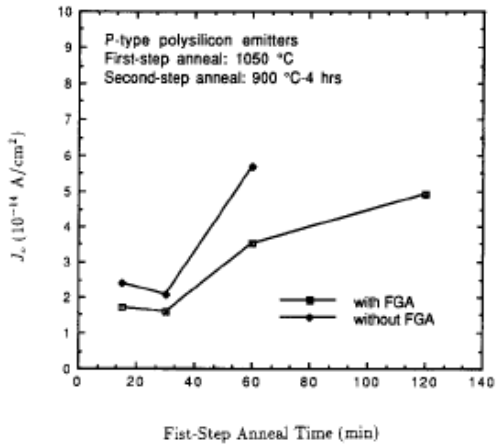


Figure 5: The J_o versus the first-step anneal time for p-type polysilicon emitters.

92. Gan concluded that "polysilicon emitters with low J_o and ρ_c can be obtained with a very small fraction of interfacial oxide breakup." EX1007, 249. J_o measures reverse saturation current and ρ_c measures the resistivity of the contact. A lower J_o indicates a lower recombination, and lower ρ_c indicates lower contact resistance of the solar cell, which, in turn, leads to lower solar cell series resistance, improved fill factor and higher efficiency. Both J_o and ρ_c are thus tied

to indicators that improve solar cell performance. Gan noted that the J_o was lower due to the "use of thermal oxide as the interfacial layer in our samples." EX1007, 248. Gan taught that "polysilicon emitters with these qualities can be quite useful for silicon concentrator solar cells." EX1007, 249. Citing to Sinton, Gan further noted that "more than one absolute percent of the cell efficiency is obtained for backside contact solar cell with polysilicon emitters with characteristics shown here …." *Id.* Backside contact solar cells were known to have their PN junction on the backside of the solar cells.

93. In its process, Gan first formed the silicon oxide layer over the substrate by oxidation of the silicon substrate in steps 1 and 3, following by the deposition of the polysilicon layer in step 4, as shown in the process steps reproduced below:

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

EX1007, 246. As shown, the dopants are diffused (*i.e.*, "drive[n]-in") from diffusion sources of "doped glass" deposited on both sides of the wafer in steps 9 and 10. Then metal contacts are formed on both sides in steps 11 and 12.

D. <u>Kwark (EX1008)</u>

94. "Kwark" refers to EX1008, Kwark, Y. H. et al. "SIPOS Heterojunction contacts to silicon," International Electron Devices Meeting (1984): 742-745 ("Kwark"). I understand from counsel that Kwark is prior art.

95. In addition to SIPOS layers, Kwark tested polysilicon films with and without an intervening chemically grown oxide layer, and found that the oxide layer greatly decreased emitter saturation current—a characteristic Kwark noted

translates into potential improvements for solar cell efficiency. EX1008, 742. Specifically, Kwark reported that addition of "POLY" (*i.e.*, pure polysilicon emitter) *without* the "chemox" (*i.e.*, chemically formed oxide layer) "does not greatly impact J_{oe} as would be expected" where J_{oe} was a measure of emitter saturation current and solar cell recombination. EX1008, 743. ***However, when the chemically formed oxide layer was present, it "greatly decrease[d] the J_{oe} as has been previously reported***." EX1008, 743 (emphasis added). J_{oe} is the same as Jo that I discussed above as the measurement of saturation current. And the lower the J_{oe} or J_o number, the better because it tends to increase Voc and therefore solar cell efficiency. Kwark illustrated this decrease in J_{oe} with the "chemox" in Figure 4:

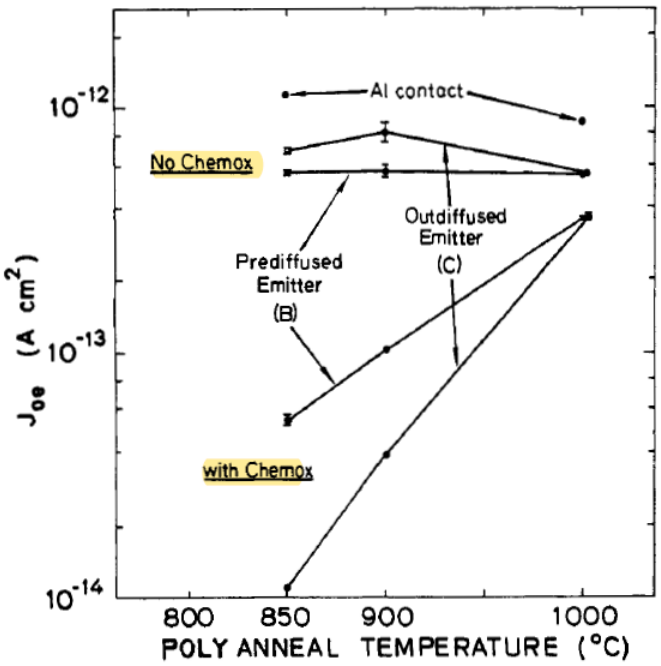


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

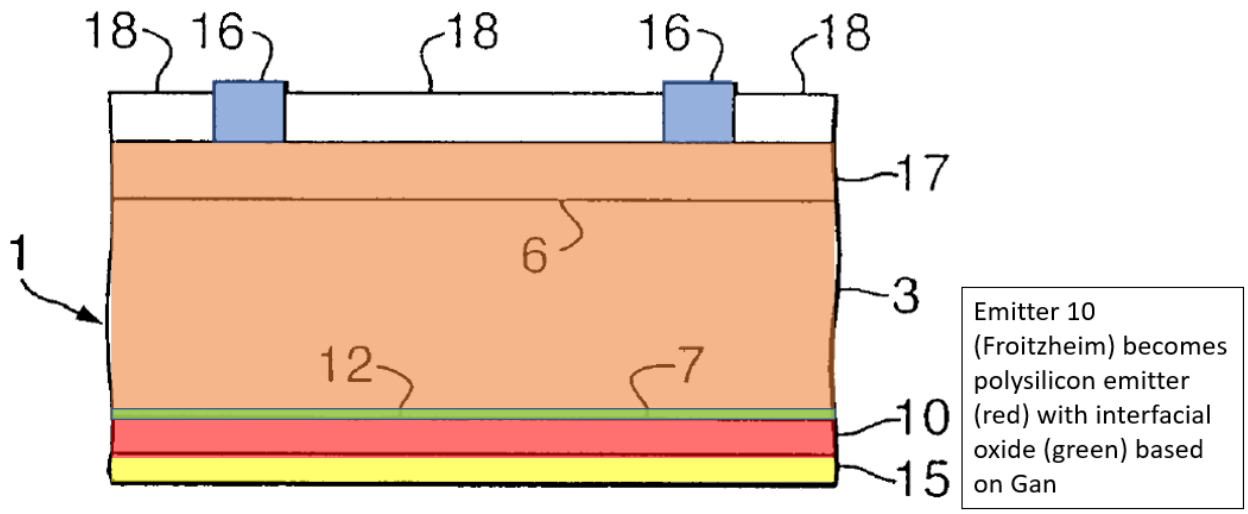
E. Borden (EX1009)

96. Borden is titled "Improved HIT Solar Cell Structure" and relates to an "improved HIT type or ***polysilicon emitter*** solar cells." EX1009, Abstract (emphasis added). Borden disclosed "forming a masking oxide layer on the front and back of the cell and then patterning holes in the masking oxide." *Id*. Afterwards, a "HIT type cell structure or a polysilicon emitter solar cell structure is then formed over the patterned oxide …." *Id*. Borden taught several advantages of the tunnel oxide layer, including "prevent[ing] epitaxial growth of amorphous silicon," "provid[ing] a layer to protect the surface from plasma damage," and "may be used in conjunction with a point contact structure to further increase

efficiency." *Id*. Thus, Borden disclosed that "the present inventors recognize that thin tunnel oxide layers can be used for solar cells" and "that tunnel oxides can be used between a heavily doped or insulating layer of polysilicon and a crystal silicon substrate, forming a polysilicon emitter solar cell." EX1009, ¶16.

VI. FROITZHEIM AND GAN WOULD HAVE RENDERED CLAIMS 9-11, 14, 16-17, AND 19-20 OBVIOUS

97. In my opinion, the combination Froitzheim and Gan would have rendered Claims 9-11, 14, 16-17, and 19-20 obvious and therefore unpatentable. To improve upon the back junction solar cell of Froitzheim, the Skilled Artisan would have replaced the p-type *diffused* in-substrate emitter of Froitzheim with a p-type deposited *polysilicon* emitter and an interfacial oxide layer, as taught by Gan. The resulting modified solar cell is illustrated below using a modified Froitzheim Fig. 1 for illustration. The combination would be no more than inserting the steps of forming the oxide layer and polysilicon emitter in Gan on the backside of the substrate in the fabrication process of Froitzheim before the diffusion process of Froitzheim, and afterwards diffusing the same p-type dopants from a boron diffusion source layer as in the manufacturing of Froitzheim's solar cell. This would form a backside junction polysilicon emitter with an interfacial oxide layer rather than a diffused in-substrate emitter layer..



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

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

99. The Skilled Artisan would have been motivated to replace Froitzheim's diffused emitter with a deposited polysilicon emitter along with an oxide layer because Gan taught and suggested that this modification would be an improvement. Gan disclosed that "***the cell performance can be improved if the diffused-emitter [e.g., of Froitzheim] is replaced with the polysilicon emitter***…." EX1007, 245. Gan also noted that "the J_o [i.e., indication of surface recombination] of the p-type polysilicon emitter (Fig 5) [beneficially] appears to be much lower than what has been previously reported," and suggested that it "may

have to do with the use of thermal oxide as the interfacial layer in our samples." EX1007, 248. Gan explained that "because the dominant recombination is likely at the oxide interface, it implies that the oxide must only be broken by a very small fraction, which is consistent with what was observed in Fig. 2." EX1007, 248.

100. Gan went on to provide lowered Jo and ρ_c data in Figure 6 and concluded the characteristics brought about by the polysilicon emitter with interfacial oxide layer structure are "quite useful for silicon solar cells." EX1007, 249. As I mentioned before, a lower J_o number indicates a lower recombination, which is beneficial to solar cell efficiency, and lower ρ_c indicates lower series resistance of the solar cell, both of which tend to improve solar cell performance. Froitzheim likewise used silicon solar cells and thus would benefit from lower J_o and lower ρ_c. EX1006, Abstract. Gan further performed modeling and determined that "more than one absolute percent of the cell efficiency is obtained for a backside contact solar cell with polysilicon emitters with characteristics shown here …." EX1007, 249. It is noteworthy that Gan's calculations are in the context of a backside contact solar cell which, like Froitzheim, would place the emitter and PN junction on the backside of the solar cell, which would further suggest the combination.

101. While Gan referred in part to silicon concentrator solar cells, it also more broadly suggested that a polysilicon emitter with interfacial oxide is "quite

useful for silicon solar cells" generally (EX1007, 249), and the Skilled Artisan would interpret Gan as recommending the feature for solar cells in general. In particular, silicon concentrator solar cells use lenses or curved mirrors to focus sunlight onto the solar cell, and often move to track sunlight. The polysilicon emitter and interfacial oxide taught by Gan, while applicable to enhancing concentrator solar cell efficiency, is also applicable generally to enhancing the efficiency of solar cells. Thus, the Skilled Artisan would understand Gan as teaching that its polysilicon emitter with interfacial oxide feature is beneficial for solar cell efficiency in general. Gan also disclosed that the benefits apply to both n- and p-type polysilicon emitters, including those formed on the back side of the solar cell, and thus would have suggested replacing Froitzheim's rear p-type diffused *in-substrate* emitter with a rear p-type deposited *polysilicon* emitter plus the beneficial interfacial oxide layer. EX1007, 249 (discussing "both n- and p-type polysilicon emitters.").

102. A Skilled Artisan would further have been motivated specifically to leave the emitter on the back side of the solar cell because Froitzheim disclosed that the back junction design "shows improved stability and good efficiency." EX1006, ¶9. Before the earliest effective filing date of the 053 Patent, it was well known that forming a backside junction often can lead to higher cell efficiency than in front junction cells. EX1041, (Abstract). The thin, diffused emitter

typically has a higher concentration than the thick base or absorber region where most of the solar photons are absorbed, leading to electron-hole pair generation. These carriers must be able to diffuse to the metal contacts if they are to result in a photocurrent at the external terminals. If the emitter is on the front side, there is strong absorption in the emitter but many of them recombine quickly in the highly doped region before they can diffuse to the metal contacts because of the short minority carrier lifetimes and diffusion lengths, leading to loss of efficiency. Also, some of the photon absorption in a highly doped emitter does not lead to electron-hole pair formation but rather Auger processes which do not lead to photocurrents. These problems are not seen in a properly designed back junction cell. For example, Dr. Martin Green, a well known solar cell researcher at the University of South Wales, published a paper in 1993 reporting higher efficiencies with back junction solar cells compared with front junction solar cells:

> Both of the rear junction n-silicon solar cells have achieved high energy conversion efficiencies of 21.9% and 21.2% respectively…. Some front junction n-silicon cells have also been fabricated to compare with the rear junction cells. The measured results have shown that the open-circuit voltage for the front junction cells is about 34 mV lower than the rear junction cells. The reason for this is discussed.

EX1041, (Abstract). After presenting his data, Dr. Green explained the same phenomenon as I described above:

> The high surface recombination at the boron-diffused top surface limits the open-circuit voltage in the front junction n-silicon cells. By using rear junction structure, the top surface becomes phosphorus-diffused and has relatively low surface recombination. The open-circuit voltage, Voc is hence significantly improved.

EX1041, 156. As such, to retain the original advantages of a back junction solar cell and to further improve upon it, the Skilled Artisan would replace the backside emitter in Froitzheim with a backside polysilicon emitter with an interfacial oxide layer, as Gan taught. This replacement merely substitutes one known element for another already known in the field, yielding a predictable result. Thus, in the combination, Froitzheim's modified emitter would continue to function as before, but with the expected additional improvement provided by the polysilicon emitter and interfacial oxide layer.

103. Aside from Gan, numerous other prior art references taught the inclusion of an interfacial oxide layer when replacing a diffused emitter with a polysilicon emitter. For example, the 771 Application Examiner found Foglietti taught the beneficial formation of an interfacial oxide with a polysilicon emitter as it suppresses the "partial realignment of the polycrystalline grains." EX1014, ¶¶2-3. While Foglietti is directed to a bipolar transistor, a Skilled Artisan would have

looked to it when designing solar cells as was commonly done in the art, as seen by the suggestion of Yablonovitch and others. EX1016, 597. Indeed, the use of polysilicon emitters in solar cells itself was an idea adapted from bipolar transistors. EX1007, 245. Foglietti further disclosed other benefits of the interfacial oxide including "hole current therewith is minimized and the transistor gain is increased" and "is substantially repeatable from wafer to wafer." EX1014, ¶¶28,46. The Skilled Artisan would have thus further been motivated to include a polysilicon emitter with an interfacial oxide in Froitzheim because these benefits are equally transferable to solar cells. For example, the same issue of epitaxial realignment present in a bipolar transistor with a polysilicon emitter applies to a solar cell with a polysilicon emitter. And having a process that is substantially repeatable from wafer to wafer is beneficial in all types of devices, including both transistors and solar cells, so that the manufacturing process is consistent and predictable.

104. In the specific context of solar cells, the Skilled Artisan would have further been motivated because Kwark taught that addition of an interfacial chemically grown oxide (chemox) between polysilicon and the substrate "greatly decreases the J_{oe}," which "translates into potential improvements of energy conversion efficiency for solar cells." EX1008, 742, 745. Kwark provided data

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

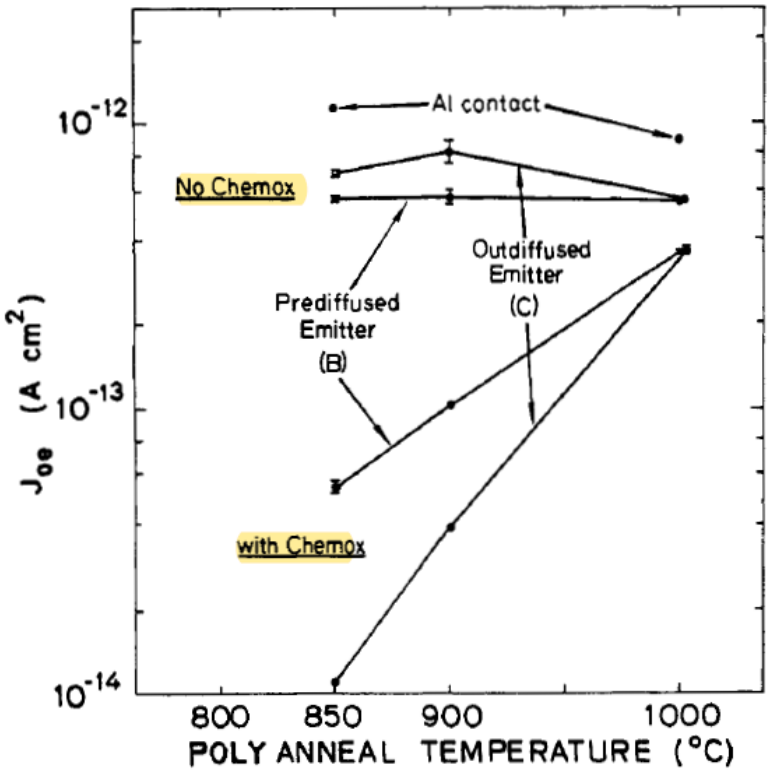


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

105. Borden also disclosed in the context of solar cells that the tunnel oxide "prevents epitaxial growth," allowing for "optimum band structure" and "provides a layer to protect the surface from plasma damage." EX1009, Abstract. These benefits apply to both amorphous silicon and polysilicon. For example, as already noted, Foglietti likewise taught the benefit of preventing epitaxial realignment in the context of bipolar transistors, which translates to solar cells. EX1014, ¶¶8-

9,28,46 (discussing epitaxial realignment between silicon substrate and polysilicon).

B. Reasonable Expectation of Success

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

107. Specifically, before introducing the boron dopant by diffusion at the rear side of the substrate (for example, as described in paragraphs 40-41 of Froitzheim), the Skilled Artisan would perform Gan's steps of growing a thin thermal oxide to form the interfacial oxide layer followed by polysilicon deposition to form the polysilicon on the oxide layer on the back side of the wafer, after which the polysilicon would be doped instead of the substrate to form the polysilicon emitter. EX1007, 246.

108. Combining Froitzheim/Gan as described here would have been well within the level of ordinary skill in the art. It would not have resulted in any unpredictable results and could have been readily accomplished without undue experimentation and with a reasonable expectation of success. Gan taught detailed

steps on how to form the oxide layer and the doped polysilicon emitter layer on a silicon substrate. EX1007, 246.

109. The combination would simply have been the combination of well-known prior art steps in solar cell fabrication to yield predictable results. Likewise, substituting Froitzheim's in-substrate emitter with a deposited polysilicon emitter and interfacial oxide layer would be simple substitution of one known element and corresponding fabrication steps for another to obtain predictable results. It would further constitute use of a known technique (depositing polysilicon emitters with an oxide layer) to improve similar devices (Froitzheim's solar cell) in the same way. It would also constitute applying a known technique to a known device ready for improvement to yield predictable results.

C. <u>Froitzheim and Gan Disclosed All Claimed Steps</u>

1. Claim 9

a) [9.a] Preamble

110. To the extent the preamble is limiting, Froitzheim and Gan both disclosed "*method[s] of fabricating a solar cell,*" as shown by the remaining elements. *E.g.*, EX1006, Abstract, Fig. 1; EX1007, 246. For example, Froitzheim disclosed methods for fabricating a solar cell in paragraphs 38-55. EX1006. Gan also disclosed method for fabricating a solar cell in steps 1-12 on page 246. EX1007.

b) [9.b] Back surface polysilicon

111. Claim 9 first recites: "*forming a layer of polysilicon over a back surface of a silicon substrate*." As discussed in paragraph 97 above, in the Froitzheim/Gan combination, the backside diffused in-substrate p-type emitter of Froitzheim is replaced with a deposited polysilicon emitter, as taught by Gan. Gan explicitly suggested that "the cell performance can be improved if the diffused-emitter is replaced with the polysilicon emitter." EX1007, 245. Thus, the step in Gan of forming the polysilicon layer, as described in paragraph 93, is inserted before the step of boron diffusion at the backside in Froitzheim, as seen in the process steps taught by Gan.

112. Specifically, Gan described first forming an oxide layer in steps 1 and 3, followed by depositing a polysilicon layer in step 4 (shown below)—steps which the Skilled Artisan would have integrated into Froitzheim's fabrication process based on the benefits of polysilicon emitters taught by Gan and discussed in paragraphs 98-107.

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

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

113. *(Intentionally left blank).*

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

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

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

EX1007, 246. Specifically, the Skilled Artisan would understand that the "doped glass deposition" step in Gan deposits a "*first dopant source layer*" on the backside polysilicon and the "drive in" step would diffuse the dopant from the "doped glass"

layer into the polysilicon layer at high temperature in step 10. It was well-known that the term dopant "drive in" is synonymous with dopant diffusion in solar cell manufacturing. For example, in Chapter 7 of the 2002 Hegedus Handbook of Photovoltaics Science and Engineering, Luque described emitter formation and disclosed that "the surface concentration and the depth of the of the emitter, is achieved by depositing, in a thermal step, the desired amount of phosphorus or boron (predeposition) and then diffusing it into the substrate (***drive-in***) during subsequent furnace steps." EX1019 (Luque) at 265. The 053 Patent specification similarly uses "drive-in" to describe the dopant diffusion step. EX1001, 4:60-66.

115. The Skilled Artisan would have been motivated to use this doping process to obtain the benefits of a polysilicon emitter and oxide layer taught by Gan (*see* ¶¶98-105), and would have had a reasonable expectation of success that applying the proven technique of Gan would work with Froitzheim (*see* ¶¶106-107). Gan's diffusion step is compatible with Froitzheim's diffusion step because they both use similar diffusion methods. For example, Froitzheim disclosed that its p-type emitter is doped "by a process which introduces dopant, preferably boron, ***only by diffusion into the rear surface of the body layer***. Several processes for boron diffusion are known in the art, including diffusion from the gas phase or from liquid and ***solid phases applied to the surface*** [*i.e.*, *doped glass layer of Gan*]." EX1006, ¶40.

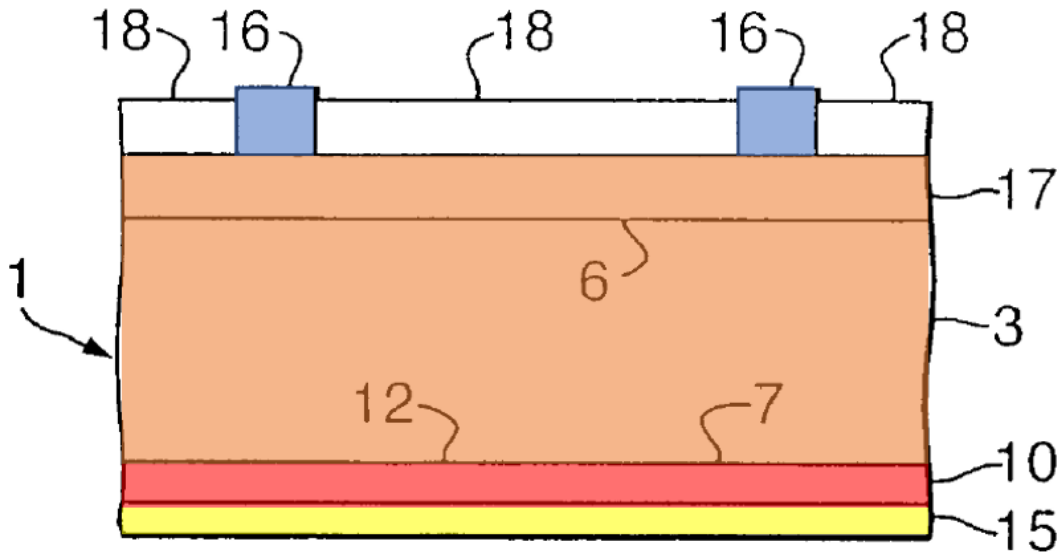
116. Alternatively, in Froitzheim's preferred process, "a diffusion source layer [*i.e.*, *a first dopant source layer*] that contains boron as a dopant is applied, e.g. spun, only onto the back of the n-doped silicon wafer. The diffusion source layer is one that contains boron and out of which the boron is thermally driven." EX1006, ¶41. The Skilled Artisan would understand that this alternative spun on diffusion source layer could also be used instead of solid diffusion sources.

117. Thus, in the Froitzheim/Gan combination, this two-step boron/p-type dopant diffusion process would similarly be performed on the back side, after deposition of the polysilicon layer, to form a *backside junction* with the N-type substrate. And instead of diffusing into the substrate, the boron/p-type dopant diffuses into the polysilicon layer in the Froitzheim solar cell, as modified by Gan, in the same way as recited in the claim. Thus, Froitzheim/Gan combination disclosed steps 9.c and 9.d.

d) [9.e] Diffusing front of substrate

118. Claim 9 next recites: "*diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation*." Froitzheim disclosed this step by forming a "front surface field," or "n+ doped region" at the front side of the substrate. EX1006, FIG. 1 (element 17), ¶15. In Froitzheim, "[d]uring normal operation of the solar cell 1 the

front side 6 faces the sun and light is received through the area of the front surface that is not covered by the front contact 16." EX1006, Figure 1, ¶32.

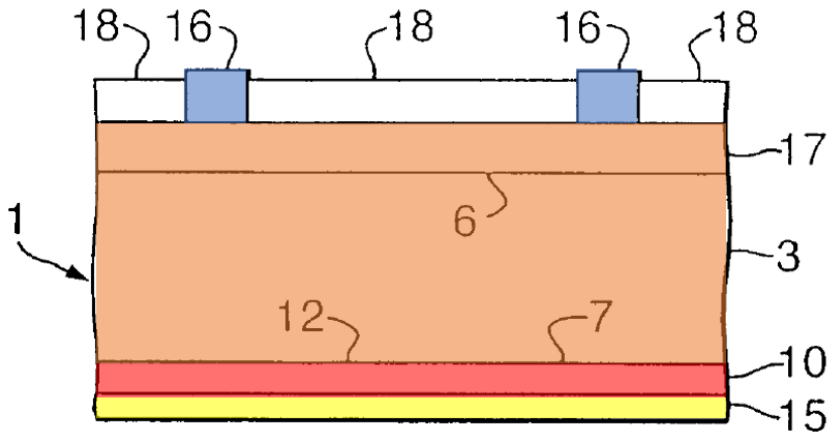


119. To form the "front surface field" or "n+ doped region" 17, Froitzheim disclosed diffusing phosphorus into a front surface of the silicon substrate. Specifically, Froitzheim disclosed: "after the p-doped region has been formed the oxide layer can be removed from the front surface, e.g., using HF, and optionally also the diffusion source layer and oxide layer from the rear surface, followed by a diffusion of Phosphorous from the gas phase to form a front side n+ layer." EX1006, ¶44. Thus, Froitzheim disclosed step 9.e.

e) [9.f] Metal front contact

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

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



122. It was well known in the art that screen-printed contacts were made from silver paste, which forms metal contacts. For example, in Chapter 7 of the 2002 Handbook of Photovoltaics Science and Engineering, Luque described that screen printing "is used to stick a paste containing ***silver*** powder to the front surface of the wafer in the comblike (finger plus bus bars) pattern." EX1019, 275. "The same operations are performed on the backside of the cell, except that the paste contains both silver and aluminum." EX1019, 275. Luque explains that "a paste for the metallic contacts of the solar cell is composed of the following: …

Conducting material, which is a powder of ***silver***." EX1019, 277. Meier similarly disclosed that silver is used for screen printing paste of front contacts. EX1011, 7:10-35. Froitzheim further teaches techniques so that "less material such as Ag [silver metal] or Al [aluminum metal] is required for the contacts," which further confirms that Froitzheim's contacts are metal. EX1006, ¶20.

123. Froitzheim likewise disclosed that "[f]ront and rear side contacts are preferably screen-printed in an industrial production process, and contacting done at elevated temperatures." EX1006, ¶48. Froitzheim further disclosed that in screen printing, the "squeegee paste for rear side contacts can contain ***silver particles***, filler, oxides, and also an amount of Aluminum." EX1006, ¶¶49,60. Although this passage refers to the "rear side contacts," the Skilled Artisan would understand that the silver paste would similarly be used on the front side screen printing, as I discussed in ¶122 above. Thus, Froitzheim's screen printed contacts would likewise be metal contacts in order to conduct electricity. Metal are good conductors of electricity and thus are used commonly as metal contacts for solar cells, such that the electricity can be transmitted out of the solar cell to power external electrical devices.

124. To the extent it is argued that Froitzheim somehow did not disclose metal contacts, a Skilled Artisan would find it obvious that Froitzheim would use silver paste for screen printing the front contacts and thus form metal contacts on

the front. For example, silver was the conventional conductive material to use in a front screen printing paste, as shown by Luque and/or Meier's disclosures discussed in ¶122. EX1019 (Luque), 277. Meier which taught the fabrication of a back junction solar cell like Froitzheim forms its front contacts out of metal. EX1011, 7:10-35. Specifically, Meier disclosed "FIG. 3D shows the structure resulting after depositing metal contacts and firing through the optional anti-reflective coating. By way of example, a silver layer is screen-printed onto the n+ layer 216, covering about 7% of the front surface in a grid pattern." EX1-11, 7:10-15. Thus, the Skilled Artisan would have been motivated to use the same silver metal contacts, with similar teaching in Froitzheim of screen printing, with a reasonable expectation of success for the same kind of solar cell.

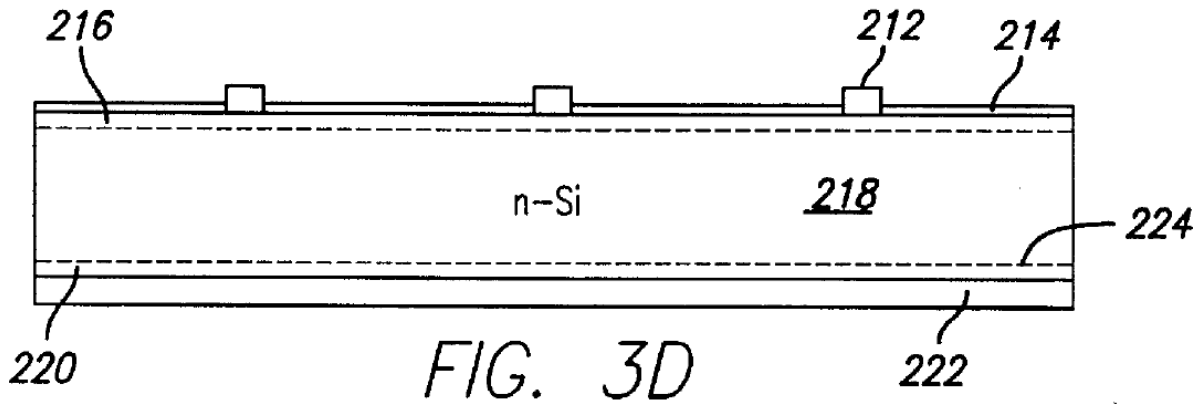


FIG. 3D

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

2. Claim 10 – P-type dopants

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

3. Claim 11 – Borosilicate glass

127. Claim 11 depends from claim 9 and recites: "*the first dopant source layer comprises borosilicate glass.*" Froitzheim also disclosed this element because it was well-known that the "spun" on boron source layer in Froitzheim would form borosilicate glass during the process. Specifically, Froitzheim disclosed doping the emitter, preferably, by spin coating a "diffusion source layer that contains boron as a dopant" and thereafter "thermally driv[ing] in" the boron. EX1006, ¶41. Such spin-on boron-containing diffusion source layer was well-known to form "borosilicate glass" upon heating. For example, in a publication in 2000, Nolan described the "spectroscopic investigation" of borosilicate glass as "dopant source for proximity rapid thermal diffusion." EX1030, 3100. Nolan explained that the composition and structure of a "borosilicate gel" that is spun on the silicon wafer changes to "borosilicate glass" upon heating. *Id.*

128. Moreover, Gan also disclosed this element because its dopant source is "doped glass," which when used with boron as the dopant would have been

known as "borosilicate glass" in the art EX1007, 246.; EX1042, 379. For example, a 1989 textbook titled Electronic Materials Science and Technology by Murarka and Peckerar explained "silicon dioxide and silicon nitride are deposited as glasses in CVD reactors." *Id*. "Borosilicate glasses are made (particularly in low-pressure reactors) using mixtures of tetrapropoxysilne, tripropyl borate, oxygen, and nitrogen." *Id*. Tripropyl borate is used as the boron doping agent in this context.

4. Claim 14

129. Claim 14 depends from claim 9 and recites: "*texturing the front surface of the silicon substrate*" and "*forming an antireflective layer over the textured front surface of the silicon substrate*." The combination of Froitzheim and Gan disclosed these additional elements as well.

a) [14.a] Texturing

130. Froitzheim disclosed *texturing the front surface of the silicon substrate*. Froitzheim stated: "***If desired a short, alkaline crystal-oriented etching can be used to texture the surface*** in order to improve the geometry of incidence of light in order to prevent reflection." EX1006, ¶39 (emphasis added). This passage refers to texturing the front side of the solar cell because that is the side that faces the sun and receives most of the incident light (*i.e.*, light striking the solar cell). Hence, avoiding reflection on the front side of the solar cell is of

particular significance. *See also* EX1015 (Jordan), ¶22 (explaining that the front surface of the wafer is "preferably textured" which "increases the efficiency" by "increasing light absorption"). The Skilled Artisan would understand that solar cells receive incident light on the front surface. And texturing of the front surface prevents reflection of the light away from the cell and deflects the light into the cell body, which is why Froitzheim says the texture will improve the geometry of incidence of light in order to prevent reflection." EX1006, ¶39. This was also well-known and taught by, for example, Luque in Chapter 7 of the 2002 Handbook of Photovoltaics:

> **7.3.6.2 Texturing**
>
> Alkaline (KOH or NaOH-based) solutions etch anisotropically a Si crystal exposing {1 1 1} planes on which the etching rate is lowest. On [1 0 0]–oriented wafers, randomly distributed, square-base pyramids are formed, whose size is adjusted to a few microns by controlling etching time and temperature. ***In a textured face, a ray can be reflected toward a neighboring pyramid (Figure 7.5a) and hence absorption is enhanced***. Though calculation of reflection requires ray tracing, a rough estimate of near-normal incidence can be derived, by assuming that each ray strikes twice the Si surface so that reflection is the square of the untextured case.
>
> ***Texturing is incorporated into both industrial and laboratory Si solar cells, and, in combination with antireflection (AR)***

> ***coating, reduces reflection losses to a few percent***. In the latter case, in order to better control the pyramid geometry and to allow delineation of fine features on the surface, photolithographic techniques are used to define inverted or upright pyramids at the desired positions. It has to be noted that in this case the reflectivity is similar to that of a random texture [64].
>
> Light entering the substrate at a textured surface is tilted with respect to the cell normal. This means that photogeneration takes place closer to the collection junction, which is very beneficial for low-diffusion length cells, by enhancing the collection efficiency of medium- to long wavelengths (Figure 7.5a). The effect is equivalent to an increase of the absorption coefficient. As a drawback, textured surfaces present higher SRVs.

EX1019 (Luque), 269 (emphasis added).

b) [14.b] Antireflective layer

131. Froitzheim also disclosed *forming an antireflective layer over the textured front surface of the silicon substrate*. The 053 Patent discloses silicon nitride as an antireflective layer. EX1001, 2:57-63.

132. Froitzheim likewise disclosed that "SiN [silicon nitride] was used in all cases as antireflection as well as surface passivation coating for n- and p-type silicon." EX1006, ¶60. Froitzheim further disclosed using silicon nitride for the front surface passivation. *Id*., ¶19, 30-31. Froitzheim also disclosed that the anti-reflection coating is applied after the steps of texturing and front dopant diffusion

in the manufacturing process. *Id.,* ¶¶38-39, 50. Thus, the Skilled Artisan would understand that the antireflective layer would be formed over the *textured front surface* of the substrate because it is applied after texturing and diffusion of the front dopants. This must be the sequence because if the antireflective layer is applied first, it would prevent the texturizing chemicals from accessing the Si surface. This is consistent with the description of the 516 Patent for forming the antireflective layer 103 after texturing (*see* EX1001, FIG. 4E and 4H, and 4:28-32 and 5:20-27) and what was well known in the art, as taught for example by Luque, disclosing that an antireflection coating (ARC) is applied after texturing:

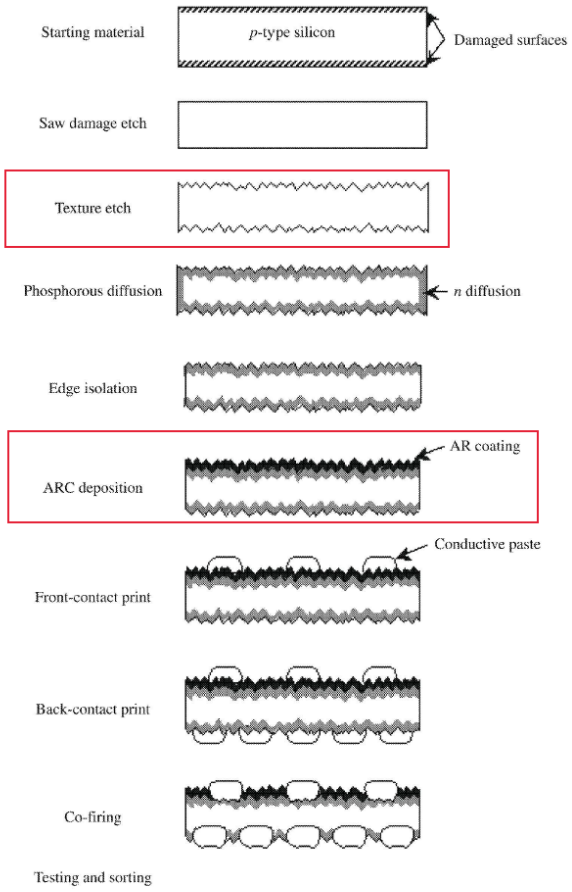


Figure 7.6 A typical processing sequence with schematic illustrations of the resulting structures

EX1019, 272 (Fig. 7.6). Duerinckx (EX1022) also illustrates that antireflective coatings are applied after texturing. It disclosed "isotropic texturization" that "randomly textures the wafers to decrease the reflection of light from the front surface," followed later by "SiN_x-deposition: As described above, the silicon nitride layer has been tailored to reduce the reflection and absorption and to increase the uniformity of the deposition." EX1022 at 239. Thus, it was well known to the Skilled Artisan even before 2008 to apply an anti-reflective layer over the textured front surface of the substrate of a solar cell.

133. It was also well known that silicon nitride functions both as an antireflective and a passivation layer at the same time, as shown by Luque. EX1019 (Luque), 274 ("Silicon nitride is also used as AR [antireflection] coating material"); *id.* 281 ("*Silicon nitride passivation*: The surface and bulk passivation properties of silicon nitride are explained below); *id.* 283-84 ("7.6.2 Passivation with Hydrogen …. For solar cells, [silicon nitride] presents the advantage of performing as an effective antireflection coating…. [S]urface passivation due to SiNx [silicon nitride] deposition has also been reported…. These three different properties (AR coating, bulk passivation, and surface passivation) cannot be varied independently."). Likewise, Duerinckx reported that "hydrogen containing silicon nitride layers are becoming widely introduced in industrial crystalline silicon solar cell processes ***thanks to the unique possibility of combining in one processing***

step an antireflection coating deposition along with surface and bulk passivation." EX1022, 232 (emphasis added).

134. Thus, Froitzheim/Gan would have likewise rendered obvious claim 14.

5. Claim 16

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

a) [16.a] Preamble

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

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

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

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

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

EX1007, 246. As discussed in paragraphs 98-105 above, the Skilled Artisan would have been motivated to replace Froitzheim's backside, diffused emitter layer with a polysilicon layer to improve the solar cell with a reasonable expectation of success. And by doing so, the Skilled Artisan would also have been motivated to form an oxide layer in between the polysilicon and substrate, as taught by Gan because of the beneficial effects of having the oxide layer in between, as discussed in paragraphs 98-105.

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

139. Froitzheim/Gan also disclosed [16.d], [16.e], and [16.f] for substantially similar reasons as steps [9.d], [9.e], and [9.f] that I discussed in ¶¶114-125. Except for omitting the element "first dopant source layer," the process steps of [16.d], [16.e], and [16.f] are identical to the process steps of [9.d], [9.e], and [9.f].

6. Claim 17 – First dopant source

140. Claim 17 depends from claim 16 and additionally recites substantially the same element as [9.c] and [9.d] of claim 9, referring to forming and diffusing

from a first dopant source layer. Froitzheim/Gan would have rendered claim 17 was obvious for similar reasons that I discussed for steps [9.c]-[9.d] of claim 9 in ¶¶114-117 above.

7. Claims 19 and 20 – Texturing and Antireflective Layer

141. Claims 19 and 20 depend from claim 16 and additionally recite substantially the same elements as claim 14. Froitzheim/Gan would have rendered claims 19-20 obvious for similar reasons that I discussed for claim 14 in ¶¶129-134.

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

1. Claim 12 – Second dopant source layer

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

143. Claim 12 would have been obvious over Froitzheim and Gan in further view of EX1012, Hartiti et al., "Low Temperature Formation of Emitter and BSF by Rapid Thermal Co-Diffusion of P, Al, or B," IEEE 1st Word

Conference on PV Energy, (1994) p.1519 ("Hartiti") ***or*** EX1013, Sivoththaman et al, "Rapid Thermal Processing of Conventionally and Electromagnetically Cast 100 cm2 Multicrystalline Silicon," Conference Record of the Twenty Fifth IEEE Photovoltaic Specialists Conference - 1996, Washington, DC, USA, 1996, pp. 621-624 ("Sivoththaman").

144. Both Hartiti and Sivoththaman taught diffusing phosphorus (n-type) dopants into the front side of the solar cell's substrate from "phosphorus doped glass films deposited by spin-on technique or AP-CVD oxides" (Hartiti, EX1012, 1519), which is otherwise known as "phosphosilicate glass PSG (P_2O_5:SiO_2)" (EX1013, 621). "Glass" is made up of silicon dioxide (SiO_2). It was well known in the art that "phosphorus doped glass films" are silicon dioxide doped with phosphorus, as evident by the formula P_2O_5:SiO_2 disclosed by Sivoththaman. The 053 Patent similarly discloses that the N-type dopant source layer 412 is made of "silicon dioxide doped with phosphorus." EX1001, 4:51-52. Thus, depositing this PSG layer on the front of the substrate meets the step of "*forming a second dopant source layer over the silicon substrate*," and the thermal drive-in step, as taught by Hartiti and Sivoththaman, for the phosphorus diffusion from the PSG meets the step of "*diffusing dopants from the second dopant source layer into the silicon substrate*," in claim 12.

a. Hartiti (EX1012)

145. I have been informed by counsel that Hartiti is prior art and apply that understanding.

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

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

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

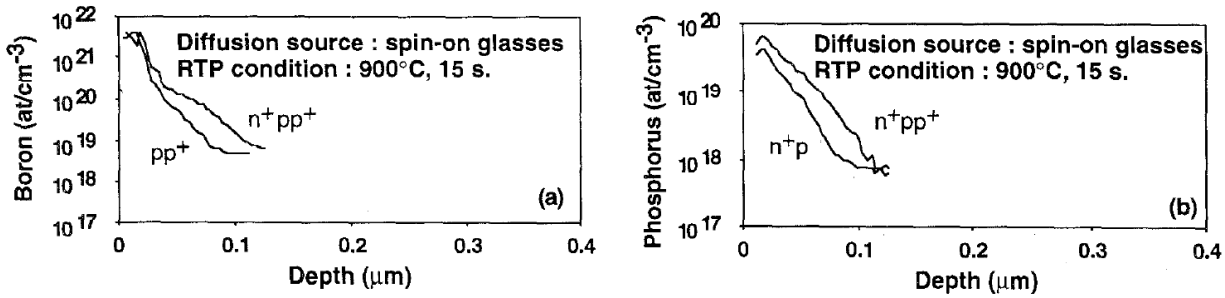


Fig. 2. Mutual enhancement in diffusion for (a) boron and (b) phosphorus.

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

b. Sivoththaman (EX1013)

147. I have been informed by counsel that Sivoththaman is prior art and apply that understanding.

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

c. Motivation to Combine

149. While Froitzheim's front diffusion process used phosphorus gas as the diffusion source, the Skilled Artisan would have been motivated to replace the phosphorus gas diffusion source with a spin-on or APCVD deposited phosphosilicate glass (PSG), as taught by Hartiti or Sivoththaman. Doing so would allow the co-diffusion of the phosphorus and boron at the front and back sides of the solar cell in a single drive-in diffusion step, as disclosed by Hartiti and Sivoththaman. Co-diffusion would enhance the diffusion kinetics and reduce the number of high temperature processing steps, as disclosed by Hartiti, which results in energy savings, cost reduction, and simplification in the manufacturing process. EX1012, 1522.

150. Such motivation is evident also from Gan's teaching where both the front and back sides of the wafer were deposited with "doped glass" and a single "drive-in" step was performed to diffuse the front and back dopants in steps 9 and 10 in Gan. EX1007, 246. The Skilled Artisan would have understood in Gan that the oppositely doped glass sources on the front and back were driven in with one simultaneous drive-in step, similar to Hartiti and Sivoththaman.

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

d. Reasonable Expectation of Success

151. The spin-on or APCVD PSG films, as taught by Hartiti or Sivoththaman would be a "*a second dopant source layer*" deposited over the front of the substrate, as recited in claim 12. The Skilled Artisan would have reasonably expected that Froitzheim's phosphorus gas source can be substituted with the PSG film and still result in a working solar cell. For example, Froitzheim's preferred method for the backside boron diffusion was the spin-on technique, which is also the technique used by Hartiti to deposit both the front and back dopants. EX1006, ¶41; EX1012, 1519. Froitzheim does not require that the phosphorus be diffused from a gas source, or that the boron be diffused only from a spun-on source. Froitzheim disclosed that diffusion can be performed as was "known in the art,

including diffusion from the gas phase, or from liquid and solid phases applied to the surface." EX1006, ¶40.

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

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

2. Claim 13 – Phosphorus

154. Claim 13 depends from claim 12 and recites: "*the second dopant source layer comprises phosphorus doped silicon dioxide*." As I discussed in

¶¶144-148 for claim 12, the deposited PSG layer, as taught by Hartiti or Sivoththaman, as the dopant source layer constitutes a "*phosphorus doped silicon dioxide*" as evident by the formula P_2O_5:SiO_2 disclosed by Sivoththaman. EX1013, 621. Thus, claim 13 would have been obvious for the same reasons as discussed for claim 12.

3. Claim 18 – Second dopant source

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

156. As I discussed in ¶¶135-139 above, Froitzheim/Gan would have rendered claim 16 obvious. Because Claim 18 recites the same additional limitations as Claim 12, it would have been obvious over Froitzheim and Gan in further view of Hartiti or Sivoththaman for the same reasons discussed for claim 12 as I discussed in ¶¶142-144 above.

4. Claim 11 – Borosilicate glass

157. Claim 11 depends from claim 9 and recites: "*the first dopant source layer comprises borosilicate glass.*" To the extent that Maxeon argues that Claim 11 would not have been obvious by the combination of Froitzheim and Gan alone,

Claim 11 would also have been obvious over Froitzheim and Gan in further view of Hartiti or Sivoththaman. Hartiti and Sivoththaman both taught the use of borosilicate glass (BSG) as the dopant source layer for the backside of the solar cell. EX1012, 1520 (The same enhancement of diffusion kinetics "can also be observed when the co-diffusion of the P[hosphorus] and B[oron] are performed from AP-CVD ***silicate*** sources."); EX1013, 622 ("For the BSF, … APCVD ***borosilicate glass (BSG)*** … was used as RT-diffusion source[]").

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

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

a *dopant source layer*, the Skilled Artisan would consider the spin-on BSG of Froitzheim and Hartiti to be reasonably interchangeable with the AP-CVD deposition of BSG technique as taught by Hartiti or Sivoththaman.

5. Claim 15 – In situ

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

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

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

EX1001, 5:9-18. Thus, in the context of the 053 Patent, "in situ" refers to processing that occurs after a single manual loading of the substrate into a furnace or other single chamber or multi-chamber processing tool. Therefore, in the context of claim 15's diffusion steps, the single, simultaneous drive-in/diffusion of the front and back dopants would constitute "in situ" steps that satisfy the claim.

162. This "in-situ" step is met by either Hartiti or Sivoththaman because they both disclose the simultaneous, single step co-diffusion of the front and back dopants in a single rapid thermal processing unit, "model FAV4 of Jipelec (Grenoble, France)." EX1012, 1519; EX1013, 621 ("A commercial RTP furnace was used.") The Skilled Artisan would understand that in a co-diffusion technique as taught by Hartiti or Sivoththaman, the fabrication personnel, after the front PSG and back BSG depositions of the dopants, would perform a single manual loading into the RTP furnace for a combined drive-in/diffusion step. In any event, the wafer must have undergone a loading into the thermal processing unit (i.e., the commercial RTP furnace) to undergo the simultaneous drive-in/diffusion. And since they were diffused simultaneously, they must have been done in the same manual loading. *Id*.

163. The Skilled Artisan would be motivated to perform co-diffusion, as I already discussed in ¶¶149-150 above, and would also reasonably expect to succeed, as I discussed in ¶¶151-153 above.

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

164. The combination Froitzheim and Kwark would have rendered Claims 9-11, 14, 16-17, and 19-20 obvious and unpatentable. The combination of Froitzheim and Kwark is similar to the previous combination of Froitzheim and Gan, except that Kwark, instead of Gan, supplies the elements for forming the polysilicon emitter and the oxide layer in between.

A. Motivation to Modify Froitzheim and Kwark

165. Froitzheim and Kwark are analogous art because each is in the same field of endeavor—solar cell design. EX1006, Abstract, ¶¶1,9; EX1008, 742. Each is also reasonably pertinent to the problems of efficiency and cost-effectiveness of solar cell designs. EX1006, Abstract, ¶¶1,9; EX1008, 742. To the extent it is argued Kwark is directed to a bipolar transistor, a Skilled Artisan would have looked to it when designing solar cells as was commonly done in the art. EX1020, 363; EX1021, 497; EX1007, 245; EX1016, 597.

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

cells." EX1008, 742, 745. Kwark provided data comparing polysilicon emitters with and without the oxide layer, and noted "the large difference when the interfacial oxide is missing." EX1008, 745 Fig. 4. Thus, the large beneficial difference seen with an interfacial oxide would have motivated a Skilled Artisan to include one with a polysilicon emitter in the modified Froitzheim.

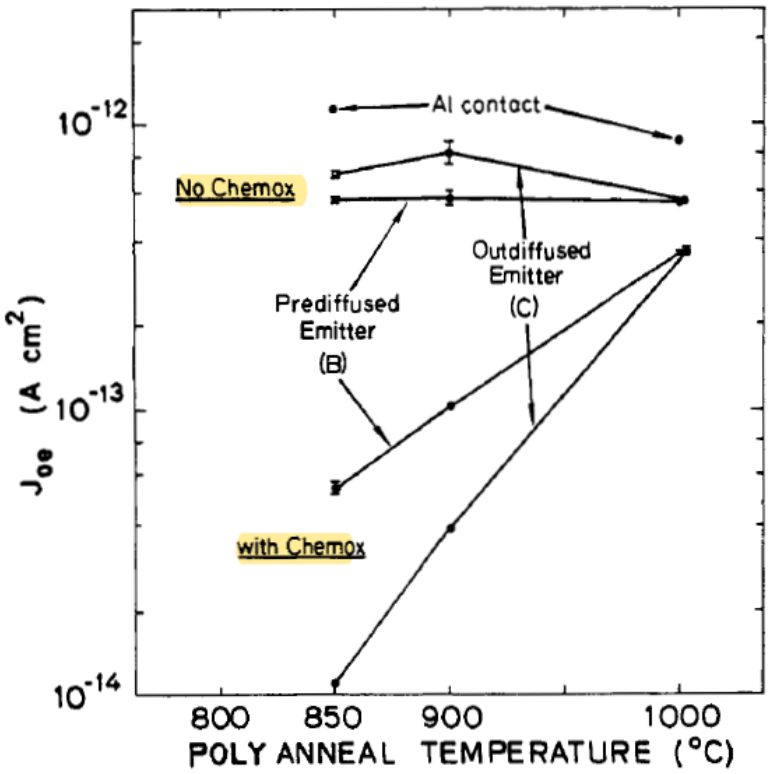


Fig. 4: emitter saturation current for POLY contacts with and without a chemically grown interfacial layer vs. anneal temperature. Thicknesses range from 3000-3600 angstroms. Note the large difference when the interfacial oxide is missing.

167. The teachings of Froitzheim, Gan, Foglietti, and Borden that I discussed in paragraphs 98-105 would similarly have motivated a Skilled Artisan to integrate a polysilicon emitter with interfacial oxide layer in Froitzheim in view

of Kwark because of the benefits discussed those paragraphs for polysilicon emitter and interfacial oxide layer.

B. Reasonable Expectation of Success

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

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

It would also constitute applying a known technique to a known device ready for improvement to yield predictable results.

C. Froitzheim and Kwark Disclosed All Elements

1. Claim 9

a) [9.a] Preamble

170. Froitzheim discloses *a method of fabricating a solar cell* as shown by the remaining elements, as does the Froitzheim/Kwark combination. *E.g.*, EX1006, Abstract, Fig. 1.

b) [9.b] Back surface polysilicon

171. Claim 9 first recites: "*forming a layer of polysilicon over a back surface of a silicon substrat*e." In the Froitzheim/Kwark combination, the backside diffused p-type emitter of Froitzheim is replaced with a polysilicon emitter, as taught by Kwark. Thus, the step in Kwark of forming the polysilicon layer by deposition using a "APCVD reactor" is inserted as a step to form the backside polysilicon layer before the step of boron diffusion in Froitzheim. EX1008, 742-743. I detail the motivation and reasonable expectation of success for this combination in paragraphs 165-169. In Kwark, the "POLY films" were "doped in situ in an RF heated cold wall APCVD reactor," which in this context refers to adding the dopant to the gas mixture that deposits as the polysilicon in the reactor. In combining with Froitzheim, it would have been routine and within the level of skill of the Skilled Artisan to adjust the process for fabricating the polysilicon

emitter. For example, the Skilled Artisan could have known to omit Kwark addition of boron dopant to the APCVD reactor during the deposition of the "POLY" layer because the Skilled Artisan would have understood that Froitzheim's process would provide for reliable doping of the polysilicon after deposition by a spun on boron dopant source. *See* ¶¶116-117. Alternatively, the Skilled Artisan could also have chosen to maintain Kwark's doping in the polysilicon deposition step and still utilized Froitzheim's boron diffusion from a diffusion source layer, as this would enhance the doping, leading to lower contact resistivity, and increase efficiency in transmitting the electricity out of the solar cell. Either of these optimization and adjustments would be well within the level of skill of the Skilled Artisan.

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

172. As I discussed in ¶¶114-116, 172, Froitzheim disclosed steps [9.c] and [9.d]. Thus, the Froitzheim/Kwark combination would meet these two steps.

d) [9.e] Diffusing front of substrate

173. As I discussed in ¶¶118-119, 173, Froitzheim disclosed step [9.e]. Thus the Froitzheim/Kwark combination would meet this step.

e) [9.f] Metal front contact

174. As I discussed in ¶¶120-123, 174, Froitzheim disclosed step [9.f]. Thus the Froitzheim/Kwark combination would meet this step. To the extent that an argument is made that Froitzheim does not disclose metal front contacts, it

would be obvious to the Skilled Artisan to use metal contacts in the screen printing process of Froitzheim because it was well known in the industry that screen printed contacts are made of metal, as I discussed in ¶¶122-124.

2. Claim 10 – P-type dopants

175. As I discussed in ¶126, Froitzheim disclosed *p-type dopants* for the "*first dopant source layer*," as recited in claim 10. Thus, the Froitzheim/Kwark combination would have rendered claim 10 obvious.

3. Claim 14

176. As I discussed in ¶¶130-134, Froitzheim disclosed "*texturing the front surface of the silicon substrate, and forming an antireflective layer over the textured front surface*." Thus, the Froitzheim/Kwark would have rendered claim 14 obvious.

4. Claim 16

a) [16.a] Preamble

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

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

178. As I discussed in ¶¶94-95, Kwark taught to form a "chemically grown oxide (chemox) layer" before the APCVD deposition of the polysilicon layer, such that the oxide layer is between the polysilicon layer and the substrate. EX1008,

743. This oxide layer beneficially "decreases the J_{oe}" which translates into improvements for solar cell efficiency. *Id.* Given this benefit, the Skilled Artisan would have modified Froitzheim's solar cell and replaced its diffused backside emitter structure with an oxide layer followed by the deposited polysilicon layer, as taught by Kwark, as I discussed in ¶¶165-169.

179. Thus, the combination of Froitzheim/Kwark disclosed first "*forming an oxide layer over the back surface of a silicon substrate*" and "*forming a layer of polysilicon over the oxide layer*," which are the same steps [9.b] in claim 9.

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

180. Froitzheim/Kwark also disclosed [16.d], [16.e], and [16.f] for substantially similar reasons as steps [9.d], [9.e], and [9.f] that I discussed in ¶¶114-116, 172.

5. Claim 17 – First dopant source

181. Froitzheim/Kwark rendered the method of claim 16 obvious as set forth above. Claim 17's further requirements are substantially similar to [9.c]-[9.d], and claim 17 was obvious for similar reasons that I discussed in ¶¶114-116, 172.

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

182. Froitzheim/Kwark rendered the method of claim 16 obvious as set forth above. Claim 19, which requires *texturing the front surface of the silicon*

substrate, was obvious for similar reasons to claim 14 that has the same requirement that I discussed in ¶176. Claim 20, which requires *forming an antireflective layer over the textured front surface of the silicon substrate*, was obvious for similar reasons to claim 14 that has the same requirement that I discussed in ¶176.

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

1. Claim 12 – Second dopant source layer

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

184. Froitzheim and Kwark would have rendered obvious Claim 9, as I discussed in ¶¶170-174. Although Froitzheim and Kwark do not disclose the additional limitation of Claim 12, Hartiti and Sivoththaman do, as I discussed in ¶¶146-148above. The Skilled Artisan would be motivated to replace the phosphorus gas diffusion source of Froitzheim with a spin-on or APCVD deposited phosphosilicate glass (PSG), as taught by Hartiti or Sivoththaman. I explained why with respect to the Froitzheim/Gan combination in paragraphs 142-153, and

the same logic applies here. Doing so would allow the co-diffusion of the phosphorus and boron at the front and back sides of the solar cell in a single drive-in diffusion step, as disclosed by Hartiti and Sivoththaman. Co-diffusion in a single step would reduce the number of high temperature processing steps, as disclosed by Hartiti, which results in energy savings, cost reduction, and simplification in the manufacturing process. EX1012, 1522.

185. Thus, Claim 12 would have been rendered obvious by Froitzheim and Kwark in further view Hartiti and Sivoththaman for substantially similar reasons that I discussed in ¶¶142-153 above with respect to the Froitzheim/Gan combination.

2. Claim 13 – Phosphorus

186. Claim 13 would have been obvious for the same reasons that I discussed in ¶154 above, with Hartiti and Sivoththaman disclosing the additional limitation of a "*phosphorus-doped silicon oxide layer*" as the "*second dopant source layer*."

3. Claim 18 – Second dopant source

187. Claim 18 would have been obvious for the same reasons that I discussed in ¶155 above, with Hartiti and Sivoththaman disclosing the additional limitation of a "*second dopant source layer*."

4. Claim 11 – Borosilicate glass

188. Claim 11 would have been obvious for the same reasons that I discussed in ¶157-159, with Hartiti and Sivoththaman disclosing the additional limitation of a "*borosilicate glass*."

5. Claim 15 – In situ

189. Claim 15 would have been obvious for the same reasons that I discussed in ¶160-163 above, with Hartiti and Sivoththaman disclosing the additional limitation of a performing the diffusion of the front and back sides "*in situ*."

X. OBJECTIVE FACTORS SUPPORT OBVIOUSNESS

A. No Commercial Success Attributable to the 516 Patent

190. I have not seen any evidence of commercial success attributable to the 053 Patent claims. I understand that the current patent owner, Maxeon, was spun out from SunPower that originally owned the 053 Patent.[1]

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[1] https://newsroom.sunpower.com/2020-08-27-SunPower-and-Maxeon-Solar-Technologies-Close-Spin-Off-Transaction; https://mediaroom.maxeon.com/2020-08-27-SunPower-and-Maxeon-Solar-Technologies-Close-Spin-Off-Transaction.

191. I have reviewed the virtual patent marking webpages of both Maxeon and SunPower, and the 053 Patent is not included either listing of patents by Maxeon or SunPower. EX1036; EX1037.[2] This leads me to conclude that neither Maxeon nor SunPower is practicing the 053 Patent.

192. Moreover, I have been in working in the solar cell research for over 15 years. That neither Maxeon nor SunPower is practicing the 053 Patent is consistent with my understanding, based on my experience in this field and what I have read and reviewed over the years, because SunPower's and Maxeon's commercial products are mainly *back-contact* solar cells, rather than *front contact* solar cells, as claimed in the 516 Patent. EX1039.[3] Back contact solar cells have both first and second metal contacts only on the backside, unlike the claimed invention of the 053 Patent that requires "*forming a metal contact on the* ***front*** *surface of the substrate*." EX1019, 108. Below is a basic schematic diagram of a back-contact solar cell as shown, for example, in a 2002 Handbook of Photovoltaics Science and Engineering, Chapter 3:

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[2] https://us.sunpower.com/solar-panels-technology/patents; https://corp.maxeon.com/patents

[3] https://sunpower.maxeon.com/int/solar-panel-products/maxeon-solar-panels

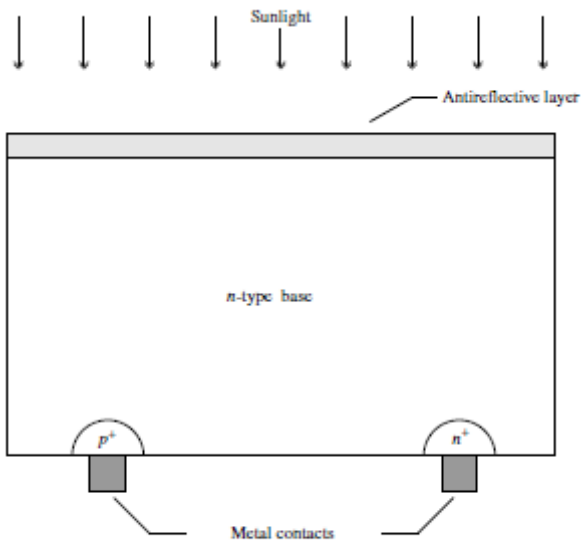

Figure 3.26 Schematic of a back-contact solar cell

193. As seen from the schematic above, the metal contacts for both positive and negative polarity are in the back side of the solar cell and no metal contacts are on the front side.

194. For example, Maxeon touts the advantage of its commercial solar panel products as "us[ing] back-contact conductivity, eliminating unsightly metal gridlines and enabling them to absorb more light" because there are no front metal contacts:

EX1039.

195. I understand that Maxeon has filed suit against CSI and others in the solar industry asserting that the 053 Patent covers TOPCon solar cells. TOPCon stands for "Tunnel Oxide Passivated Contact." To the extent that Maxeon argues commercial success based on the TOPCon solar cells, there is also at minimum no causal connection between TOPCon solar cells and the 053 Patent. The TOPCon cell design does not practice the 053 Patent because it does not involve "*diffusing dopants from the first dopant source layer to the layer of polysilicon to form* ***a backside junction*** *with the silicon substrate*," as required by independent claim 9 of the 053 Patent, nor "*diffusing dopants into the layer of polysilicon to form* ***a backside junction*** *with the silicon substrate*" as required by independent claim 16 of the 053 Patent.

196. The "TOPCon" solar cell design was initially described by researchers from the Fraunhofer Institute for Solar Energy Systems ("Fraunhofer Institute") in

2013 as a solar cell design based on prior art approaches using polysilicon emitter solar cells that I discussed, for example, in ¶¶65-74. This TOPCon solar cell design was published in Feldman, et al., "A Passivated Rear Contact for High-Efficiency n-Type Silicon Solar Cells Enabling High VocS and FF > 82%" at 1 (28th European PV Solar Energy Conference & Exhibition, Paris, Sept. 30 – Oct. 4, 2013) ("Feldman Paper"). EX1040.

197. As described by the Feldman Paper, the TOPCon solar cell "consists of an ultra-thin tunnel oxide and *phosphorus-doped* silicon layer" formed on the backside of an *n-type silicon base substrate*, as shown in Figure 3 of the Feldman Paper and reproduced below. EX1040, 1.

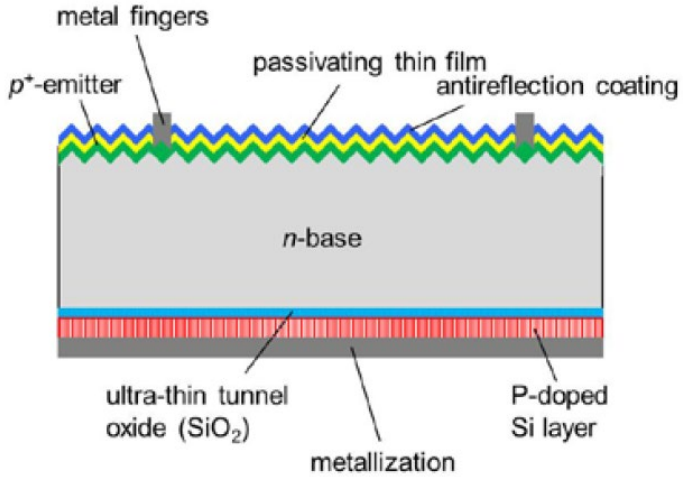

Figure 3: Solar cell with boron-doped emitter at the front and passivated rear contacts.

198. The back side layer of Figure 3 of Feldman is labeled "P-doped Si layer," and the text is clear that "P" in this figure is referring to phosphorus. In multiple places, Feldman describes this silicon layer as being "phosphorus-doped."

For example, Feldman describes: "Our approach, which we have called TOPCon (Tunnel Oxide Passivated Contact) is based on these prior approaches and consists of an ultra-thin tunnel oxide and a phosphorus-doped silicon layer." EX1037, 1. In its summary, Feldman again describes: "A thermally stable passivated contact for the rear side base contact of n-type silicon solar cells has been presented. It has been shown that our TOPCon structure based on a tunnel oxide and phosphorus doped Si layer passivates the surface effectively for both MPP and OC conditions and enables the extraction of Vocs higher than 710mV." EX1037, 4.

199. Because phosphorus is an n-type dopant, and has the same dopant polarity as the n-type substrate, the "phosphorus-doped silicon layer" on the backside of the TOPCon solar cell forms a ***back surface field ("BSF")*** layer with the n-type substrate because the dopant type of the "phosphorus-doped silicon layer" is the same as the dopant type of the n-type substrate. They both have n-type dopants.

200. In contrast, a backside junction, like in the back junction solar cells of Froitzheim that I discussed in ¶¶86-89 and of Meier (EX1011) that the Examiner cited during prosecution, is formed with opposite dopant types. The 053 Patent describes that "a backside junction [is] formed by an N-type silicon substrate and a P-type polysilicon emitter on the backside of the solar cell." EX1001, Abstract and 1:53-55. A back surface field layer cannot form a backside junction with the

substrate because it has the same polarity as the substrate. A back surface field layer also has a different function and structure compared to a backside junction because a back surface field repels minority carriers in the solar cells, while the backside junction collects minority carriers in the solar cells.

201. My opinion is confirmed by the Applicant's own statements made during prosecution of the 053 Patent and continuation applications. For example, during the prosecution of the 053 Patent, the Applicant said the same thing that I am saying now: "As is well known, a BSF [i.e., back surface field] has the same dopant type as the substrate, but at a higher concentration to keep minority charge carriers away from the back surface." EX1002, 217. The Applicant distinguished the prior art used by the Examiner to reject the claims of the 053 Patent during that prosecution, saying that in the prior art "the polysilicon forms a BSF with the substrate, as opposed to a backside junction with the substrate." EX1002, 218.

202. Based on the argument distinguishing a back surface field and a backside junction, the Examiner of the 053 Patent allowed the claims. In the Examiner's Notice of Allowability dated June 10, 2014, the examiner stated his "Reasons for Allowance" as follows:

> The following is an examiner's statement of reasons for allowance: The prior art of record lacks the instantly claimed backside junction formed at the interface of a first material of a silicon substrate comprising ***one dopant type*** and a second

> material of a polysilicon layer of an ***opposite dopant type***. Furthermore the backside junction is formed on the backside of the solar cell which is opposite to the light incident front side of the solar cell. Silvestre is the closest prior art, but no fair reason or motivation to modify the solar cell of Silvestre to include the backside junction as claimed. Therefore the instant invention as claimed is considered patentable over the prior art.

EX1002, 250.

203. Likewise, during prosecution of the 771 Application, which is a continuation of the 053 Patent, the Applicant again drew the same distinction between a backside junction and a back surface field based on the polarity of the dopants, a distinction that was well known in the industry. For example, in its appeal brief to the PTAB for the 771 Application, the Applicant argued:

> Okayasu discloses a manufacturing method for a BSF type solar cell. ***As is well known, a BSF layer is a backside layer that has the same polarity as the substrate.*** That is, an n-type substrate would have an n-type BSF layer, and a p-type substrate would have a p-type BSF layer (Okayasu, paragraph [0008]). ***More particularly, a BSF layer cannot form a backside junction with the substrate because it has the same polarity as the substrate.***

EX1005, 461 (emphasis added). Again, in its Reply Brief in the 771 Application, the Applicant again made the distinction between a back surface field and a backside junction:

> A BSF layer forms a high-low (HL) junction, i.e., the highly doped and lightly doped layers of the BSF have the ***same polarity*** on the ***backside*** of the solar cell (Okayasu, paragraph 14) This is opposite to a backside junction, whose layers have ***opposite polarity*** on the ***backside*** of the solar cell.

EX1005, 496 (emphasis in original). These statements expressed by the Applicant expressed the same understanding of the Skilled Artisan that a backside junction is different from a back surface field, and that a backside junction is formed by substrate and backside emitter layer that have opposite dopant polarities, just as described in the 053 Patent, Meier (EX1011), and Froitzheim (EX1006).

204. The TOPCon solar cell design has a back surface field, rather than a backside junction, and therefore cannot support any assertion of commercial success attributable to the 053 Patent.

B. <u>No Evidence of Unexpected Results</u>

205. There is no unexpected result in replacing the backside diffused emitter in a back junction solar cell like Meier and Froitzheim with a polysilicon emitter having an interfacial oxide layer in between. The Skilled Artisan would have reasonably expected to reap the many benefits from such a modification such

as higher solar cell efficiencies and lower recombination, as taught by the prior art such as Kwark and Gan. And including an oxide layer between the polysilicon layer and the substrate was well-known to confer expected benefits as well, as I discussed in ¶¶65-74, 90-96, 98-105. Making such a modification to Froitzheim would have been simply following the conventional wisdom, as taught in the prior art.

206. There was also no unexpected result from using spin-on or APCVD silicate glass films as dopant source layers for diffusing the front and back of the solar cells, as these were well known techniques before the 053 Patent as I discussed in ¶¶114-117, 144-148. Neither was there any unexpected result in simultaneously co-diffusing "in situ" the front and back dopants. Performing such steps was nothing more than following the conventional wisdom as taught for example by Hartiti and Sivoththaman that I discussed in ¶¶144-153, 152-163.

207. There was also no unexpected result from forming metal contacts on the front side of the solar cell, as this was well known and conventional for solar cells to have front metal contacts that were formed by screen printing, as I discussed in ¶¶121-124.

208. Thus, the objective indicia demonstrate that the 053 Patent claims were nothing but obvious.

TABLE OF APPENDICES

APPENDIX A: Table Comparing Claims 9-20 of 053 Patent to Claims of 771 Application and 035 Application

APPENDIX B: List of Exhibits Considered

APPENDIX A

Comparing Claims 9-20 of 053 Patent to

Claims of 771 Application and 035 Application

053 Patent Claims 9-15	'771 Application Claims 1-2, 4, 7	'035 Application Claims 21, 23-25
9. A method of fabricating a solar cell comprising:	1. A solar cell, comprising:	21. A solar cell, the solar cell comprising:
[claim 14: 14. The method of claim 9 further comprising: texturing the front surface of the silicon substrate; and forming an antireflective layer over the textured front surface of the silicon substrate.	a substrate having a front surface that faces the sun to collect solar radiation during normal operation and a back surface opposite the front surface; an oxide layer disposed on the front surface of the substrate; an anti-reflective coating on the oxide layer;	a N-type silicon substrate having a front surface and a back surface, wherein the front surface comprises a textured surface;
	a tunnel dielectric disposed over the back surface of the substrate;	an *oxide* region disposed over the *back surface* of the N-type silicon substrate;
forming a layer of polysilicon over a back surface of a silicon substrate; forming a first dopant source layer over the layer of polysilicon; diffusing dopants from the first dopant source layer to the layer of polysilicon to form a backside junction with the silicon substrate;	an emitter disposed over the tunnel dielectric, the emitter forming a backside junction with the substrate; [*2. The solar cell of claim 1, wherein the emitter is a polysilicon emitter.*]	a *polysilicon emitter* disposed over the oxide region;
diffusing dopants into a front surface of the silicon	a doped diffusion region in the substrate;	

053 Patent Claims 9-15	'771 Application Claims 1-2, 4, 7	'035 Application Claims 21, 23-25
substrate, the front surface of the silicon substrate facing the sun during normal operation; and	[claim 9: a doped diffusion region in the substrate on the front surface of the substrate;]	
forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.	a front electrode that is coupled to the doped diffusion region on the front surface of the substrate; and	a first metal contact disposed on the front surface of the N-type silicon substrate, wherein the first metal contact is in electrical contact with the plurality of dot-shaped N-type doped regions; and
	a back electrode that is coupled to the emitter on the back surface of the substrate.	a second metal contact disposed on the polysilicon emitter.
10. The method of claim 9 wherein the first dopant source layer comprises P-type dopants.		23. The solar cell of claim 21, wherein the polysilicon emitter comprises a P-type doped polysilicon.
12. The method of claim 9 wherein diffusing dopants into the front surface of the silicon substrate comprises forming a second dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate.		
15. The method of claim 9 wherein the diffusion of dopants from the first dopant source layer to the layer of polysilicon and the diffusion of dopants into the front surface of		

053 Patent Claims 9-15	'771 Application Claims 1-2, 4, 7	'035 Application Claims 21, 23-25
the silicon substrate are performed in situ.		

053 Patent Claims 16-20	'771 Application Claims 1-2, 4, 7	'035 Application Claims 21, 23-25
16. A method of fabricating a solar cell comprising:	1. A solar cell, comprising:	21. A solar cell, the solar cell comprising:
[19. The method of claim 16 further comprising: texturing the front surface of the silicon substrate.] *[20. The method of claim 19 further comprising: forming an antireflective layer over the textured front surface of the silicon substrate.]*	a substrate having a front surface that faces the sun to collect solar radiation during normal operation and a back surface opposite the front surface; an oxide layer disposed on the front surface of the substrate; an anti-reflective coating on the oxide layer;	a N-type silicon substrate having a front surface and a back surface, wherein the front surface comprises a textured surface;
forming an oxide layer over a back surface of a silicon substrate;	a tunnel dielectric disposed over the back surface of the substrate; [*4. The solar cell of claim 1, wherein the tunnel dielectric is a tunnel oxide*]	
forming a layer of polysilicon over a back surface of a silicon substrate; diffusing dopants into the layer of polysilicon to form a backside junction with the silicon substrate;	an emitter disposed over the tunnel dielectric, the emitter forming a backside junction with the substrate;	an *oxide* region disposed over the *back surface* of the N-type silicon substrate; a *polysilicon emitter* disposed over the oxide region; 23. The solar cell of claim 21, wherein the polysilicon emitter comprises a P-type doped polysilicon.
diffusing dopants into a front surface of the silicon substrate, the front surface of the silicon substrate facing the sun during normal operation; and	a doped diffusion region in the substrate; [claim 9: a doped diffusion region in the substrate on the front surface of the substrate;]	

053 Patent Claims 16-20	'771 Application Claims 1-2, 4, 7	'035 Application Claims 21, 23-25
forming a metal contact on the front surface of the silicon substrate, wherein the metal contact is electrically coupled to the silicon substrate.	a front electrode that is coupled to the doped diffusion region on the front surface of the substrate; and	a first metal contact disposed on the front surface of the N-type silicon substrate, wherein the first metal contact is in electrical contact with the plurality of dot-shaped N-type doped regions; and
	a back electrode that is coupled to the emitter on the back surface of the substrate.	a second metal contact disposed on the polysilicon emitter.
17. The method of claim 16 wherein diffusing dopants into the layer of polysilicon to form the backside junction with the silicon substrate comprises: forming a first dopant source layer over the layer of polysilicon; and diffusing dopants from the first dopant source layer into the layer of polysilicon.		
18. The method of claim 16 wherein diffusing dopants into the front surface of the silicon substrate comprises forming a second dopant source layer over the silicon substrate and diffusing dopants from the second dopant source layer into the silicon substrate.		

APPENDIX B

List of Exhibits Considered

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

Exhibit #	Reference Name
1016	Yablonovitch, Eli et al., "A Study of n^+-SIPOA:p-Si Heterojunction Emitters." Nov. 1985, IEEE Election Device Letters, Vol. EDL-6, No. 11 ("Yablonovitch")
1017	Sinton, R. A. et al., "Design Criteria for Si Point-Contact Concentrator Solar Cells." Oct. 1987, IEEE Trans. on Electron Devices, Vol. ED-34, No. 10
1018	File History of U.S. Patent Application No. 16/460,035 ("035 Application")
1019	Luque, A. et al., "Handbook of Photovoltaic Science and Engineering." Wiley (2003)
1020	Lindholm, F.A., et al., "Heavily Doped Polysilicon-Contact Solar Cells." July 1985, IEEE Electron Device Letters, Vol. EDL-6, No. 7
1021	Silvestre, S. et al., "Series Resistance in Double-Polysilicon-Contacted Silicon Solar Cells." May 13-17, 1996, IEEE 25th PVSC
1022	Duerinckx, F. et al., "Defect passivation of industrial multicrystalline solar cells based on PECVD silicon nitride." 2002, Elsevier, Solar Energy Materials & Solar Cells
1023	Ashburn, P. et al., "Comparison of Experimental and Theoretical Results on Polysilicon Emitter Bipolar Transistors." July 1984, IEEE Trans. on Electron Devices, Vol. ED-31, No. 7
1024	U.S. Patent No. 6,998,288 to Smith ("Smith288")
1025	U.S. Patent No. 5,057,439 to Swanson ("Swanson439")
1030	Nolan, M. et al., "Spectroscopic Investigations of Borosilicate Glass and Its Application as a Dopant Source for Shallow Junctions." 2000, Journal of The Electrochemical Society (ResearchGate)
1034	Press Release, SunPower and Maxeon Solar Technologies Close Spin-Off Transaction, dated Aug. 27, 2020 https://newsroom.sunpower.com/2020-08-27-SunPower-and-Maxeon-Solar-Technologies-Close-Spin-Off-Transaction

Exhibit #	Reference Name
1035	Patent Assignment
1036	SunPower Virtual Patent Marketing https://us.sunpower.com/solar-panels-technology/patents
1037	Patents | Maxeon Solar Technologies, Ltd. https://corp.maxeon.com/patents
1038	Press Release, SunPower and Maxeon Solar Technologies Close Spin-Off Transaction, dated Aug. 27, 2020 https://mediaroom.maxeon.com/2020-08-27-SunPower-and-Maxeon-Solar-Technologies-Close-Spin-Off-Transaction
1039	SunPower Maxeon Solar Panels https://sunpower.maxeon.com/int/solar-panel-products/maxeon-solar-panels
1040	Feldman, et al., "A Passivated Rear Contact for High-Efficiency n-Type Silicon Solar Cells Enabling High VocS and FF > 82%" at 1 (28th European PV Solar Energy Conference & Exhibition, Paris, Sept. 30 – Oct. 4, 2013) ("Feldman Paper").
1041	Green, M.A. et al., "High Efficiency N-Silicon Solar Cells Using Rear Junction Structures." IEEE, 1993
1042	Murarka, S. et al., "Electronic Materials Science and Technology." 1989, Academic Press, Inc.