UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Canadian Solar Inc.,
Petitioner,

v.

Maxeon Solar Pte. Ltd.,
Patent Owner.

Case No. IPR2024-01194
U.S. Patent No. 11,251,315
Issued: February 15, 2022
Filed: May 18, 2020
Inventors: David D. Smith, Tim Dennis, Russelle De Jesus Tabajonda
Title: Solar Cells with Improved Lifetime, Passivation and/or Efficiency

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DECLARATION OF SANJAY BANERJEE, Ph.D.
REGARDING
U.S. PATENT NO. 11,251,315

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: July 19, 2024

Sanjay Banerjee

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 opinion about the state of the art of the technology related to U.S. Patent No. 11,251,315 ("315 Patent") (EX1001) and on the patentability of Claims 16 and 19 of this patent. The following is my written declaration on these topics.

B. Background and Qualifications

2. My educational background, career history, and other relevant qualifications are summarized below. I attach to this Declaration my *curriculum vitae* (EX1004) which provides a full and accurate description of my educational background, professional experience, and qualifications.

3. 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.

4. 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.

5. 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, attached to this declaration as EX1004.

6. 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").

7. 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.

8. 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.

9. 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).

10. 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, attached to this declaration as EX1004.

C. Compensation and Prior Testimony

11. 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.

12. I have previously submitted declarations in multiple IPR proceedings, and have also testified as an expert witness in Federal Court and the ITC, as summarized at EX1004, 1. I also recently submitted a declaration in IPR2024-01038 on behalf of the Petitioner CSI in which I opined on the invalidity of Claims 10-15 of the 315 Patent. For consistency purposes, and given the similar issues at play between the two petitions, I have repeated my analysis of those claims in this declaration, although only Claims 16 and 19 are specifically at issue here.

D. Information Considered

13. 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.

14. 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.

15. 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

16. 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.

17. 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.

18. 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.).

19. 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.

20. 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.

21. 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.

22. 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. Anticipation

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

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

25. 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.

26. 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.

27. 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.

28. 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. Obviousness

29. 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.

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

31. 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.

32. 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.

33. 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.

34. 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.

35. 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.

36. 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.

37. 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.

38. 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.

39. 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.

40. 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.

41. 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.

42. 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.

43. 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).

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

45. 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 315 PATENT

A. Effective Filing Date of the 315 Patent

46. I understand from the face of the patent that the 315 Patent was filed on May 18, 2020 and issued February 15, 2022. EX1001, Face. I understand from counsel that the 315 Patent claims priority to a series of earlier patents, the earliest of which was filed on December 22, 2014. EX1001,1:5-17. I have been asked by counsel to assume for purpose of my analysis that the 315 Patent's effective filing date is December 22, 2014.

B. The Person of Ordinary Skill in the Art

47. I have reviewed the 315 Patent specification and its claims. Based on my review together with my experience in the field and information disclosed in the 315 Patent, I believe that the person of ordinary skill in the art ("Skilled Artisan") in the 315 Patent's field of solar cell design or manufacture at the time of the effective filing date of the 315 Patent in the December 2014 timeframe would have been someone with an advanced degree involving the discipline of 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 designing, developing, or researching in the field.

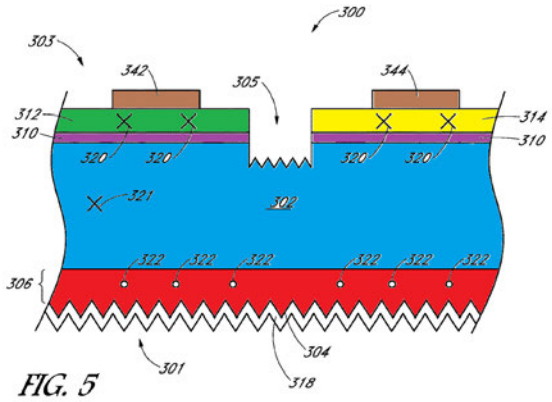
48. I was a Skilled Artisan before December 22, 2014 by this definition.

C. The 315 Patent's Specification

49. The 315 Patent is titled "Solar Cells with Improved Lifetime, Passivation, and/or Efficiency." EX1001. For the purposes here, I will describe one of the embodiments in the 315 Patent that is relevant to the claims that I have been asked to opine on.

50. Figure 5 of the 315 Patent describes a "solar cell 300" that has "a front side 301 which faces the sun during normal operation and a back side 303 opposite

the front side 301." EX1001,6:40-44. I have reproduced Figure 5 below and added coloring to the figure to assist in the discussion of the various components of the solar cells. In this figure, the bottom side of the figure is the front side of the solar cell that faces the sun, and the top side of the figure is the back side of the solar cell opposite the sun-facing side.



51. The solar cell described includes a "silicon substrate 302" (shown in blue below) which "can be single-crystalline or multicrystalline," and, further, "can be a N-type silicon substrate." EX1001,3:35-38, 6:44-47.

52. According to the 315 Patent, dopants are diffused into the substrate on the front side, and this dopant-diffused front "portion 306 of the silicon substrate 302 can have a doping concentration 322 of approximately less than or equal to $2x10^{18}$ cm^{-3}." EX1001,4:15-24, 6:47-49. FIG. 5 shows this front dopant-diffused portion (reproduced as layer 306 shown in red above), where the bottom side of FIG. 5 is the front side of the solar cell. The solar cell also includes an

antireflection layer 318 (no color) further deposited on the front portion of the cell. EX1001,7:9-12.

53. The 315 Patent also describes that at the back side (which is the topside in FIG. 5), the solar cell "can have a dielectric region 310 formed over the silicon substrate 302," which "can be a tunnel oxide" such as "silicon dioxide." EX1001,6:50-53 (shown in purple below). On the dielectric region 310, the solar cell's rear is described as having "first and second emitter regions 312, 314" which "can be P-type and N-type doped polysilicon regions, respectively." EX1001,6:53-57 (shown in green and yellow below). The patent further describes that "impurities and/or contaminants 320, e.g. metal impurities 320 and/or metal contaminants, can be located in the first and second emitter regions 312, 314 as shown," while "some impurities 321" can "remain []" in the substrate itself. EX1001,6:57-62.

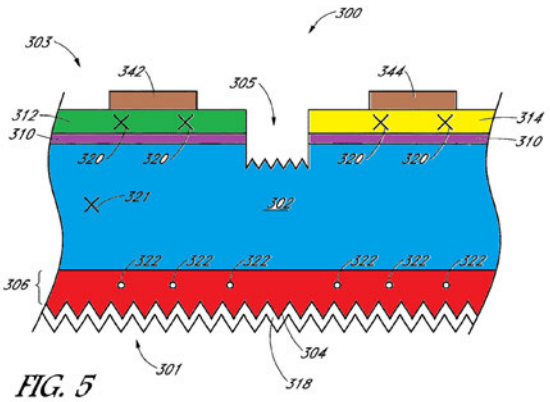


FIG. 5

54. Finally, at the rear side, "the solar cell 300 can have first and second metal contacts 342, 344 formed on the first and second emitter regions 312, 314,

respectively." EX1001,6:63-65 (shown in brown above). In FIG. 5, when all metal contacts are arranged at the backside away from the sun, the solar cell is called "a back contact solar cell." EX1001,7:13-14.

55. The patent specification describes the method of making the solar cell of FIG. 5 in Figures 1-4. EX1001, 6:40-42. The specification also describes "Example Process C of FIG. 11" as exemplifying the Figures 1-4 method for fabricating the solar cell of FIG. 5, and compares it with other methods (Examples A, B, and D) for forming different solar cells. EX1001,8:40-9:9; FIG. 11.

56. Specifically, in Example Process C, the front "surface, or a portion near the surface, of a silicon substrate was doped at approximately less than or equal to $2x10^{18}$ cm^{-3}." EX1001,8:40-45; FIG. 11 ("Surface Dopant Conc."). In contrast, Examples B and D have surface dopant concentrations of $4x10^{18}$ cm^{-3}, significantly higher than the $2x10^{18}$ cm^{-3} used in Example Process C. The front portion of Example Process A is doped in the same way as Example Process C. EX1001,8:40-9:9; FIG. 11. However, in Example Process A (and also Example Process B), the solar cell was heated below 900 degrees Celsius, while in Example Process C (and also in Example Process D), the solar cell is heated to a temperature above 900 degrees Celsius. EX1001,8:44-9:9.

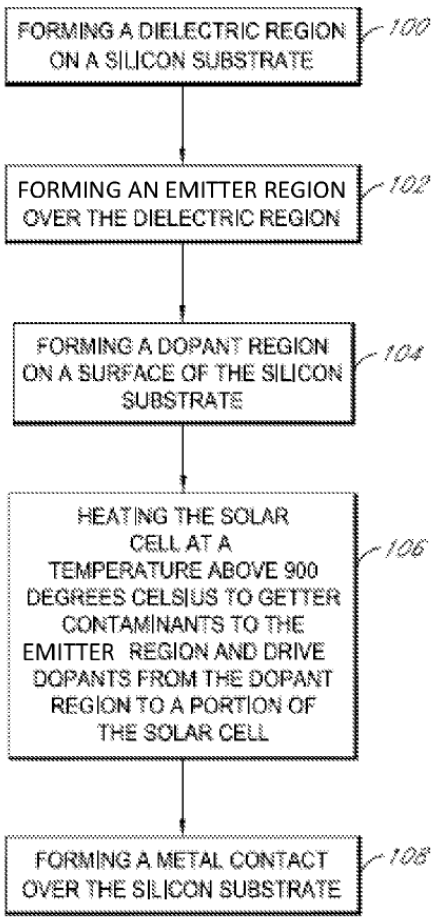


FIG. 1

57. Figure 11 supposedly summarizes these conditions, but I note that FIG. 11 appears to have typographical errors for the "Temp" column for Examples C and D as the temperature should have been above 900°C according to the description in the text. EX1001,8:44-46, 9:3-5. With respect to this temperature, the 315 Patent describes in FIG. 1 step 106 to "heat [] the solar cell at a temperature above 900

degrees Celsius to getter contaminants to the emitter region and to drive dopants from the dopant region to a portion of the solar cell."

Example Process	Temp	Surface Dopant Conc.	Gettering Location	Surface Passivation	Lifetime	Efficiency
A	≤ 900 deg-C	$2x10^{18}$ cm^{-3}	non-poly	$2fA/cm^2$	~3msec	Baseline
B	≤ 900 deg-C	$4x10^{18}$ cm^{-3}	non-poly	$5fA/cm^2$	~10msec	Baseline
C	≤ 900 deg-C	$2x10^{18}$ cm^{-3}	poly	$2fA/cm^2$	~10msec	+0.5 % abs.
D	≤ 900 deg-C	$4x10^{18}$ cm^{-3}	poly	$5fA/cm^2$	~10msec	Baseline

Table 1. Example Processes for Solar Cell Fabrication

FIG. 11

58. Regarding gettering, the 315 Patent explains that the emitter/polysilicon regions "can be a good sink and/or trap for the metal impurities" and that "[a] gettering process can be used to trap the metal impurities 220 in the emitter regions 212, reducing recombination within the silicon substrate 202 and improve solar cell lifetime." EX1001,5:10-15. As an example, "heating at temperatures above 900 degrees Celsius can include gettering metal impurities 220 through the dielectric region 210, e.g., tunnel oxide, to into the emitter region 212, e.g., polysilicon regions." EX1001,5:21-25.

59. In contrast, according to the 315 Patent, heating at 900°C or below "can be ***insufficient*** to diffuse metal impurities through a tunnel oxide and into a polysilicon region." EX1001, 5:18-20 (emphasis added). The 315 Patent states that "[o]xides and/or tunnel oxides, such as the dielectric region 210 of FIG. 2, can be barriers to gettering of the metal impurities 220 to emitter regions 212." EX1001, 5:15-17. Thus, the 315 Patent teaches to heat above 900°C so that the metal impurities can getter through the tunnel oxide layer into the polysilicon region. *Id.*, 5:21-25.

60. The process of Example C in the specification of the 315 Patent exemplifies the process of both doping the front portion of the silicon substrate at approximately equal or less than $2x10^{18}$ cm^{-3} and heating the solar cell above 900°C to getter the metal impurities to the polysilicon region. EX1001, 8:40-50. The solar cell resulting from Example Process C is claimed by claims 10-15 that I will discuss below.

D. Claims 10-15, 16, and 19 of the 315 Patent

61. The claims of the 315 Patent are directed to a solar cell structure and do not recite limitations to any particular process or temperature, but include the requirements of having a front dopant concentration of "*approximately less than or equal to* 2×10^{18} cm^{-3}" and "*metal impurities*" being present in a "*first emitter*

region." Both requirements correspond to the solar cell that the 315 Patent describes would result from the processing conditions of Example Process C.

62. Claim 10 of the 315 Patent recites:

> *A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:*
>
> *a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to* $2\times10^{18}\ cm^{-3}$ *and wherein the portion of the silicon substrate is formed at the front side of the solar cell;*
>
> *a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar;*
>
> *a first emitter region having metal impurities formed over the dielectric region; and*
>
> *a first metal contact formed over the first emitter region.*

63. Claim 11 depends from claim 10 and recites: "*The solar cell of claim 10, wherein the portion of the silicon substrate comprises N-type dopants*."

64. Claim 12 depends from claim 10 and recites: "*The solar cell of claim 10, wherein the portion of the silicon substrate comprises phosphorus*."

65. Claim 13 depends from claim 10 and recites: "*The solar cell of claim 10, wherein the portion of the silicon substrate comprises P-type dopants*."

66. Claim 14 depend from claim 10 and recites: "*The solar cell of claim 10, wherein the portion of the silicon substrate comprises boron."*

67. Claim 15 depends from claim 10 and recites: "*The solar cell of claim 10, wherein the first emitter region comprises polysilicon*."

68. Claim 16 depends from claim 10 and recites "*The solar cell of claim 10, further comprising: a second emitter region having metal impurities formed over the dielectric region; and a second metal contact formed over the second emitter region.*"

69. Claim 19 depends from claim 16 and recites: "*The solar cell of claim 16, wherein the second emitter region comprises polysilicon.*"

E. Prosecution History

70. I have also reviewed the prosecution history of the 315 Patent to understand what the Examiner has considered during prosecution and the reasons for why the claims were allowed. The 315 Patent was allowed without any rejections. EX1002, 206-207.

F. Claim Construction

71. 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, unless otherwise specified.

IV. OVERVIEW OF THE PRIOR ART

A. Known Background Technologies

1. Back-Contact Solar Cells

72. In my opinion, the basic concept and structure of "back-contact solar cells" had been known in the art for decades before December 22, 2014, the effective filing date of the 315 Patent. Generally, it was well known that a back-contact solar cell has all the metal contacts on the back side opposite the side that faces the sun. The sun-facing side does not have any metal contacts such that they do not block any portion of the solar cell's front side from receiving incoming light. In a back-contact solar cell, it was also well known that back side negative and positive metal contacts were formed over and electrically contacting the N-type doped and P-type doped regions of the solar cell, respectively, both of which were also formed on the back side of the solar cell.

73. For example, a 2002 Handbook of Photovoltaic Science and Engineering edited by Antonio Luque and Steven Hegedus ("Luque"), disclosed a basic "[s]chematic of a back-contact solar cell," showing that the front side of the

substrate (having no metal contacts) faces the sun and the opposite/back side of the substrate contains both P-type and N-type doped regions, with both the positive and negative metal contacts formed at the backside and contacting the oppositely-doped regions, respectively:

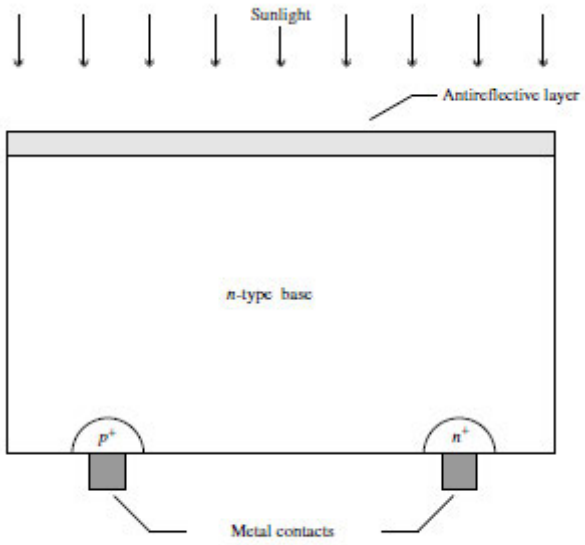


Figure 3.26 Schematic of a back-contact solar cell

EX1010, 108.

74. Similarly, a 2007 review paper by Neuhaus and Münzer ("Neuhaus") recognized that "[i]nterdigitated back contact (IBC) solar cells were investigated by Lammert and Schwartz" as far back as 1977. EX1011, 11. Neuhaus recognized "[k]ey design features that contribute to high efficiency" of back-contact solar cells include "localized back contacts," each over oppositely-doped regions, and "a gridless front surface which permits optimization of light trapping and passivation," as shown in the "IBC solar cell structure" of Neuhaus Figure 8. As

shown below, the front side also includes a "front surface field" having the same dopant type (N-type) as the substrate and further passivated by silicon oxide and silicon nitride layers on top:

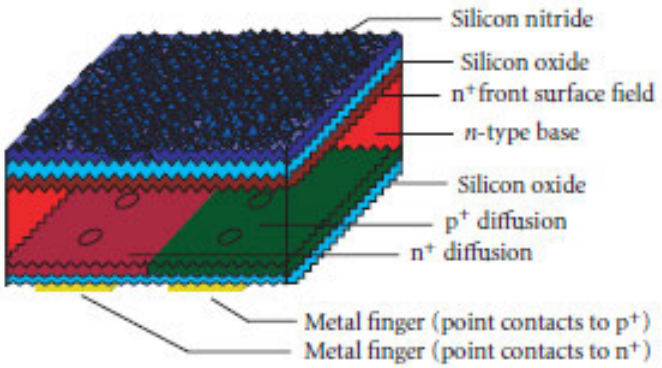
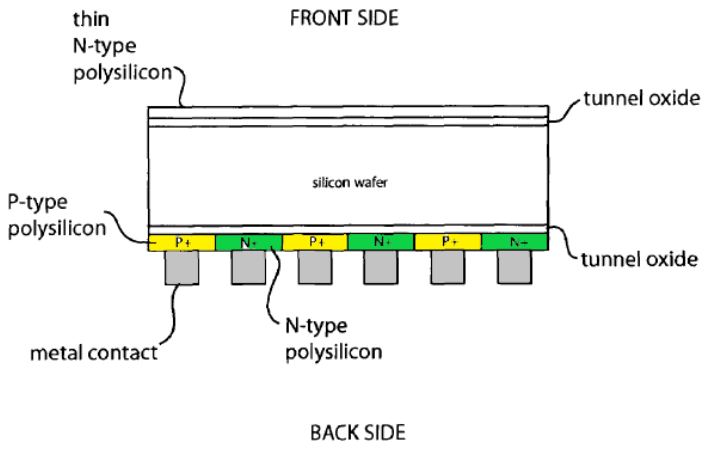


FIGURE 8: Schematic drawing of an IBC solar cell of SunPower.

EX1011, 11.

75. U.S. Patent 7,468,485 ("Swanson-485"), issued in 2008, shows a back-contact solar cell having metal contacts (shown in gray) over oppositely-doped polysilicon regions (shown in yellow and green) formed over a tunnel oxide dielectric layer, all on the back side:



EX1012, Fig. 1. Swanson-485's "Description of the Background Art" recognized that "[i]n a back side contact solar cell, the p-type and n-type regions are coupled to metal contacts on the back side of the solar cell to allow an external electrical circuit or device to be coupled to and be powered by the solar cell." EX1012,1:20-23. Forming metal contacts over doped regions including polysilicon regions were well known and well within the level of ordinary skill in the art, as seen above. Indeed, according to Swanson-485, forming them can use "[c]onventional solar cell back-end processes" which further confirms that forming metal contacts over doped regions in a back contact solar cell was nothing new and within the level of the Skilled Artisan long before 2014. EX1012,6:38-46.

2. Front Surface Doping in Back-Contact Solar Cells

76. Before December 2014, it had been known for decades that the front portion of the silicon substrate of a back-contact solar cell should be optimally doped at a concentration of less than or equal to 2×10^{18} cm^{-3}.

77. For example, King and Swanson published in 1990 and reported that the optimum front dopant concentration for a back-contact solar cell was approximately 1×10^{18} cm^{-3} for untextured and textured front surfaces:

> In the case of a back-contacted cell in which the sunside diffusion is used mainly to reduce surface recombination, not to collect current, the optimum emitter is the one with the lowest J_0. For untextured surfaces, this corresponds an emitter with $N_{D,surf} \approx 1 \times 10^{18}$ cm^{-3} that is as thin as possible. Fig. 3

> shows an emitter with these specifications is probably near optimum in J_0 when it has textured front surface, as well.

EX1006, 369. "$N_{D,surf}$" refers to the surface dopant concentration. EX1006, 365. J_0 measures reverse saturation current, and a lower J_0 indicates a lower recombination, which tends to increase solar cell efficiency. Surface recombination in solar cells leads to lower cell efficiency.

78. To provide context for King and Swanson's teaching, I will discuss the effects and relationship of dopant concentration and surface recombination and conductivity of the doped region and the metal contacts. A front dopant concentration 1 to 2 x 10^{18} cm^{-3} is lower than what is usually the front dopant concentration for a front contact solar cell. A lower front dopant concentration is preferred for back contact cells because it reduces surface recombination leading to higher cell efficiency. Because back contact solar cells do not have any metal contacts on the front side, the doped region on the front side of the back contact solar cell is used mainly to reduce surface recombination by repelling minority carriers, as alluded to by the paragraph quoted above from King and Swanson. And a lower front dopant concentration reduces surface recombination, while a higher front dopant concentration increases surface recombination. In contrast, front contact solar cells have one of the metal contacts on the front side and require a higher front dopant concentration because higher front dopant concentration reduces contact resistance and increases electrical conductivity between the front

doped region and the front metal contacts.[1] The increased electrical conductivity of the front doped region offsets the increased front surface recombination on balance. But in the context of back contact solar cells where there are no metal contacts requiring increased electrical conductivity and surface recombination is the main consideration, a lower front dopant concentration of $1x10^{18}$ cm^{-3} is thus preferred, as King and Swanson recommended decades ago.

79. King and Swanson also reported that although front surface dopant concentration cannot be measured directly on textured surfaces, decreasing the front surface dopant concentration also lowered J_0 or recombination for "textured sunward surface" as well:

> Since most high-efficiency silicon solar cells have a textured sunward surface, it is important to know what effect texturing has on the J_0. Fig. 3 shows measured values of J_0 for passivated emitters with a textured surface. $N_{D,\text{surf}}$ and x_j could not be measured directly on the textured samples by SIMS, because of the rugged topography of the surface. Instead, the values of $N_{D,\text{surf}}$ and x_j used in Fig. 3 are those measured on companion wafers that were processed identically, except that they were untextured. The value of J_0 for the textured emitters is typically higher than for the corresponding untextured emitter, but ***the same trends of***

[1] Solar cells in which the positive and negative metal contacts are on opposite sides of the solar cell (i.e., one on the front side and one on the back side) are also considered "front contact" solar cells, due to the location of one metal contact on the front, sun-facing side.

> ***lower J_0 with decreasing $N_{D,surf}$ and decreasing x_j persist in the textured case.***

EX1006, 366 (emphasis added).

80. Notably, one of the authors of the King and Swanson paper, Richard Swanson, is referred to by the Maxeon as "[t]he father of solar in the U.S." (EX1013, ¶2). In 1989, he received a patent describing, consistent with the King and Swanson publication, that for a "photovoltaic cell" with contacts on the back surface, the "***maximum*** surface dopant concentration" of the front diffused region "is 10^{18} atoms per cubic centimeter." EX1015, 4:38-51, 5:9-41, Figs. 3-10 (emphasis added). I will discuss this patent in more detail in ¶¶113-117 below.

81. Other studies have confirmed these findings. For example, a 1989 study by Marvin and Froedge of the Aerospace Corporation of back-contact solar cells for space use, concluded that optimal performance and efficiency should include a silicon substrate "with a graded front surface field with characteristic length approximately 15 μm and ***peak*** [dopant] concentration roughly 1E18 [1 x 10^{18}]" cm^{-3}. EX1007, 5, 21, 25; *see also* EX1035, 826-827. This report was also published with the IEEE concluding that in the design of the back-contact solar cell for space applications, the "FSF [i.e., front surface field] is graded over 15 μm with a peak doping concentration of 1E18 cm^{-3} [i.e., $1x10^{18}$ cm^{-3}]." EX1035, 827.

82. More recently, in September 2014, Muller et al. published the results of a study of back-contact solar cells with either an ion implanted boron doped or ion implanted phosphorous doped front region. EX1008, 269. In both cases, the peak dopant concentration was approximately 2×10^{18} cm^{-3} or less. EX1008, 269.

83. I will discuss each of King and Swanson ("King"), Swanson-352, Marvin and Froedge ("Marvin"), and Muller et al. ("Muller") in greater detail below.

3. Gettering of Metal Impurities in Silicon Substrates

84. Recombination is one of the the primary factors controlling solar cell performance. In solar cell manufacturing, the presence of other metallic impurities such as iron, nickel, or gold in silicon substrates have long been known to lead to recombination, in which energized electrons recombine with "holes," thus reducing the ability of the cell to generate electricity from those electrons. EX1018, 1; EX1016, 697.

85. It was well known before December 2014 to remove these metal impurities from the substrate by "gettering" them into another location of the device where they do not affect the device's performance. It was well known that "[g]ettering techniques eliminate or reduce contaminant impurities in a [silicon] wafer," as discussed, for example, by Luque in the Handbook of Photovoltaic Science and Engineering. EX1010, 262. Even before December 2014, those

skilled in the art have long recognized, as expressed in a review paper by Seibt et al. in 2006, that "the incorporation of gettering steps into the processing scheme is a ***prerequisite*** for the production of efficient solar cells." EX1016, 696 (emphasis added).

86. "[I]n a gettering process a sink region is formed, which is able to accommodate the lifetime-killing impurities in such a way that they are not harmful to the device being manufactured." EX1010, 262. Specifically, small lifetimes correspond to high rates of recombination. In this context, "lifetime" refers to the lifetime of the electrons or holes before they recombine together and lose their activated energy state. Known gettering methods before 2014 included moving the metal impurities from the substrate and into a back side polysilicon layer. For example, a 1977 IBM issued patent by Hu disclosed that during heating in the range of 1000 °C or less, "getterable impurities such as copper, lithium, sodium, potassium, iron, cobalt, nickel, chromium, and gold will diffuse to, and become trapped in, the polycrystalline silicon film impurity sink" formed on the back surface of the silicon substrate. EX1017,5:61-6:6.

87. In solar cell manufacturing, it was also standard industry practice before 2014 to use the dopant diffusion step for simultaneously gettering metal impurities because it was also well known that gettering would occur during the high temperature formation and doping of emitter regions. Numerous publications

before 2014 described the simultaneous diffusion of dopants and gettering in solar cell fabrication. For example, a 2011 publication by Ferre et al. titled "Simultaenous gettering and emitter formation in multicrystalline-Si wafers by annealing phosphorus doped amorphous silicon compounds," described in its background section:

> Multicrystalline silicon wafers are commonly used in the solar industry for the production of wafer-based solar cells. Metal impurities such as iron are present in the wafers due to the manufacturing process of the multicrystalline silicon mc-Si ingots and reduce the carrier bulk lifetime. ***These metal impurities are gettered during the formation of the emitter, conventionally done by diffusion at 800–900 °C in $POCl_3$ atmosphere to form an n_+-type emitter on a p-type substrate***.

EX1018, 1 (emphasis added).

88. Tobias et al. in Chapter 7 of the photovoltaic handbook by Luque in 2002 also described that "[i]n solar cell fabrication, we take advantage of the fact that phosphorus and aluminum diffusions, appropriate candidates for emitter and BSF layers, respectively, produce gettering." EX1010, 262. Likewise, Seibt et al, in a review paper in 2006 titled "Gettering in silicon photovoltaics: current state and future perspectives," also made the same point, saying: "[s]tandard processing schemes for silicon solar cells produced on p-type materials include furnace annealing steps for emitter diffusion and back-surface field formation which simultaneously serve as PDG [phosphorous diffusion gettering] and AlG [aluminum gettering] steps, respectively." EX1016, 707. U.S. Patent Publication

No. 2010/0105190 to Tomas (published in 2010) also described that "[t]o improve the properties of solar cells based on mc-Si, a so-called gettering of impurities, and thereby inactivation of impurities, may be performed, which typically includes a phosphorous diffusion at high temperatures. Phosphorous is able to retain, for instance, Fe and other metallic impurities in the emitter." EX1020, ¶0006.

89. Thus, by 2014, it was well known that "[b]ecause of economic reasons, the purity of the silicon feedstock used in photovoltaics is much lower than in integrated circuit industry [and t]herefore, high gettering efficiency … provided by the conventional diffused phosphorus emitter is a great benefit in solar cell processing," as expressed by Vahanissi et al. EX1019, 1.

90. Although "gettering processes are also used in monocrystalline [silicon] processing," "they are even more important to improve material quality" in multicrystalline silicon substrates, as Luque disclosed. EX1010, 283. Because of their lower quality, multicrystalline silicon substrates were known to contain substantial concentrations of metal impurities. For example, Buonassisi, in 2006 in a paper titled, "Transition metals in photovoltaic-grade ingot-cast multicrystalline silicon: Assessing the role of impurities in silicon nitride crucible lining material," recounted that "[r]ecent neutron activation analysis (NAA) studies revealed metal concentrations in ingot-cast multicrystalline silicon (mc-Si) materials as high as 10^{13}–10^{16} cm^{-3} (i.e., in the ppb to ppm range)." EX1021, 402. Luque also

described that "[multicrystalline]-material quality is poorer because … metallic impurities (dissolved or precipitated), giving lower bulk lifetimes and hence lower cell efficiencies." EX1010, 283. The US patent publication by Tomas also describes the same point that "[m]ulti-crystalline silicon wafers may contain a high density of recombination centers, for instance lattice defects, e.g., impurities, such as iron (Fe) or nickel (Ni). This results in undesirable recombination of charge carriers, thereby affecting the electrical properties of the solar cell." EX1020, ¶0006.

91. And the iron impurities in multicrystalline silicon substrates were known to be as high as 10^{14}-10^{16} cm^{-3} in concentration. EX1016, 696.

92. At and around 2014, it was well known that "[m]ulticrystalline silicon wafers [were most] commonly used in the solar industry for the production of wafer-based solar cells." EX1018, 1. For example, the National Renewable Energy Laboratory reported that as of 2013, for multicrystalline silicon wafers accounted for the vast majority (at least 65%) of silicon substrates used for solar panels worldwide. EX1022, 66.

V. LI COMBINED WITH KING OR SWANSON-352 OR MARVIN WOULD HAVE RENDERED CLAIMS 10-12, 15, 16, AND 19 OBVIOUS

93. In my opinion, the combination of Li in view of King, Swanson-352, or Marvin (each discussed below) would have rendered Claims 10-12, 15, 16, and 19 obvious.

94. I understand from counsel for CSI that Li (EX1005), King (EX1006), Swanson-352 (EX1015), and Marvin (EX1007 and EX1035) each qualifies as prior art, and I have been asked to assume them to be so.

A. Li (EX1005)

95. Li is U.S. Patent Publication 2011/0214719, entitled "Method of Fabricating a Back-Contact Solar Cell and Device Thereof." EX1005, Face. Li published on September 8, 2011, more than three years before the earliest effective filing date of the 315 Patent. *Id.* The Li patent names a common inventor as the 315 Patent, David Smith.

96. Like the claims of the 315 Patent and FIG 5 of the 315 Patent, Li disclosed a back-contact solar cell with a textured front side that faces the sun (bottom side in the figures below) and a back side (top side in the figures below) that is opposite the front side. FIG. 3 and FIG. 5E of Li disclosed the identical structure and device.

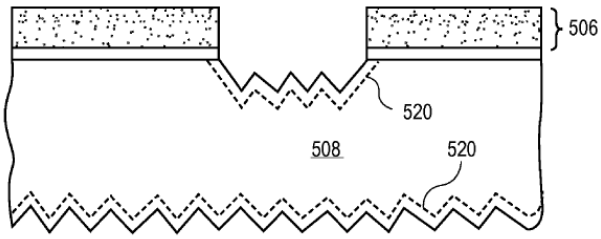


FIG. 5E

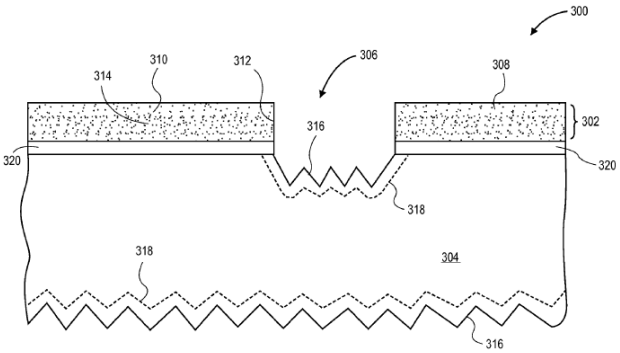


FIG. 3

97. The Skilled Artisan, reviewing Li, would understand that FIG 5E and FIG. 3 of Li disclosed the identical structure and device even though the numerical labels are different. The Skilled Artisan would understand that FIG. 5A-5E disclosed the different stages within the fabrication of the solar cell of FIG. 3, and the process steps in FIGS 5A-5E result in the same structure shown in FIG 5E and FIG. 3. EX1005, ¶¶0029, 0036-0049.

98. The Skilled Artisan would understand the textured surface indicates the front side of the cell that faces the sun as the texturing is intended to minimize incoming light reflection and improve solar cell efficiency. EX1010, 269.

99. For example, on the backside (which is the top side of the figures), both FIG 3 and FIG 5E of Li disclosed a "material layer" which is "poly-crystalline" identified as 302 in FIG. 3 and 506 in FIG. 5E. EX1005, ¶¶0037, 0042. The polycrystalline material layer 302/506 is formed on a dielectric film made of silicon dioxide identified as 320 in FIG 3 and 510 in FIGS. 5A-5B. EX1005, ¶¶0039, 0043. This material layer 302/506 is etched to form a trench identified as 306 in FIG. 3 and 516 in FIG. 5C, and separating the material layer into two regions. *Id*., ¶¶0038, 0047. The two regions are then doped with opposite dopants, forming an "N-type region 308" (right) and a "P-type region 310" (left) as shown in FIG. 3. Although FIG. 5E does not label these two doped regions with numerical identifiers, they are labeled as 512 and 514 in FIG. 5B and they are same two regions as 308 and 310 of FIG. 3 because Li disclosed that by heating, "N-type dopants and P-type dopants, respectively" are "transferred" into "portions 512 and 514, respectively of material layer 506, as depicted in FIG. 5B." EX1005, ¶0045.

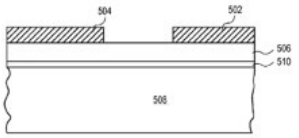


FIG. 5A

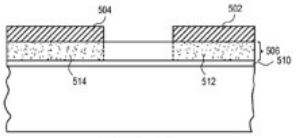


FIG. 5B

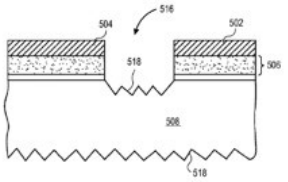


FIG. 5C

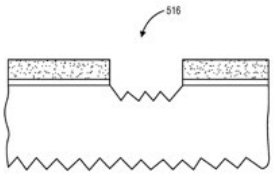


FIG. 5D

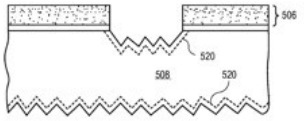


FIG. 5E

100. On the front side and in the trench of FIG. 3, a portion of the substrate with "N-type dopants 318" are identified "at or near surfaces of substrate 304 not covered by material layer 302." EX1005, ¶0038. In FIG. 5E, Li described that these same regions identified as 520 in FIG. 5E are identically doped with N-type dopants from a "gaseous N-type dopant source." EX1005, ¶0049.

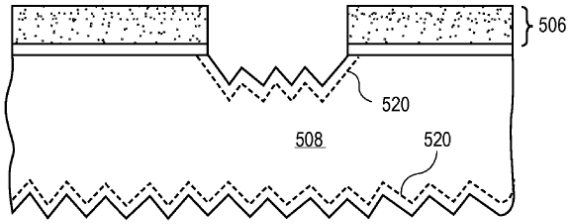


FIG. 5E

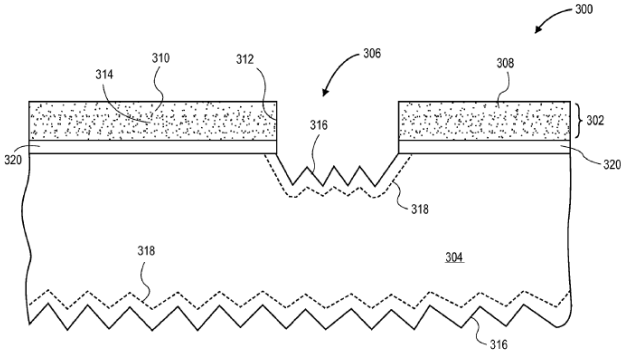


FIG. 3

101. Thus, FIG. 3 and 5E disclosed identical structures and later discussions in this declaration may refer to numerical elements in either FIG. 3 or FIGS. 5A-5E for the same elements.

102. As shown in the annotated version of Li Fig. 5E below, it is my opinion that the Skilled Artisan would also understand that the back-contact solar cell of Li (left) discloses substantially identical structure to the 315 Patent (right):

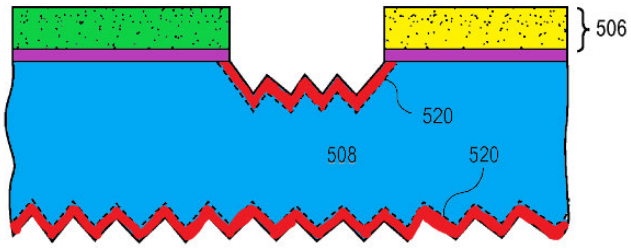


FIG. 5E

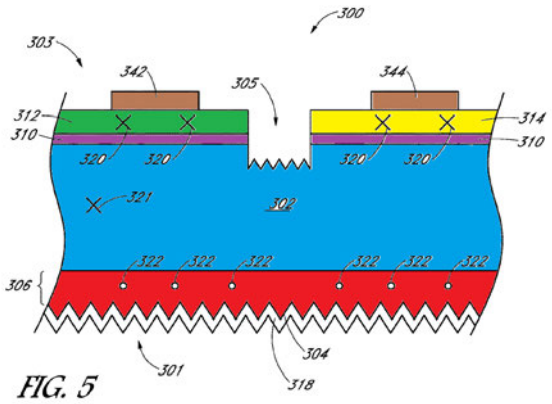


FIG. 5

103. Specifically, like the 315 Patent, the solar cell of Li comprises a silicon substrate 508 (blue). The substrate is described as a "single-crystalline silicon substrate" or, alternatively, "a multi-crystalline substrate is used in its place." EX1005, ¶0042; *id.* ¶0037 (same).

104. Next, at the front surface, Li described "doping, with the gaseous N-type dopant source, substrate 508 at or near surfaces of substrate 508 not covered by material layer 506, as depicted by the dopant regions 520 of Fig. 5E" (shown above in red). EX1005, ¶0049. Li likewise described with respect to FIG. 3 that "substrate 304 of back-contact solar cell 300 includes N-type dopants 318 at or near surfaces of substrate 304 not covered by material layer 302, as further depicted in Fig. 3." *Id.*, ¶0038.

105. This means that the front portion 520 shown in red would be doped with phosphorus because it is not covered by the material layer 506 of the back. As can be seen in Fig. 5E, the presence of N-type dopants specifically "at or near surfaces of the substrate" includes the front portion facing the sun, as indicated by

the numeral 520 on the textured (jagged) surface. The concentration of the dopant in this portion of the substrate is not specified by Li. At the same time, in the trench area 306 (Figure 3) on the backside, a portion of the substrate would also be doped with the phosphorus.

106. On the back-side, Li disclosed a "dielectric film 510" formed over the substrate backside surface. This "dielectric film 510" may be "composed of silicon dioxide and has a thickness approximately in the range of 1-2 nanometers" and may be "a tunnel oxide barrier layer film." EX1005, ¶0043. Although the layer 510 is not labeled in Fig. 5E, it corresponds to the purple layer noted above, as confirmed by Fig. 5B, which shows an earlier step in Li's fabrication process. This same dielectric film is labeled 320 in FIG. 3. EX1005, ¶0039.

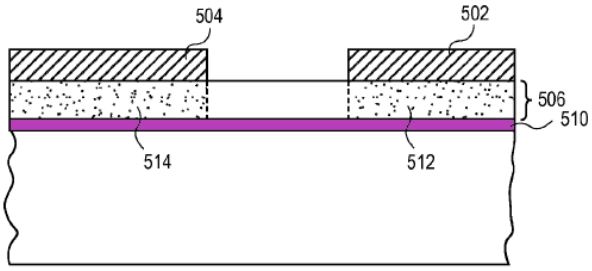


FIG. 5B

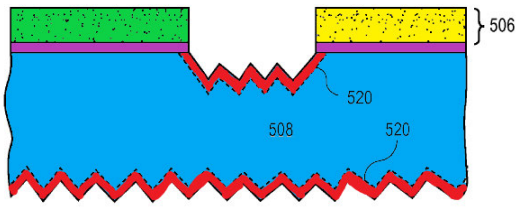


FIG. 5E

107. On the "dielectric film" is formed a "material layer 506" which may be "poly-crystalline silicon." EX1005, ¶0042; EX1005, ¶0037. "Poly-crystalline silicon" is another name in the art for "polysilicon." EX1042, 3 ("Polycrystalline silicon (polysilicon) comprises small grains of single-crystal silicon separated by thin grain boundaries.").

108. In the fabrication process, on the polysilicon layer 506 are applied two dopant source layers: an "N-type dopant source layer 502" and a "P-type dopant source layer 504." EX1005, ¶0044.

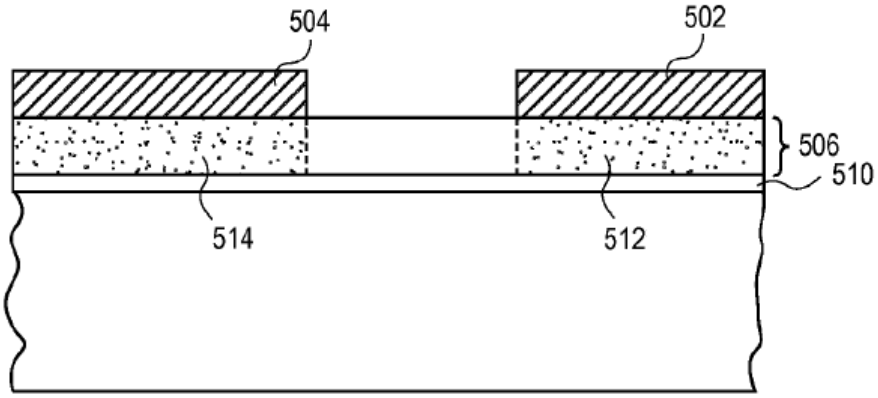


FIG. 5B

109. To diffuse dopants into the polysilicon layer 506, Li describes heating these dopant source layers "at a temperature of approximately 950 degrees Celsius." EX1005, ¶0045; EX1005, claim 9. By so doing, "N-type dopants and P-type dopants" are "transferred" "into portions 512 and 514, respectively, of material [polysilicon] layer 506, as depicted in Fig. 5B." EX1005, ¶0045. As shown in Fig. 3 (same as Fig. 5B), the "transferring" (i.e., diffusing) of the dopants into the polysilicon material layer forms an "N-type region 308 and a P-type region 310." EX1005, ¶0036. Li further describes that P-type dopants include "boron dopant impurity atoms" and N-type dopants include "phosphorous dopant impurity atoms." EX1005, ¶0037. The Skilled Artisan would have understood the heating of these dopant source layers to mean heating the entire structure, which is done in

a furnace. EX1010, 273.[2] Indeed, in another embodiment, Li described the same heating step to diffuse dopants from dopant source layers into the polysilicon material layer and described it as "the structure of FIG. 2C is heated or annealed to diffuse, from layers 202 and 204, dopants into material layer 206 to provide an N-type doped material region 226 and a P-type doped material region 228." EX1005, ¶0033.

110. Finally, Li described that in solar cells, it was well known that "[t]he doped regions are connected to metal contacts on the solar cell to direct an electrical current from the cell to an external circuit coupled thereto." EX1005, ¶0004. Although Li does not depict the metal contacts in its figures, the Skilled Artisan would have understood from Li's description that "doped regions are connected to metal contacts on solar cells" that Li's "back-contact solar cell" would also necessarily include metal contacts on the back surface over the N-doped and P-doped regions 502 and 504 to direct an electrical current from the cell to an external circuit. Without the addition of metal contacts on the back surface, a

[2] The 2002 Luque Handbook of Photovoltaics, Chapter 7, disclosed that "[s]olid dopant sources are also compatible with furnace processing. Five to fifteen minutes at temperatures in the range from 900 to 950°C can be considered representative." EX1010, 273.

"back-contact solar cell" cannot extract the electrons for use to power an external circuit. Having metal contacts contacting the doped N and P poly-crystalline regions of a back-contact solar cell was well known and the standard practice for back contact solar cells, as I discussed in ¶¶72-75. Indeed, by Li's repeated reference to its solar cell as "***back-contact*** solar cell," the Skilled Artisan would have understood Li's solar cell to necessarily have all its metal contacts on the back because that was the definition of a back-contact solar cell, as understood in the art.

B. King (EX1006)

111. King is entitled "Studies of Diffused Phosphorous Emitters: Saturation Current, Surface Recombination Velocity, and Quantum Efficiency." EX1006, 365. King was published in February 1990. The other author of King was Richard Swanson.

112. King "report[ed] experimental measurements of the emitter saturation current density for a variety of emitters, with differing surface concentration and junction depth." EX1006, 365. King observed that in solar cells, "[o]ne of the most important parameters for predicting J_0 [saturation current density] and the quantum efficiency of a passivated emitter is the surface recombination velocity s as a function of **surface dopant concentration** $N_{surf.}$" EX1006, 365 (emphasis added). In its "Discussion" section, King concluded that the optimum front surface

dopant concentration for textured and untextured front surfaces would be 1 x 10^{18} cm^{-3}:

> In the case of a back-contacted cell in which the sunside diffusion is used mainly to reduce surface recombination, not to collect current, the **optimum emitter** is the one with the **lowest J_0**. For untextured surfaces, this corresponds an **emitter with $N_{D,\,surf} \approx$ 1 x 10^{18} cm^{-3} that is as thin as possible**. Fig. 3 shows an emitter with these specification is probably near optimum in J_0 when it has a **textured front surface, as well**.

EX1006, 369 (emphases added). Because the front surface dopant concentration for the textured sunward surface could not be measured directly by SIMS because of the rugged topography, King measured "companion wafers that were processed identically, except that they were untextured" to provide the data presented in Figure 3. EX1006, 366. Based on the data, King concluded that the same trends seen in untextured surface "persist in the textured case"; the trend being that decreasing front surface dopant concentration lowers J_0, which translates into higher solar cell eficiency. *Id*., 366. This trend can also be seen in Figure 6 that shows the lowest J_0 when the front surface dopant concentration is approximately 1 x 10^{18} cm^{-3}. Thus, the Skilled Artisan would have understood that for both untextured and textured front surfaces, King recommended that the front surface dopant concentration should be **1 x 10^{18} cm^{-3}.** King contrasted this conclusion with the concentration "of the emitter on the sunward surface of a conventional [i.e., front-contact] solar cell," in which surface dopant concentrations at or above 2 x

10^{19} cm^{-3} were preferred. *Id*., 369. Conventional non-back contact solar cells would have metal contacts on the back and front, which would require a higher dopant concentration on the front in order to reduce the contact resistivity and increase conductivity for the collection of electric current, as I discussed in ¶78 above. Therefore, King taught that the optimal front dopant concentration for a front-facing doped region of a back-contact solar cell was approximately 1 x 10^{18} cm^{-3}.

C. Swanson-352 (EX1015)

113. Swanson-352 is U.S. Patent 4,234,352, entitled "Thermophotovoltaic Converter and Cell for Use Therein." EX1015, Face. It issued on November 18, 1980, decades before 2014. *Id.* Richard M. Swanson is the inventor who was also an author of the King publication discussed above. *Id.*

114. Swanson-352 pertains to "improved photovoltaic cell[s]," which is another name for solar cells. EX1015,1:5-17, 2:5-6. Specifically, Swanson-352 also described a back-contact solar cell, with electrical contacts 68 and 72 formed only on the back surface over and contacting the P-type and N-type doped regions 53 and 55, respectively. *See* FIGS. 6 and 10 to the right. EX1015, 5:5-41. Figures 5 through 10 show the fabrication steps of the solar cell and are "bottom side up for illustration purposes." EX1015,4:38-51.

FIG_5

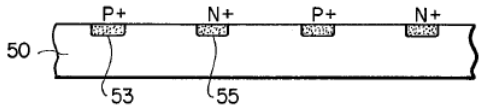


FIG_6

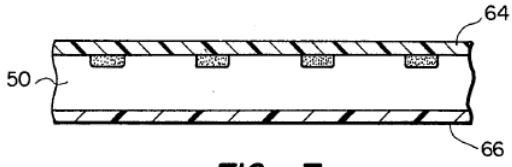


FIG_7

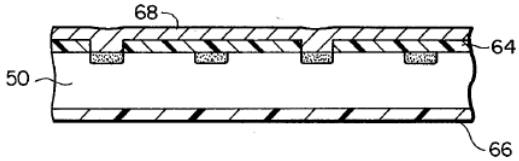


FIG_8

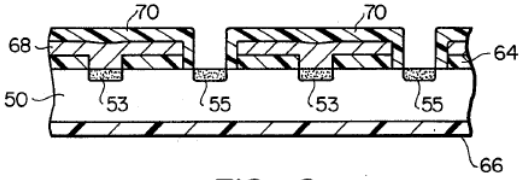


FIG_9

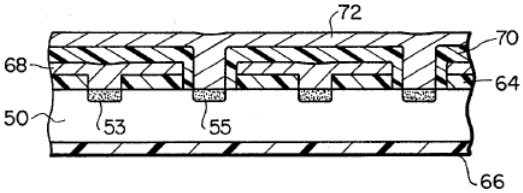


FIG_10

115. The fabrication process in Swanson-352 starts with Fig. 5, which depicts "an intrinsic or lightly doped N-type silicon substrate 50." EX1015,4:42-43. This lightly doped N-type substrate "[p]referably" is doped at "10^{14} dopant atoms per cubic centimeter or less." EX1015,4:43-51. Swanson-352 further described that a "shallow diffused region" 62 in the front portion of the substrate is formed by "diffusion of an N type dopant such as phosphorous into the surfaces to a depth of 0.1 micron." EX1015, 4:45-49. Swanson-352 disclosed that "[t]he

maximum surface dopant concentration of the diffused regions 60 and **62 is 10^{18} atoms per cubic centimeter**." EX1015,4:43-51 (emphasis added). Diffused region 62 is on the front side of the solar cell. EX1015, 4:38-51. A silicon oxide layer 66 is also formed on the front side on top of the diffused region. *Id*. 4:60.

116. Diffused region 60 is on the backside and is further doped in later steps to become p+ and n+ regions having dopant concentration of 10^{20}- 10^{21} atoms/cubic centimeter, as shown in FIG. 6. EX1015, 4:52-57. Connected to these backside p+ and n+ regions are metal contacts 68 and 72 (made of silver or titanium) to electrically contact the doped regions. EX1015, 5:5-41.

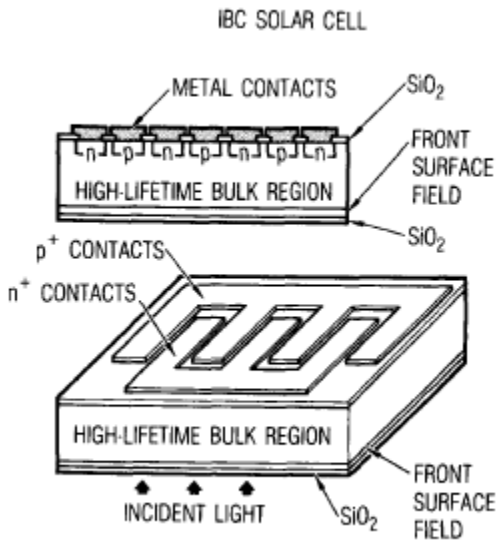
117. Finally, Swanson-352 explains that the "photovoltaic cell substrate processed in accordance with the present invention provides a high minority carrier lifetime," which the Skilled Artisan would understand leads to a higher efficiency solar cell. EX1015,5:42-44.

D. Marvin (EX1007 and EX1035)

118. Marvin is entitled "Analysis of Interdigitated Back Contact Solar Cells for Space Use." EX1035, 821. It was published in 1989 by IEEE, which is before 2014. EX1035, 821.

119. Like Li, Marvin disclosed a back contact solar cell (IBC) with a silicon substrate having a doped portion on the front side, referred to as "FSF" or "front surface field." On the back side, there were both P-type and N-type doped

regions with separate, oppositely-charged "metal contacts" formed over the backside oppositely-doped regions, as shown in the figures reproduced below:



EX1035, 822, Fig. 1.

120. The same authors as Marvin also authored a government report entitled "Interdigitated Back Contact Silicon Solar Cell Analysis and Design Recommendations for Space Use." EX1007, Cover. The report was submitted by Aerospace Corporation, dated September 30, 1989, and was approved for public release, and published on April 11, 1990. *Id.* The government report appears to discuss the same study as Marvin and reported substantially the same conclusions. The government report is entitled "Interdigitated Back Contact Silicon Solar Cell Analysis and Design Recommendations for Space Use." EX1007, Cover.

121. Marvin is a study whose purpose was "to evaluate the IBC cell design for use in space missions." EX1035, 822. Reasoning that the "primary incentive"

for use of back-contact solar cells is "increased efficiency," Marvin studied "optimum design[s]" for "concentrated light." EX1035, 822, 826. Among other characteristics, Marvin simulated different cell thicknesses and FSF doping concentrations, and calculated "End of Life" (EOL) efficiencies. EX1035, 822-823.

122. Specific "consideration was given to optimization of the front surface field region" of the back-contact solar cell. EX1035, 826. With respect to this issue, "[i]t was found that by replacing [front surface field uniformly doped at 5E18] with a Gaussian doping profile with a characteristic width of 15 [micrometers] and a peak concentration of 1E17, the EOL efficiency was 12.3%." EX1035, 826. With thinner silicon wafers, the efficiency increased more. EX1035, 826.

123. Based on these findings, Marvin concluded that, especially for high radiation space environments, the FSF should be "graded over 15 [micrometers] with a peak doping concentration of 1E18 cm^{-3}," which, at high radiation, yields "EOL efficiency [that] approaches 16%." EX1035, 827.

E. Motivation to Combine Li with King or Swanson-352 or Marvin

124. In my opinion, it would have been obvious to the Skilled Artisan to combine the back-contact solar cell of Li with the dopant concentrations specified

in King, Swanson-352, or Marvin to arrive at claims 10-12, and 15 of the 315 Patent.

125. Li disclosed a back-contact solar cell in which the front portion of the silicon substrate should include a doped region on the front side of the solar cell, which is not covered by the material layer 506/302. EX1005, ¶49, FIG. 3 (318) and 5E (520). Although Li did not specify the precise concentration of dopants to be used for this front-doped region, the optimal concentration for this front-doped region was well known in the art and would have been obvious in view of the teachings of King, Swanson-352, or Marvin.

126. Li, King, Swanson-352, and Marvin are analogous art, and they all relate to solar cell design and in particular, ***back-contact*** solar cells. The Skilled Artisan would have been motivated to combine Li's back contact solar cell with the front doping concentration of $1x10^{18}$ cm^{-3} or less as disclosed in King, Swanson-352, or Marvin. All three disclosed this dopant concentration. King taught that this concentration was the "optimum" for back-contact solar cells, and Swanson-352 taught to use it as the maximum concentration for such solar cells.

127. Marvin likewise taught that for space applications, a "peak doping concentration of 1E18 [1×10^{18}] cm^{-3}" or lower with a "Gaussian doping profile with a characteristic width of 15 [micrometers]" resulted in better efficiency metrics than higher doping concentrations. EX1035, 826-827. The government

report version of Marvin's study also confirmed this, thus bolstering the motivation to rely on Marvin's FSF doping concentration. For example, for cells of the same thickness, Marvin reported that EOL efficiency as a function of cell thickness was consistently worse at higher FSF doping concentrations, including when comparing cells with thickness of 65 and 80 microns at concentrations of 1 x 10^{18} cm^{-3} and 5 x 10^{18} cm^{-3} (*see* Table 8 of Marvin, EX1007, annotated below):

Table 8. EOL Efficiency as a Function of cell Thickness and FSF at 100 Suns

Cell Thickness (μm)	Graded FSF (μm)	Step FSF (μm)	FSF Doping cm^{-3}	*Spacing a/b/c	Cell Efficiency (%)
50	15	—	1E18	10/20/10	14.64
50	15	—	1E18	5/10/5	15.44
65	15	—	1E18	5/10/5	11.57
80	15	—	1E18	5/10/5	8.97
200	15	—	5E18	5/10/5	1.18
65	—	0.5	5E18	5/10/5	8.17
80	—	0.5	5E18	5/10/5	6.83

*a,c = spaces between right and left edges of collectors and unit cell boundaries, resp.; b = space between collectors. All dimensions are in micrometers.

EX1007, Table 8. Based on this data, the report concluded that "to maximize the EOL performance," the "FSF is graded over 15 [microns] with a peak doping concentration of 1E17 to 1E18 cm^{-3}." EX1007, 25.

128. Given Li's acknowledgement that "[e]fficiency is an important characteristic of a solar cell as it is directly related to the solar cell's capability to generate power" and that "[a]ccordingly, techniques for increasing the efficiency

of solar cells are generally desirable" (EX1005, ¶0005), the Skilled Artisan reviewing Li would further have been motivated to select the front doping concentration disclosed by any of King, Swanson-352, or Marvin.

129. I understand that Maxeon has alleged that Dr. Richard Swanson, one of the authors of King, is often referred to as "[t]he father of solar in the U.S." EX1013, ¶2. In that situation, it would only be natural for the Skilled Artisan to look to Dr. Swanson's patents and publications (including King and Swanson-352) regarding the "optimum"/"maximum" doping concentrations for the front surface (including a "textured front surface") of back-contact solar cells to determine the concentration of dopant to be used at the textured front surface of the back-contact solar cell disclosed in Li (EX1005, ¶0049, FIG. 5E). EX1006, 369; EX1015,5:42-44.

130. It is my opinion that Marvin's focus on high radiation environments, such as space, would not have deterred the Skilled Artisan from combining with Li at least because Li does not limit its back-contact solar cell to low radiation or terrestrial environments. Li stressed the importance of increased efficiency in solar cell design (EX1005, ¶0005), and increased efficiency of the solar cell is no less important in space environments than in terrestrial environments. And Marvin described the high efficiency that can be achieved with its disclosed FSF doping concentration in space applications. *E.g.*, EX1035, 826-827.

F. Reasonable Expectation of Success

131. The Skilled Artisan would have considered the combination of Li with King, Swanson-352, or Marvin to be merely an arrangement of old elements with each performing the same function it had been known to perform (the back contact solar cell of Li continuing to be a back contact solar cell, but implemented with the recommended front dopant concentration of King, Swanson-352, or Marvin) and yielding no more than what one would expect from such an arrangement (a solar cell with lower surface recombination and improved performance). Combining the back-contact solar cell of Li with the front doping concentration taught by King or Swanson-352, or Marvin for back-contact solar cells would have been straightforward and done with a reasonable expectation of success by the Skilled Artisan. It is nothing more than using the same technique disclosed by Li to diffuse the front dopants to a certain concentration as taught by King, Swanson-352, or Marvin. Specifically, Li described using an N-type dopant for the front portion of the substrate. EX1005, ¶0049.

132. The Skilled Artisan would have recognized that King and Swanson-352's teaching to dope the front surface with phosphorous (the same N-type dopant disclosed in Li) to a surface concentration of 1 x 10^{18} cm^{-3} (EX1006, 369; EX1015, 4:43-51) could be readily implemented using Li's disclosed process of heating the substrate in the presence of a gaseous N-type dopant (phosphorous). Doping a

silicon surface to a particular surface doping concentration would have been within the level of skill of the Skilled Artisan. EX1041. Doping a silicon surface at a certain concentration is a routine part of optimizing the diffusion process, and is a matter of simply altering certain parameters such as flow rates, time, and temperature. EX1041, 2242. The Skilled Artisan can also confirm whether they have doped to the desired concentration, as the dopant concentration of a silicon surface is measurable. EX1041, 2242. Thus, combining Li with King, Swanson-352, or Marvin, 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.

133. Although Marvin appears to have used a "p+" FSF on a P-type substrate (EX1035, 823; EX1007, 15, 26), it would have been obvious to the Skilled Artisan that the *concentration* taught by Marvin is equally applicable to an N-type front doped region on an N-type substrate, as seen from the teachings of King and Swanson-352. As Dr. Green disclosed even in 1990, the effective densities of states in the conduction and valence bands in silicon are comparable. Hence, there will be comparable bandbending and generation of a FSF (which is given by the gradient of the bandbending) for P- and N-type doping. EX1043 at 2946-47.

134. Finally, combining Li with the front-side doping concentration of King or Swanson-352, or Marvin would not have changed Li's inherent disclosure of gettering metal impurities from the silicon substrate to the emitter region. As I discussed further below in ¶¶155-172, the natural result of Li's process of doping the emitter region at 950°C would be to getter metal impurities from the silicon substrate, through the 1-2 nm thick silicon oxide dielectric layer, and into the N-doped and P-doped regions of the polysilicon layer. The combination would simply have been the combination of prior art elements according to known methods to yield predictable results.

G. The Combination of Li and King or Swanson-352 or Marvin Disclosed All Elements of Claims 10-12, 15, 16, and 19

1. Claim 10

i. *Preamble*

135. Claim 10 recites: *"A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising."*

136. Li disclosed the preamble. Specifically, Li disclosed a "back-contact solar cell." EX1005, Title, Abstract, ¶0041. The Skilled Artisan would have recognized that a "back-contact solar cell," as is depicted, for example, in Li Figure 5E, has a front side facing the sun during normal operation (shown at the

bottom) and a back side opposite the front side that contains the N-doped and P-doped regions of the polysilicon layer (506), as shown below:

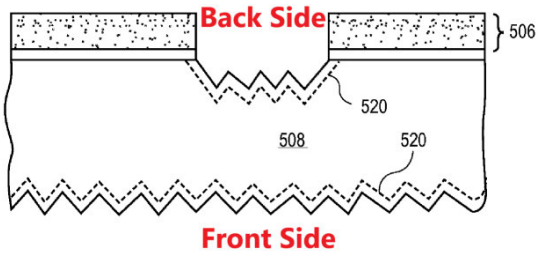


FIG. 5E

The Skilled Artisan would have further recognized that the jagged/textured side in FIG. 5E is the front side because solar cells are often textured on the front side to reduce the reflection of incident light. Texturing the front surface was well-known and taught by, for example, in Chapter 7 of the 2002 Luque 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.

EX1010, 269 (emphasis added).

ii. *Front portion of substrate and its doping concentration*

137. Claim 10 requires *"a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3} and wherein the portion of the silicon substrate is formed at the front side of the solar cell."*

138. Li disclosed "*a silicon substrate*," (EX1005, ¶¶0037, 0041) identified with numeral 508 (blue) in FIG. 5E shown below.

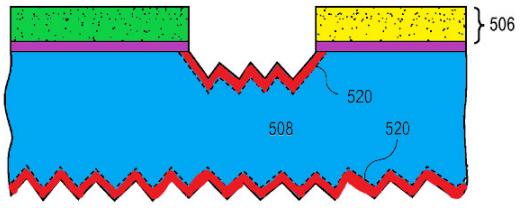


FIG. 5E

139. Li also disclosed that a front "*portion of the silicon substrate*" is doped with phosphorus, as identified in red with numeral 520 on the bottom side of the FIG. 5E. EX1005, ¶0038, 0049. This doped front "portion of the silicon substrate" would naturally have a certain "*dopant concentration*" when doped. Further, because the phosphorus dopant in Li is diffused into the substrate, rather than deposited, the doped front portion would be part of, i.e., "*a portion*" of the substrate.

140. While Li does not specify the dopant concentration of the front portion of the substrate, it would have been obvious to the Skilled Artisan to use a concentration "*approximately less than or equal to* 2×10^{18} *cm*$^{-3}$." As I discussed above in ¶¶77-79, 111-112, decades before the 315 Patent, King studied this very question, and taught that, for back-contact solar cells with front textured surfaces (such as Li), the front surface dopant concentration should be approximately 1×10^{18} cm^{-3}. EX1006, 369. Likewise, Swanson-352 (from the same author as King) taught that the "maximum surface dopant concentration" of the silicon substrate should be 1×10^{18} cm^{-3} for a depth of 0.1 micron, and that the remainder of the substrate is "[p]referrably" doped at 1×10^{14} cm^{-3} or less. EX1015, 4:48-51. 0.1 micron is 100 nanometers.

141. The Skilled Artisan would have understood that when the front surface dopant concentration is at 1×10^{18} cm^{-3}, as taught by King and Swanson-

352, the concentration in the rest of the doped front portion in Li would be below 1×10^{18} cm^{-3}. Specifically, when gaseous phosphorus dopant (as used by Li) is diffused into silicon, the concentration is highest at the surface of the silicon and decreases as a function of the depth of diffusion, as seen for example in the figure below.

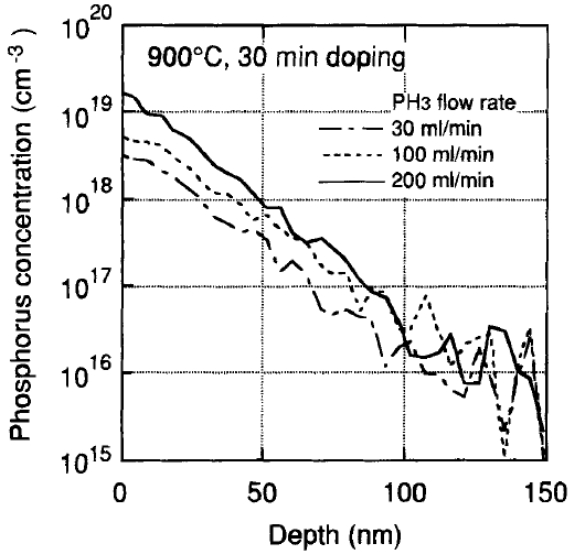


Fig. 1. SIMS profiles of phosphorus. Doping was carried out at 900°C for 30 min. PH_3 flow rate was varied from 30 to 200 ml/min.

The above figure is reproduced from Kiyota, a 1994 publication, showing the diffusion profiles for PH_3, a gaseous phosphorus dopant, at 900°C for 30 min at various flow rates. EX1041, Figure 1. The surface phosphorus concentration is highest at the surface (0 nm depth) and decreases as the depth of diffusion increases into the solid substrate. Generally, the slower the flow rate, the lower the surface phosphorus concentration. Swanson-352 taught a depth of 0.1 micron or 100 nm for the doped front portion, which is about the depth of the gaseous

phosphorus diffusion shown in Kiyota for gaseous phosphorus dopant. *Id*. EX1041 at 2242. Kiyota specifically reported that based on doping time of 30 minutes, "[s]hallow phosphorus-doped layers were formed about 100 nm deep." *Id*. To increase the depth of diffusion, Kiyota also reported that increasing the time can increase the depth of diffusion without increasing the surface concentration, as shown below.

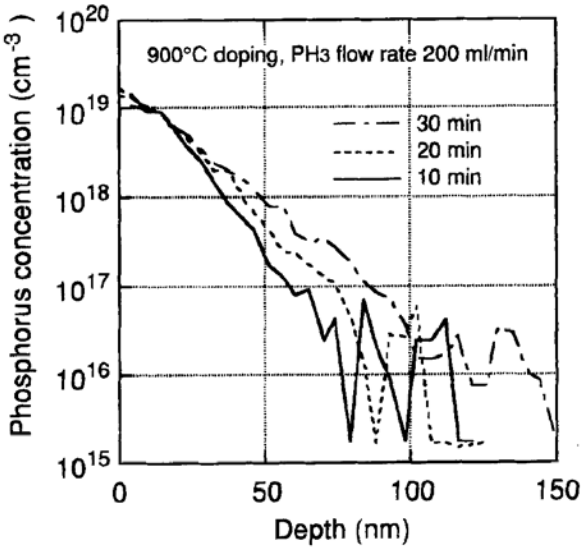


Fig. 4. SIMS profiles of phosphorus. Doping was carried out at 900°C, PH_3 flow rate of 200 ml/min. The doping time was varied from 10 to 30 min.

142. Marvin also expressly disclosed that, for a back contact solar cell to be used in space applications, the front portion of the substrate should be doped at a "peak doping concentration" of approximately 1×10^{17} to 1×10^{18} cm^{-3} with dopant distributed according to a Gaussian distribution. EX1007, 25-26. "It was found that by replacing this with a Gaussian doping profile with a characteristic width of 15 [micrometers] and a peak concentration of 1E17 [cm^{-3}], the EOL efficiency was

12.3%.... The FSF is graded over 15 [micrometers] with a peak doping concentration of 1E18 cm^{-3}." EX1035, 826-27. Because 1×10^{18} cm^{-3} is the "peak," the dopant concentration within the front doped portion of the substrate, as taught by Marvin, would not exceed 1×10^{18} cm^{-3} as well.

143. Thus, in my opinion, the combination of Li with King, Swanson-352, or Marvin would have disclosed and rendered obvious the claimed front portion dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3}.

iii. *Backside dielectric region*

144. Claim 10 requires *"a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of the solar cell."* Li disclosed this element. The back-contact solar cell described in Li Fig. 3 or 5E includes, on the back side of the solar cell, a "dielectric film 510" formed above the silicon substrate (508), which may be "composed of silicon dioxide and has a thickness approximately in the range of 1-2 nanometers" and may be "a tunnel oxide barrier layer film." EX1005, ¶0043. Although the layer 510 is not labeled in Fig. 5E, it corresponds to the purple layer noted below, as confirmed by Fig. 5B, which shows an earlier step in Li's fabrication process, as I discussed in ¶¶99, 106. This same "dielectric film" is depicted as 320 in FIG. 3. EX1005, ¶0039.

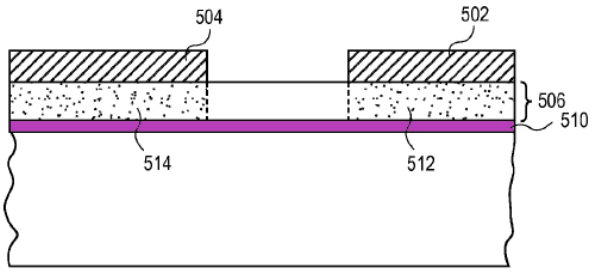


FIG. 5B

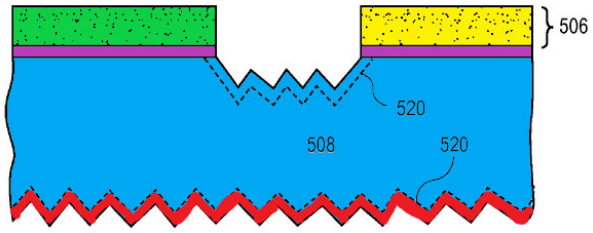


FIG. 5E

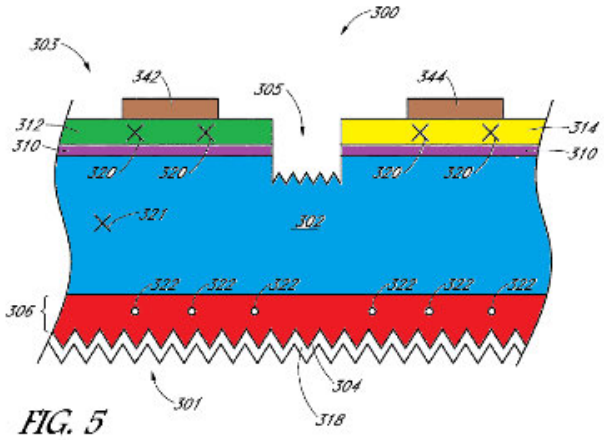
145. "Silicon dioxide" is a dielectric material, and Li's silicon dioxide dielectric film (510 in FIG. 5B or 320 FIG. 3) is the same material used by the 315 Patent for its dielectric region. EX1001, 4:47-48.

iv. *Emitter region*

146. Claim 10 requires *"a first emitter region having metal impurities formed over the dielectric region."* Li disclosed this element.

147. In the solar cell art, "emitter" usually refers to the doped region that has an opposite dopant polarity as the substrate, while "surface field" (either back or front) refers to the doped region that has the same dopant polarity as the substrate. EX1008, 269 (Figure 3(a)).

148. In the specific context of the 315 Patent, the 315 Patent refers to the "P-type and N-type doped polysilicon regions" formed over the dielectric region 310 (purple) in FIG. 5 as "the first and second emitter regions 312, 314" (green and yellow). EX1001,6:55-57.



149. Based on this usage in the 315 Patent, Li also disclosed a "*first emitter region … formed over the dielectric region*." Just like the 315 Patent, Li described that the same structures of a polysilicon "material layer" (506 in Fig. 5E or 302 in Fig. 3) made up of an "N-type region 308 [yellow circle] and a P-type region 310 [green circle]" formed over dielectric region 320 (purple circle below). EX1005, ¶¶0036-37. Li's polysilicon "P-type region 310" and "N-type region 308" (in Fig. 3) are the same structure, arrangement, and doping as the "P-type and N-type doped polysilicon regions" in FIG. 5 and thus, would satisfy the "the first and second emitter regions" of the 315 Patent claims.

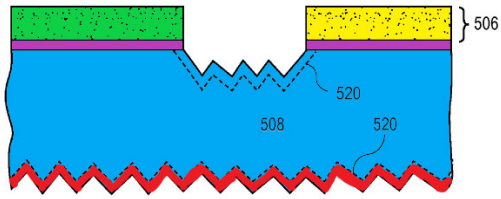


FIG. 5E

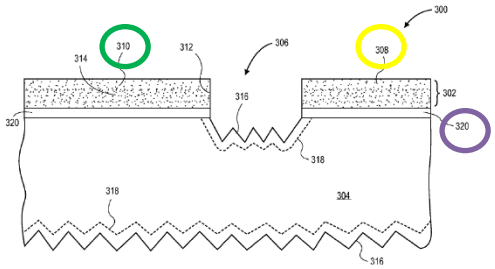


FIG. 3

150. Specifically, the "P-type and N-type doped polysilicon regions" in FIG. 5 of the 315 Patent are formed on a silicon dioxide dielectric layer 310, which is formed on a silicon substrate 302. EX1001, 6:50-62. The P-type and N-type polysilicon regions are described as the "first and second emitter regions, 312, 314." EX1001, 6:55-57.

151. This is the same arrangement as Li. The Li's polysilicon "P-type region 310" and "N-type region 308" are likewise formed on a silicon dioxide dielectric layer 320, which is formed on the silicon substrate 304. These doped polysilicon regions are the same as the "emitter" regions described and claimed by the 315 Patent.

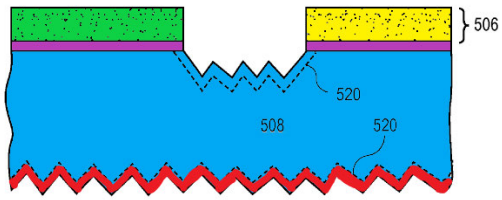


FIG. 5E

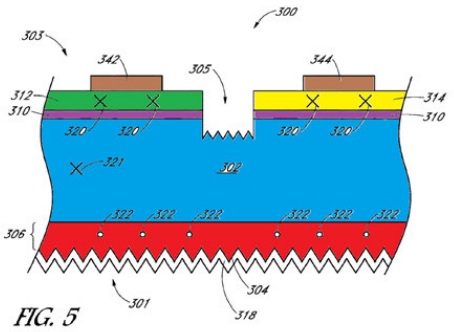


FIG. 5

152. At one point, the 315 Patent also says that "[i]n an embodiment, the silicon substrate can be an N-type silicon substrate." EX1001, 5:45-46. To the extent it is argued that an N-type substrate is required, the Skilled Artisan would have understood that Li's silicon substrate is N-type even though Li does not explicitly disclose the dopant type of its substrate. This is because Li disclosed to diffuse the front portion of the substrate with an N-type dopant (EX1005, ¶49) just

as Swanson-352, Neuhaus, and Swanson-485 taught to diffuse the front portion with N-type dopant (EX1015, 4:45-49; EX1012, 5:38-47; EX1011, 11 (Figure 8)). The purpose of the diffusing the front portion of a back contact solar cell (such as in Li, Swanson-352, Neuhaus, or Swanson-485) with the N-type dopant would be to create a front surface field to reduce surface recombination. Front surface fields have the same dopant type as the substrate but at a higher dopant concentration than the substrate. EX1008; EX1011, 11 (Figure 8).

153. Thus, because the 315 Patent calls the same polysilicon "P-type region" and "N-type region" as "emitter regions," Li disclosed *a first emitter region formed over the dielectric region,* as claimed, by disclosing the same structures.

154. To the extent that it is argued the Li's substrate is not n-type, this does not change my opinion because it would have been obvious to the Skilled Artisan that Li's substrate can likewise be an n-type substrate, as taught by Swanson-352, Luque, Neuhaus, and Swanson-485 that I discussed in ¶¶73-75, 114-117, 152. For example, Swanson-352 taught that the substrate "lightly doped N-type silicon substrate 50" and the front portion 62 is further diffused with an N-type dopant at a maximum dopant concentration of $1x10^{18}$ cm^{-3}. EX1015, 4:42-43. Neuhaus also taught that a back contact solar cell with an N-type substrate doped with an N-type front portion or front surface field. EX1011 (Figure 8). Swanson-485 similarly

used an "***n-type*** FZ or ***n-type*** CZ silicon wafer 102" for its substrate and diffuses the front side with n-type dopants. EX1012, 3:23-24; 5:38-49 (emphasis added). And given Li's teaching to dope the front portion of the substrate with an n-type dopant, and Swanson-352, Neuhaus, and Swanson-485's teaching that the front n-type dopant is diffused into an n-type substrate, the Skilled Artisan would have been motivated to use an n-type substrate for Li's solar cell to create a front surface field and thereby reduce surface recombination on the front side.

v. *Emitter region with metal impurities*

155. Claim 10 further requires the "*first emitter region*" to have "*metal impurities*." Li also disclosed this element.

156. As an initial matter, the 315 Patent specification describes that heating the solar cell above 900°C can getter metal impurities into the emitter region and, at the same time, perform diffusion of the dopant. EX1001, 5:21-31. The 315 Patent notes that heating at or below 900°C "can be insufficient to diffuse metal impurities through a tunnel oxide and into a polysilicon region." EX1001, 5:15-20.

157. In Li, dopant diffusion is also conducted above 900°C and more specifically at 950°C. EX1005, ¶0045. While Li does not explicitly state that its polysilicon "emitter region" "*ha[s] metal impurities*," the Skilled Artisan would have understood that this limitation is inherently disclosed because the doping method disclosed in Li (of heating above 900°C) would necessarily and inevitably

result in metal impurities being present due to gettering of metal impurities from the silicon substrate and into the polysilicon doped regions of the polysilicon material layer 506, in the same way as described in the 315 Patent.

158. I understand from counsel that inherency can be applied during an obviousness analysis. Evidence both before and after December 2014 demonstrates that Li's backside polysilicon doped regions would inherently include metal impurities. Harmful impurities such as metals are generally interstitials which diffuse much faster than substitutional dopants. Diffusivities are especially high through grain boundaries in multi-crystalline silicon. The diffusion coefficients have a strong Arrhenius dependence on temperature. Based on these factors, I expect such inherency of metal impurities to be present in the polysilicon regions of Li. This is bolstered further by the following cited prior art and publications.

159. First, Li disclosed that either a single crystalline or multicrystalline silicon substrate may be used. EX1005, ¶0037, ¶0042. Particularly in the case of multi-crystalline silicon substrates (which are contemplated by both Li and the '315 Patent (EX1001, 3:35-36), and which accounted for the majority of substrates used in the solar cell industry in 2013-2014 (EX1022, 66)), the Skilled Artisan would have immediately recognized that substantial metal impurities were known to exist in all such substrates, as I discussed in ¶¶90-92 above.

160. Second, combining gettering and dopant diffusion into a single step of heating was the standard practice and well known in the solar cell industry, as I discussed in ¶¶87-89 above.

161. Third, publications both before and after December 2014 have shown that metallic impurities are transferred from silicon substrates into polysilicon layers, including through thin silicon oxide layers, is achieved when the solar cell is heated at Li's processing temperature of 950°C.

162. For example, in 1977, an IBM patent by Hu explained that heating a "semiconductor "body" with a deposited backside "polycrystalline layer" at temperatures 1000°C or less, result in "getterable impurities such as copper, lithium, sodium, potassium, iron, cobalt, nickel, chromium, and gold [diffusing] to, and becom[ing] trapped in, the polycrystalline silicon film." EX1017, 5:61-6:6. In particular, the Hu patent described "gettering with a backside layer of polycrystalline silicon" to remove "unwanted impurities" from the semiconductor. *Id.* at Abstract. Hu described "deposition of a polycrystalline silicon film on a semiconductor wafer prior to any or some high temperature processing steps," after which "[t]he semiconductor body is then subjected to the normal semiconductor processing steps to form semiconductor devices on the surface opposite to the surface having the polycrystalline silicon layer." *Id.* Hu explained that "[d]uring these high temperature processing steps, unwanted impurities such as copper, iron,

nickel, sodium and potassium ions move toward and into the polycrystalline silicon layer and thereby away from the semiconductor devices." *Id.* Thus, Hu confirmed that during the heating steps of Li, metal impurities in the silicon substrate would have naturally and inevitably gettered to the backside polysilicon "material layer" of Li that comprises the N-doped and P-doped regions.

163. Another publication by Ramappa et al. in 1999 confirmed that the natural gettering effect would have occurred despite the presence of Li's 1-2 nm silicon dioxide dielectric layer. EX1025, 3374. Ramappa observed that metal impurities such as iron "exhibit[] very high diffusivity (10^{-6} cm^2/s at 900°C) and solubility (2 x 10^{13} cm^{-3} at 900°C) in silicon." EX1025, 3773. Similarly, it noted that "[d]iffusion in SiO_2 of other metallic contaminants like Na, Au, Cu, Ni, Ag, Pd, and Ti have been studied." *Id.* Ramappa then "present[ed] results on diffusion of iron in SiO_2 films grown on Si," showing that at the temperature used by Li, iron diffuses readily across even much thicker silicon dioxide layers (50-100nm) than the 1-2 nm layer used by Li. *Id.* at 3773-3774, Fig. 1. As alluded above, iron impurity levels in multicrystalline silicon were reported to be as high as 10^{14}-10^{16} cm^{-3} in concentration as I discussed in ¶¶90-92. I have added a red line to the Figure 1 of Ramappa reproduced below to show approximately where 1-2 nm thickness would be in this figure. As seen from the figure, iron readily diffuses across silicon dioxide in the temperatures shown between 900-1100°C. This

demonstrates that there would be no difficulty for the iron to getter across the 1-2 nm silicon dioxide layer of Li and into the polysilicon layer.

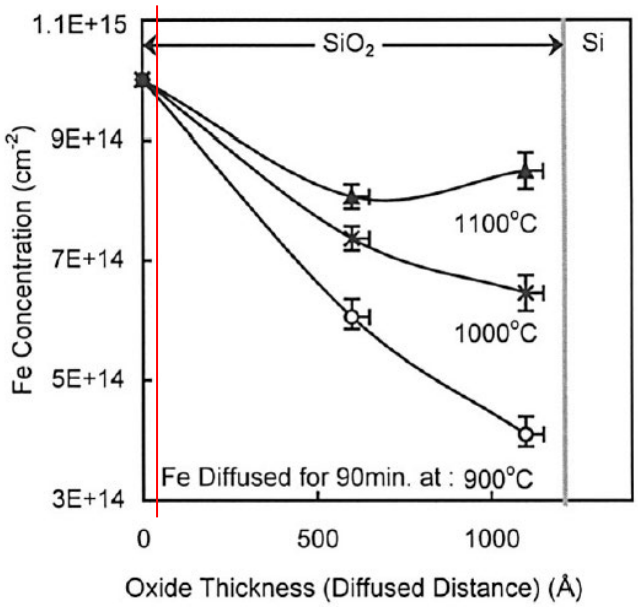


Figure 1. Iron concentration profile in SiO_2 following in-diffusion at temperatures of 900, 1000, and 1100°C for 90 min. Iron concentrations were measured by TXRF.

164. Looking at this data, the Skilled Artisan would conclude that the metal impurities in Li's substrate would necessarily have diffused across the thin silicon oxide layer of Li at the temperature disclosed in Li.

165. Likewise, Yoshimura, published in 2006, confirmed that during gettering processes, a "silicon oxide film" having "thickness of 0.5 to 1 nm thereabouts" necessarily allowed "impurity metal Md" to "readily pass through." EX1026, ¶0056.

166. More recently, in one publication in 2018, Liu et al. ("Liu-1") reported direct observations of iron impurities being gettered and present in both

phosphorous-doped polysilicon and boron-doped polysilicon layers despite the presence of interfacial silicon oxide layers grown on the silicon wafer surface at "thickness of around 1.3-1.4 nm." EX1028, 2276-2277. For example, as shown by the red line in Figure 4 of Liu-1 reproduced below, iron atoms are gettered and present in the phosphorus-diffused polysilicon ("Poly-Si") layer as they move from the substrate to the PSG layer. EX1028, Figure 4. PSG refers to phosphosilicate glass. The phosphorus diffusion was performed at 890°C. EX1028, 2276.

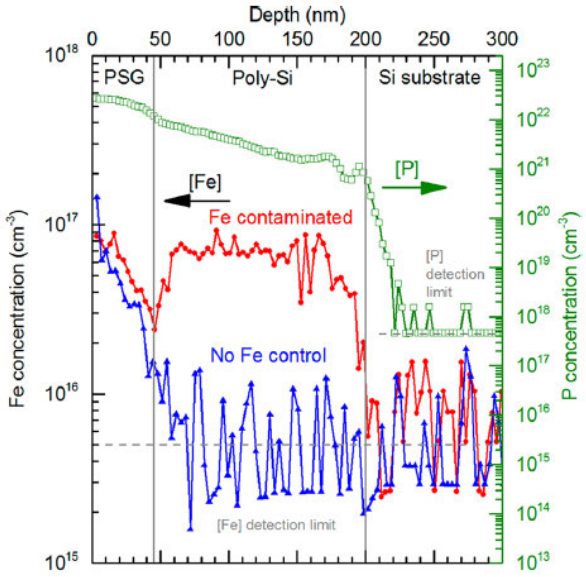


Figure 4. SIMS Fe and P concentrations (top) and uncalibrated O signal (bottom) in $POCl_3$-diffused polysilicon passivating contact layers and the near-surface silicon substrate, for samples with and without an initial bulk Fe contamination of 10^{14} cm^{-3} prior to the contact formation.

167. Similarly Liu-1 reported that for boron-diffusion polysilicon layers, iron impurities are gettered and present in the polysilicon layer ("Poly-Si") as they move from the substrate to the BSG layer, as seen from the red line in Figure 7

reproduced below. EX1028, Figure 7. BSG refers to borosilicate glass. The boron diffusion was performed at 900ºC. EX1028, 2276.

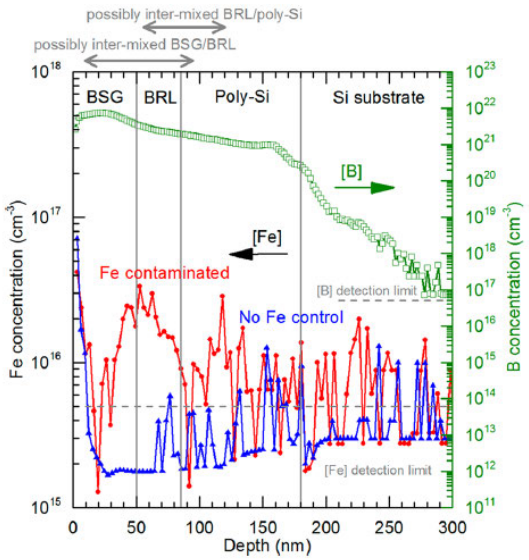


Figure 7. SIMS Fe and B concentrations in BBr_3-diffused polysilicon passivating contact layers and the near-surface silicon substrate, for samples with and without an initial bulk Fe contamination of 10^{14} cm^{-3} prior to the contact formation. Note that the positions of the BSG/BRL and BRL/poly-Si interfaces are indicative only, as the boundaries are intermixed (particularly at the BSG/BRL interface).

168. Another paper by the same author in 2018, Liu-2, specifically confirmed "the strong impurity gettering effects associated with the formation of both phosphorous and boron doped polysilicon/oxide passivating contacts for silicon solar cells, doped via thermal diffusion from $POCl_3$ and BBr_3 sources." EX1029, 136. Liu-2 recognized that:

> industrial silicon wafers have varying levels of purity and crystallinity, and they are subjected to different environments in terms of contamination control. Impurities such as transition metals are commonly found in silicon wafers for solar cells, creating recombination centres in the silicon wafer bulk and therefore lowering device efficiencies. Phosphorous (P) diffusions are commonly used to achieve effective impurity gettering in silicon solar cell fabrication.

EX1029, 136.

169. Specifically with respect to silicon dioxide layer, Liu-2 reported that while a "thin oxide interlayer hinders the gettering effectiveness at low diffusion temperatures… its blocking effect becomes small at the moderate temperatures used to fabricate optimum polysilicon contacts," and "[t]he gettering effectiveness increases with increasing diffusion temperature." *Id*. In particular, Liu-2 studied phosphorous diffusion carried out between 780-890 °C and observed gettering through "chemical oxide interlayers" in the range of ~1.3 nm (in the same thickness range contemplated by Li). EX1029, 137-139. Although Liu-1 and Liu-2 post-date the 315 Patent, I understand from counsel for CSI that they can be considered in evaluating Li's inherent disclosures.

170. Therefore, the art I discussed above demonstrates that Li's heating and diffusing of the dopants into the polysilicon layer at 950°C would have necessarily resulted in impurities being gettered and present in the doped polysilicon regions 308 and 310, despite a thin 1-2 nm interfacial silicon oxide layer in between.

171. The metal impurities would be present in the polysilicon emitter regions using Li's two-step heating approach for the back and front of the solar cell. In my opinion, it would also have been obvious to the Skilled Artisan to

combine the two heating steps of Li to a single heating step for both the doping of the front and back sides of the solar cell. This would have saved energy and cost of manufacturing, and would not have had any negative impacts on the resulting solar cell. This would have been readily implemented by the Skilled Artisan by using a single loading of the solar cell into a single heating furnace after the deposition of the back side dopant sources onto the polysilicon layer and include the gaseous dopant for diffusion into the front portion. Diffusion masks (i.e., barriers) were routinely used in the art and the Skilled Artisan would know that a diffusion mask can be deposited on the backside to block the gaseous phosphorus dopant from cross-doping the p-type polysilicon region. Li also disclosed a single heating step for both front and back diffusion in connection with another embodiment disclosed in FIGS. 2A-2E. EX1005, ¶0033.

172. It is notable that Li's disclosed heating process is nearly identical to the heating process described in the 315 Patent. The 315 Patent describes that "the silicon substrate 202 can have contaminants and/or impurities 220, for example metal contaminants and/or metal impurities." EX1001, 4:65-67. In one example, the 315 Patent discloses using a temperature of 975°C, while Li used a temperature of 950°C. EX1001, 5:40-44. Nonetheless, the 315 Patent describes that "heating at temperatures above 900 degrees Celsius can include gettering metal impurities 220 through the dielectric region 210, e.g., tunnel oxide, to into the emitter region 212,

e.g., polysilicon regions, as discussed in detail at 106 of FIG. 1 below." EX1001, 5:21-25. Hence, a temperature of above 900°C would be sufficient according to the 315 Patent. In contrast, the 315 Patent discloses that a temperature at or below 900°C would be insufficient. EX1001, 5:10-39. Thus, given the identical structures and processing temperatures—greater than 900°C (315 Patent) and 950°C (Li)—of the solar cells disclosed in the 315 Patent and Li, the gettering effect observed in the 315 Patent would also have necessarily and inevitably been observed in Li for precisely the same reasons. Liu-2 describes that "the gettering effectiveness increases with increasing diffusion temperature." EX1029, 136.

vi. *Metal contact*

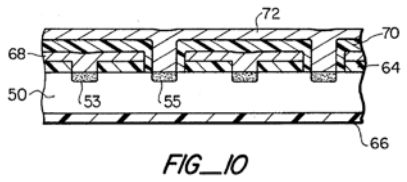
173. Claim 10 requires "a first metal contact formed over the first emitter region." Li disclosed this element.

174. Li described that in solar cells, it was well known that "[t]he doped regions are connected to metal contacts on the solar cell to direct an electrical current from the cell to an external circuit coupled thereto." EX1005, ¶0004. From this, the Skilled Artisan would have understood that Li's "back-contact solar cell" would, by definition, be fabricated with a metal contact formed over each of the doped emitter regions on the back surface of the solar cell to direct an electrical current from the cell to an external circuit, even if not expressly shown in FIG. 3 or 5E. Li stated that "well-known fabrication techniques … are not described in

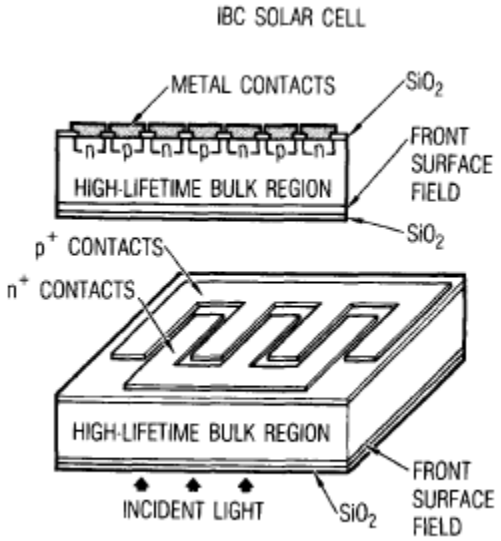
detail in order to not unnecessarily obscure embodiments of the present invention." EX1005, ¶0021.

175. Although Li does not depict metal contacts in its figures, the Skilled Artisan would have understood from Li's description that "doped regions are connected to metal contacts on solar cells" and that Li's "back-contact solar cell" would also have necessarily included negative and positive metal contacts on the back surface over the N-doped and P-doped regions 502 and 504, respectively, to direct an electrical current from the cell to an external circuit. Metals were known to be good conductors of electricity and hence were used in the art even before 2014 as metal contacts for solar cells. Without the addition of metal contacts on the back surface, a "back-contact solar cell" cannot transmit electricity to an external circuit.

176. As I discussed in ¶¶73-75 above, forming positive and negative metal contacts on the respective doped regions of the back-contact solar cell was well known in the art and was the standard practice for solar cells, as further seen for example in Swanson-352 (FIG. 10, element 72) and Marvin, as reproduced below, from the 1989 and 1990. Both Swanson-352 (FIG. 10, elements 68 and 72) and Marvin, as reproduced below, showed positive and negative metal contacts formed over the doped regions, respectively, and contacting them.



EX1015, Fig. 10;



EX1035, Fig. 1; *see also* EX1007, Fig. 1.

177. To the extent that it is argued that Li does not disclose metal contacts, the combination of Li and Swanson-352 or Marvin disclosed such element. The metal contacts would have been obvious to the Skilled Artisan based on Li in combination with the general knowledge of the Skilled Artisan, or, alternatively, by the combination of Li with either of Swanson-352 or Marvin, as the Skilled Artisan would have recognized that metal contacts are necessary for a back-contact solar cell to perform its intended function, and therefore would have been motivated to employ them with the cell of Li. Only metal contacts can provide the

sort of low contact resistance which can lead to low series resistance, high fill factor and high efficiency.

2. Claim 11

178. Claim 11 recites: *"The solar cell of claim 10, wherein the portion of the silicon substrate comprises N-type dopants."*

179. As I discussed above in ¶¶139-140, Li described "*the portion of the silicon substrate,*" which refers back to the front portion of claim 10. Further, Li describes doping the front portion 520 (shown in red) "with the gaseous ***N-type dopant*** source." EX1005, ¶0049 (emphasis added). "[S]ubstrate 304 of back-contact solar cell 300 includes ***N-type dopants*** 318 at or near surfaces of substrate 304 not covered by material layer 302, as further depicted in Fig. 3." EX1005, ¶0038 (emphasis added).

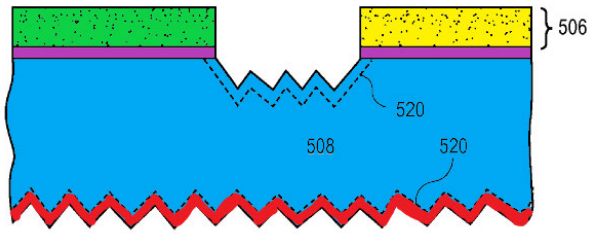


FIG. 5E

180. Additionally, Swanson-352 also taught to dope the front portion of the silicon substrate with "an N-type dopant such as phosphorous." EX1015, 4:38-51. Figures 1-6 of King all disclosed phosphorus for the dopant concentration. EX1006, 367.

3. Claim 12

181. Claim 12 recites: *"The solar cell of claim 10, wherein the portion of the silicon substrate comprises phosphorous."*

182. As discussed above for Claim 11, Li describes "*the portion of the silicon substrate comprises N-type dopants.*" Li further discloses that N-type dopants "include[] phosphorous dopant impurity atoms." EX1005, ¶0037. Swanson-352 and King also disclose to use phosphorous. EX1015, 4:38-51.

4. Claim 15

183. Claim 15 recites: *"The solar cell of claim 10, wherein the first emitter region comprises polysilicon."*

184. Li discloses that "*the first emitter region comprises polysilicon*." As I discussed above in ¶¶149-151 either one of the P-typed doped or N-type doped regions (310, 314) in the "material layer 506" or 302 of Li would have been an "emitter region" corresponding to and according to the "first and second emitter regions 312 and 314" referred to by the 315 Patent.

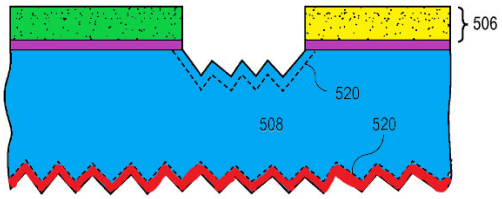


FIG. 5E

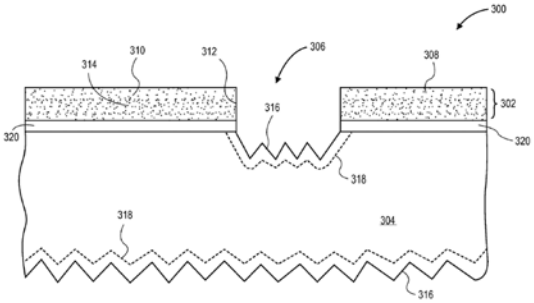


FIG. 3

185. Li also described its material layer 506/302 to be "a poly-crystalline silicon layer," i.e., polysilicon layer. EX1005, ¶¶0037, 0042. ("[M]aterial layer 302 of a back-contact solar cell 300 is a poly-crystalline silicon layer"). Thus, Li's "first emitter region comprises polysilicon."

5. Claim 16

186. Claim 16 depends on Claim 10 and further recites: *"a second emitter region having metal impurities formed over the dielectric region" and "a second metal contact formed over the second emitter region."*

187. As I discussed above, the 315 Patent refers to the "P-type and N-type doped polysilicon regions" formed over the dielectric region 310 (purple) in FIG. 5 as "the first and second emitter regions 312, 314" (green and yellow). EX1001,6:55-57.

188.

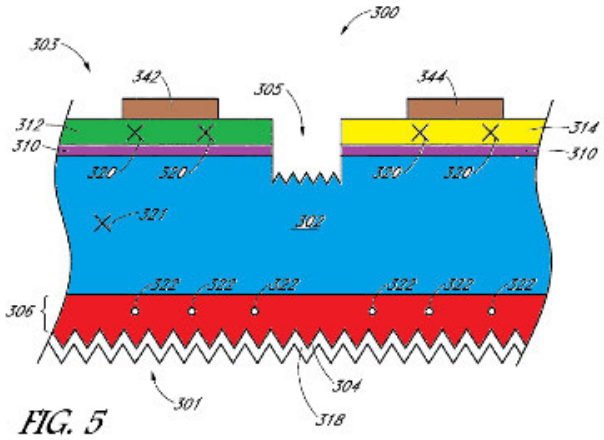


FIG. 5

189. Claim 16 requires both "emitter region[s]" to be formed "over the dielectric region," which in Claim 10 is said to be "formed over the back side of the solar cell." Thus, in Claim 16 (and also Claim 19 that depends on Claim 16) both of the doped emitter regions are on the back side, just as shown in FIG. 5E of the 315 Patent (as 312 and 314).

190. As I discuss above in ¶¶ 96-99, Li disclosed the same structure and arrangement as FIG. 5 of the 315 Patent and thus, disclosed a "*second emitter region … formed over the dielectric region*." Just like the 315 Patent, Li described that the same structures of a polysilicon "material layer" (302 in Fig. 3) made up of an "N-type region 308 [yellow circle] and a P-type region 310 [green circle]" formed over dielectric region 320 (purple circle). EX1005, ¶¶0036-37. Li's polysilicon "P-type region 310" and "N-type region 308" (in Fig. 3) are the same structure, arrangement, and doping as the "P-type and N-type doped polysilicon regions" in FIG. 5 of the 315 Patent and thus, would satisfy "the first and second emitter regions" of the 315 Patent claims, as I discussed in ¶¶ 96-99, 146-154 above.

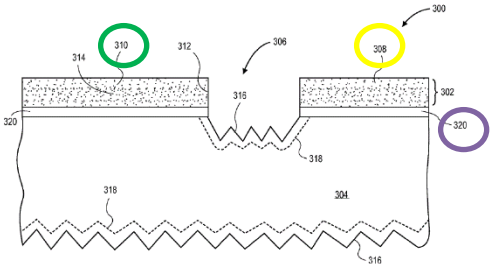


FIG. 3

191. Specifically, the "P-type and N-type doped polysilicon regions" in FIG. 5 of the 315 Patent are formed on a silicon dioxide dielectric layer 310, which is formed on a silicon substrate 302. EX1001, 6:50-62. The P-type and N-type

polysilicon regions are described as the "first and second emitter regions, 312, 314." EX1001, 6:55-57.

192. This is the same arrangement as Li. Li's polysilicon "P-type region 310" and "N-type region 308" are likewise formed on a silicon dioxide dielectric layer 320, which is formed on the silicon substrate 304. These doped polysilicon regions are the same as the "emitter" regions described and claimed by the 315 Patent, including the "*second emitter region*" of Claim 16.

193. Further, just as the "first emitter region" of Li would necessarily and inevitably have "metal impurities" as a result of inherent gettering during the heating process used to dope the polysilicon regions, the "second emitter region" of Li uses the same heating process and temperature (EX1005, ¶45) and would also necessarily and inevitably have metal impurities for the same reasons as I describe above in ¶¶ 155-172.

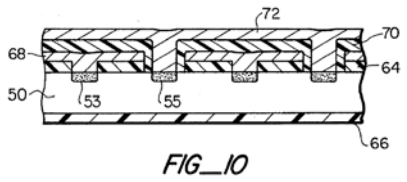
194. Finally, Claim 16 requires "a second metal contact formed over the second emitter region." Li disclosed this element.

195. As I discussed above with respect to the "first metal contact" of Claim 10, Li described that in solar cells, it was well-known that "[t]he doped regions [plural] are connected to metal contacts [plural] on the solar cell to direct an electrical current from the cell to an external circuit coupled thereto." EX1005, ¶0004. From this, the Skilled Artisan would have understood that Li's "back-

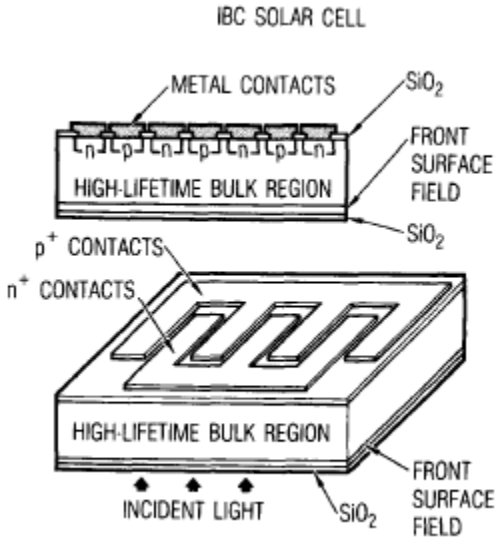
contact solar cell" would, by definition, be fabricated with metal contacts formed over the doped emitter regions on the back surface of the solar cell to form separate positive and negative polarity contacts to direct an electrical current from the cell to an external circuit, even if not expressly shown in FIG. 3 or 5E. Li stated that "well-known fabrication techniques … are not described in detail in order to not unnecessarily obscure embodiments of the present invention." EX1005, ¶0021.

196. Although Li does not depict metal contacts in its figures, the Skilled Artisan would have understood from Li's description that "doped regions are connected to metal contacts on solar cells" and that Li's "back-contact solar cell" would also have necessarily included two opposite polarity metal contacts (i.e., first and second metal contacts) on the back surface, with one over the N-doped region 502 and another over the P-doped region 504, respectively, so that an electrical current from the cell can flow to an external circuit. Metals were known to be good conductors of electricity and hence were used in the art even before 2014 as metal contacts for solar cells. Without the addition of metal contacts on the back surface, a "back-contact solar cell" cannot transmit electricity to an external circuit.

197. As I discussed in ¶¶73-75, 176 two metal contacts (i.e., first and second metal contacts) are formed over the two oppositely doped regions and contacting them, respectively.

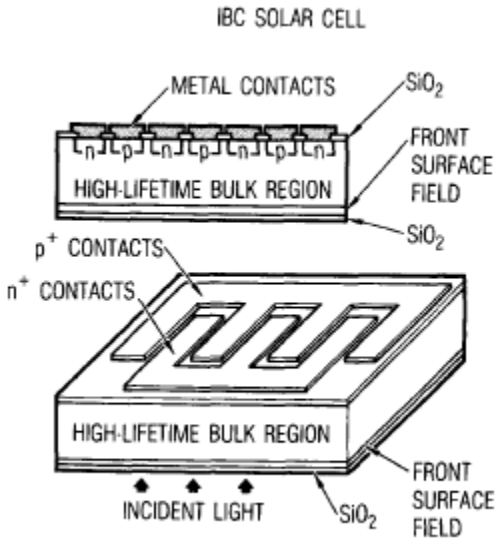


EX1015, Fig. 10;



EX1035, Fig. 1; *see also* EX1007, Fig. 1. Specifically, in Swanson-352, the two oppositely doped regions are identified as 53 and 55 in FIG. 10 (left above), and they are contacted by the metal contacts 68 and 72, respectively. Notably, the two metal contacts 68 and 72 do not touch each other and they are insulated from each other by an insulating layer 70, thus forming positive and negative metal contacts, respectively. EX1015, 5:29-41. In Marvin, the two oppositely doped regions are identified as "n" and "p" and they are electrically contacted by metal contacts labeled "n+ contacts" and "p+ contacts," as shown in FIG. 1 of Marvin EX1035. Notably, the two metal contacts do not touch each other and are interdigitated and

discontinuous such that they form the positive and negative metal contacts of the solar cell, respectively.



198. To the extent that it is argued that Li does not disclose a second metal contact, the combination of Li and Swanson-352 or Marvin disclosed such element. The second metal contact would have been obvious to the Skilled Artisan based on Li in combination with the general knowledge of the Skilled Artisan, or, alternatively, by the combination of Li with either Swanson-352 or Marvin, as the Skilled Artisan would have recognized that positive and negative metal contacts are necessary for a back-contact solar cell to perform its intended function, and therefore would have been motivated to employ them with the cell of Li. Only metal contacts can provide the sort of low contact resistance which can lead to low series resistance, high fill factor and high efficiency.

6. Claim 19

199. Claim 19 depends on Claim 16 and further recites: *"wherein the second emitter region comprises polysilicon."*

200. As discussed above with respect to Claim 15, and in ¶¶149-151, Li discloses that the P-typed doped or N-type doped regions (310, 314) in the "material layer 506" or 302 of Li would have corresponded to the "first and second emitter regions 312 and 314" referred to by the 315 Patent.

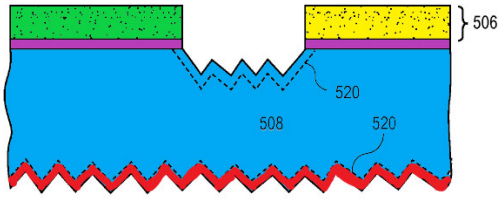


FIG. 5E

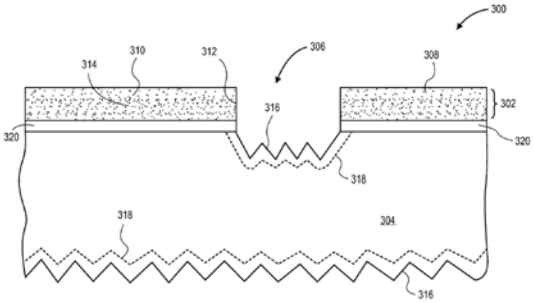


FIG. 3

201. Li also described its material layer 506/302 to be "a poly-crystalline silicon layer," i.e., polysilicon layer. EX1005, ¶¶0037, 0042. ("[M]aterial layer 302 of a back-contact solar cell 300 is a poly-crystalline silicon layer"). Thus, Li's "second emitter region comprises polysilicon."

VI. LI COMBINED WITH MULLER WOULD HAVE RENDERED CLAIMS 10, 13-15, 16, AND 19 OBVIOUS

202. In my opinion, the combination of Li in view of Muller would have rendered Claims 10, 13-15, 16, and 19 obvious.

203. I understand from counsel for CSI that Muller (EX1008) qualifies as prior art, and I have been asked to assume them to be so.

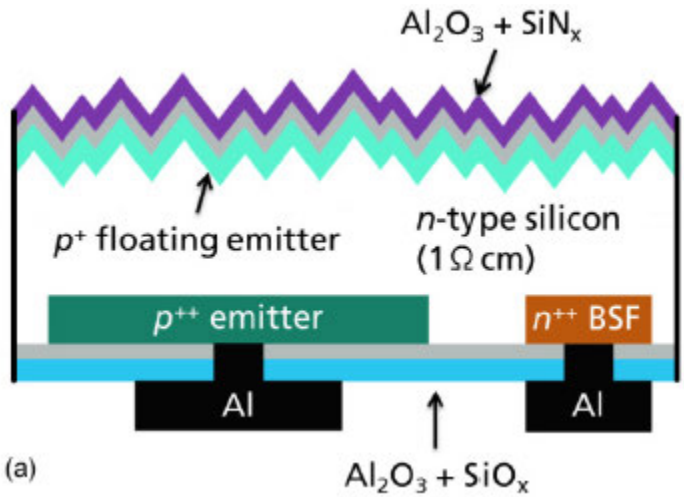
204. Li disclosed all of the elements of claim 10 except for the front dopant concentration, which as discussed above, was disclosed by King, Swanson-352, or Marvin. In the following combination of Li and Muller, Muller (instead of King, Swanson-352 or Marvin) is used for its disclosure of the front dopant concentration. Additionally, Muller disclosed that the front portion of the substrate is doped with boron, a P-type dopant, as required by claims 13 and 14. As discussed above with respect to the previous combinations, Li disclosed that the first and second emitter regions comprise polysilicon, as required by Claims 15 and 19, respectively. Further, as also discussed in the above combinations, Li disclosed the "second emitter region having metal impurities formed over the dielectric region," and the "second metal contact formed over the second emitter region" as required by Claim 16. To the extent it is disputed that Li discloses the "second metal contact" limitation, I explain below that Muller disclosed that limitation and would have been obvious to the Skilled Artisan to combine them with Li.

A. Muller (EX1008)

205. Muller is a paper entitled "Ion implantation for all-alumina IBC solar cells with floating emitter." EX1008, 265. Muller was published online on

September 19, 2014 in Energy Procedia 55 (2014) at pages 265-271, before December 22, 2014. EX1047, 1.

206. Like Li, Muller disclosed a back contact solar cell, referred to therein as "interdigitated back contact (IBC) solar cells." EX1008, 265. Muller described that such solar cells "have a high efficiency potential as there are no metal contacts on the front side resulting in a maximum absorption of incident light," and both[] *n*- and *p*-contacts [are] on the back side." *Id*. The back-contact solar cells of Muller included an N-type substrate having a doped portion on the front side (identified as the "p+floating emitter") and a "p++ [doped] emitter" and an "n++ [doped] BSF" (i.e., back surface field) on the back side with two metal contacts (each made of aluminum) formed over and contacting the back side doped regions, as shown below in Muller Fig. 3a:



EX1008, 269. The "p++ emitter" and "n++ BSF" regions on the backside of Muller are equivalent to to the P-type doped regions and N-type doped regions of

Li, except that Li's regions are made of polysilicon, while Muller regions are ion-implanted into the substrate. In the parlance of the 315 Patent, discussed above in ¶¶ 147-150, the "p++ emitter" and "n++ BSF" regions on the backside of Muller would each be considered "emitter regions."

207. Muller investigated "*n*-type IBC solar cells with a low-dose ion-implanted [boron-doped] front floating emitter (FFE) which [Muller] compare[d] to a low-dose ion implanted [phosphorus-doped] front surface field (FSF) passivated by SIO_2." EX1008, 265. "Ion implantation" is a process in which dopant atoms are ionized and then accelerated at the silicon substrate to implant the ions/dopant atoms into the substrate.

208. In particular, Muller constructed and compared two back contact solar cells both of which have front doped region with a concentration of approximately equal to or less than 2×10^{18} cm^{-3}. In both cases, Muller disclosed that the front portion of the substrate was doped by "ion implanation." EX1008, 265. One solar cell was fabricated with an ion-implanted boron doped front region (as a "front floating emitter" "FFE") which had front portion peak dopant concentration equal to approximately 2×10^{18} cm^{-3}. The other solar cell was fabricated with a phosphorus doped front region (as a "front surface field" "FSF"), which had front portion peak dopant concentration less than approximately 2×10^{18} cm^{-3}. EX1008, 269. The orange dotted lines in Figure 1 of Muller reproduced below showed the

dopant profiles of the two back-contact solar cells constructed and compared by Muller.

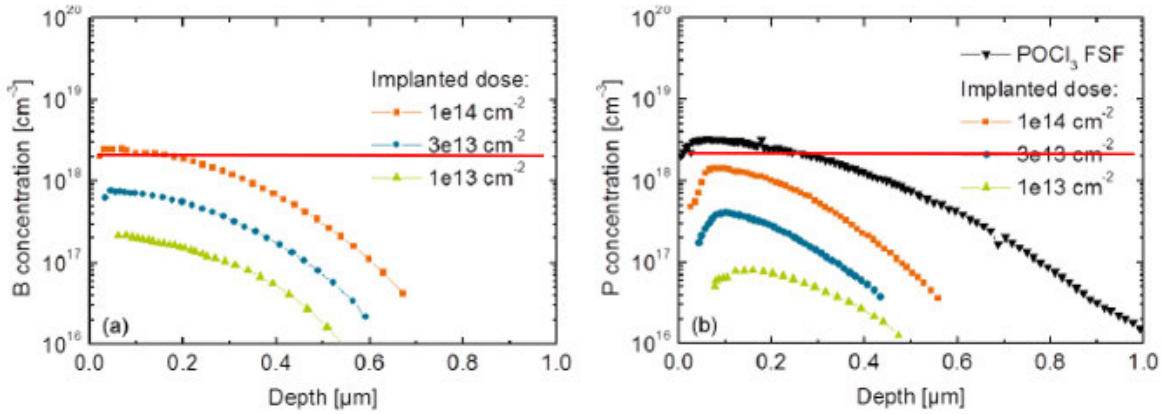


Fig. 1. ECV profiles measured on planar samples after ion implantation and annealing for 80 min at 1050 °C. (a) Low dose boron implantations for a floating emitter; (b) low dose phosphorus implantations for a front surface field. A conventional $POCl_3$-diffused FSF used in Ref [8] is shown for comparison.

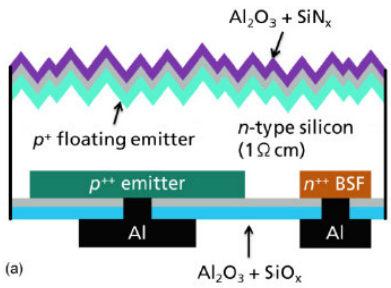
EX1008, 267. In both cases, the concentration of dopant at or near the front surface of the cell is highest and the concentration decreases with depth into the substrate, as shown in Muller Fig. 1. EX1008, 267. I have added the horizontal red lines to show where the concentration of 2×10^{18} cm^{-3} is on the vertical axis. The vertical axis is on a logarithmic scale and thus the first tick above 10^{18} marks the concentration of $2x10^{18}$ cm^{-3}. In both cases, the front portions of the substrates were doped by "ion implantation." EX1008, 265.

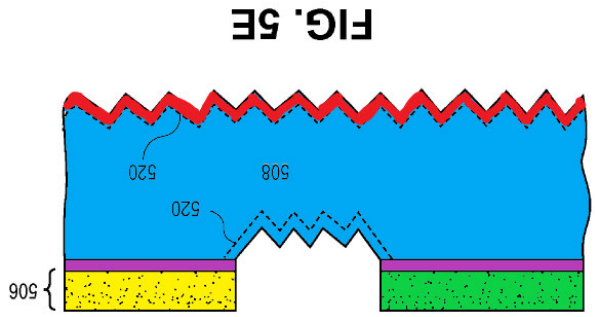
209. Muller reported that in comparative testing, "[t]he best solar cell with a boron doped [FFE] has a conversion efficiency of 21.8% (see Fig. 3b)." EX1008, 269. This boron ion-implanted FFE solar cell was also passivated on the front by aluminum oxide, instead of the silicon oxide that was used with the

phosphorus doped FSF solar cell. *Id.* The boron FFE doped at a surface dopant concentration of 2×10^{18} cm^{-3} lowered Auger and surface recombination, and when implemented together with aluminum oxide and silicon nitride passivation on the front side, resulted in greater resistance to UV degradation of solar cell efficiency, compared to phosphorus doped FSF that was front passivated with silicon oxide. EX1008, 271. Muller also described that "[f]or textured FFE samples, J_0 values down to 5 fA/cm^2 were measured with an Al_2O_3 passivation. This configuration turned out to be quite stable against UV-irradiation." *Id.* Muller also reported that under UV-illumination, "[t]he efficiency of [ion-implanted] FSF cells dropped dramatically by more than 50% while the [ion-implanted] FFE cells lost only about 1 % absolute."*Id. See also*, *id.* at 269-270, Table 2; *id.* at 265, Abstract.

B. Motivation to Combine Li and Muller

210. The Skilled Artisan would have been motivated to combine the ion-implanted front floating emitter and aluminum oxide and silicon nitride passivation of Muller with Li because of its better solar cell efficiency and resistance to UV degradation, as disclosed by Muller. In the combination of Muller and Li, the ion-implanted boron-doped FFE of Muller (along with its frontside aluminum oxide and silicon nitride passivation) would replace the phosphorus (N-type) doped front portion 520 of Li's back-contact solar cell.





211. Li and Muller are both directed to back-contact solar cells and their fabrication. Specifically, Li disclosed a back-contact solar cell in which the front portion 520 of the silicon substrate should be doped (EX1005, ¶0049), but Li did not specify the concentration of dopants that should be utilized at the front surface. Muller supplies that information by showing that, for a back-contact solar cell utilizing an N-type substrate (as in Li) using a boron-doped ion-implanted front floating emitter ("FFE") at a front dopant concentration of approximately $2x10^{18}$ cm^{-3} or less for an N-type back-contact solar cell and then passivating the front side of the solar cells with a Al_2O_3/SiN_x stack, resulted in better resistance to surface recombination (J_o), and UV degradation, and overall efficiency of the solar cell was better than a N-type back contact solar cell having a phosphorus-doped ion-implanted front surface field (FSF), passivated by SiO_x and/or SiN_x. EX1008, Tables 1 and 2.

212. As recognized in the art, using ion implantation for doping solar cells "provides a unique opportunity to obtain grid-parity because it simplifies the fabrication of advanced cell structures." EX1036, 10. Ion implantation had also

been shown before 2014 to increase solar cell efficiency while reducing the process sequence in production. *Id*. at11.

213. And, as seen in Muller Table 1 (below), the solar cell with the ion-implanted boron-doped FFE and Al_2O_3 passivation had a lower *Jo* (leakage current, where a lower value indicates better passivation) than the ion-implanted phosphorus-doped FSF solar cell.

Table 1. Characteristics of the investigated profiles (best values achieved so far). Sheet resistance was measured by 4 point probe on planar reference samples. J_0 was extracted from QSSPC measurements (textured samples for FSF & FFE and planar samples for emitter and BSF) using the high injection method [11].

Sample type	Species	Implanted dose [cm^{-2}]	R_{Sheet} [Ω/sq]	J_0 [fA/cm^2]	Passivation
Floating emitter (FFE)	Boron	1e13	3900	5	Al_2O_3
		3e13	1500	6	
		1e14	650	7	
Front surface field (FSF)	Phosphorus	1e13	2200	12	SiO_2/SiN_x
		3e13	880	15	
		1e14	440	10	
Emitter	Boron	7e14	147	9	Al_2O_3
		1e15	108	22	
		1.5e15	73	24	
Back surface field (BSF)	Phosphorus	3e15	39	370	Al_2O_3

214. Further, as seen in Muller Table 2 (below), when the FFE and FSF were tested with 1.5X UV-illumination to assess degradation, the ion-implanted phosphorus FSF solar cell conversion efficiency (η) dropped 2 fold from 20.9% to 9.6% after UV exposure, while the ion-implanted boron FFE η only dropped 1.1%:

Table 2. Degradation of IBC solar cells under UV-illumination in a sun tester for 36 h at 500 W/m^2.

Front side	State	V_{OC} [mV]	J_{SC} [mA/cm^2]	*FF* [%]	*η* [%]
Front surface field (FSF)	before UV exposure	672	39.2	79.6	20.9
	after UV exposure	612	19.8	79.3	9.6
Floating emitter (FE)	before UV exposure	673	39.9	77.3	20.7
	after UV exposure	668	38.2	76.7	19.6

215. Given Li's acknowledgement that "[e]fficiency is an important characteristic of a solar cell as it is directly related to the solar cell's capability to generate power" and that "techniques for increasing the efficiency of solar cells are generally desirable" (EX1005, ¶0005), the Skilled Artisan reviewing Li would have been motivated to modify Li's solar cells to replace the diffusion doped front portion 520 with the more efficient ion-implanted boron-doped FFE and passivation layers as disclosed by Muller. And, as between Muller's ion-implanted FSF and FFE, the Skilled Artisan would have been highly motivated to select the ion-implanted FFE with concentration of approximately $2x10^{18}$ cm^{-3} because of its higher efficiency and stability (though it is notable that either choice would have resulted in front dopant concentration of approximately 2×10^{18} cm^{-3} or less). EX1008, 267, Fig. 1.

C. Reasonable Expectation of Success

216. The Skilled Artisan would have considered the Li/Muller combination to be merely an arrangement of old elements with each performing the same function it had been known to perform (the back contact solar cell of Li continuing to be a back contact solar cell, but modified to have the boron-doped front floating emitter and front passivative stack of Muller) and yielding no more than what one would expect from such an arrangement (a solar cell with improved performance).

217. Combining the back-contact solar cell of Li with the front side ion-implanted floating emitter of Muller would have been straightforward and done with a reasonable expectation of success by the Skilled Artisan, given that Li does not disclose any other layers on the front surface of the solar cell (EX1005 at Fig. 5E). The Skilled Artisan would recognize that Muller's teaching to dope the front surface with an ion-implanted boron floating emitter to a peak concentration of approximately 2 x 10^{18} cm^{-3} could be readily implemented by the Skilled Artisan. Any modifications or optimization of the process steps to implement the ion-implanted boron FFE of Muller would have been within the level of skill of the Skilled Artisan before 2014. For example, it is within the level of skill of the Skilled Artisan before 2014 to insert the Muller ion-implanted boron FFE process steps before Li's process steps of forming the backside dielectric region and polysilicon emitter regions, and the doping the remaining exposed surfaces of the substrate (i.e., trench) with a gaseous N-type dopant. (EX1005, ¶0049). The Skilled Artisan would have recognized that the fabrication of the front portion of the solar cell could be done independently of the application and treatment of layers on the back surface of the solar cell, and without impacting the layers applied to the back surface of the solar cell. Muller's boron-implanted FFE and passivation layers would also be entirely consistent with the solar cell fabrication process described in Li, even for the diffusion of the back side trench region 520

using a gaseous N-type dopant source. In the combination of Li and Muller, the Skilled Artisan in 2014 would have known and it would have been well within the level of skill of the Skilled Artisan to utilize diffusion masking techniques to mask the front surface of the solar cell to prevent the cross doping during the gaseous phosphorus doping of the back side trench. Diffusion masking, that is forming a barrier layer to prevent diffusion of the dopants were well known and routinely practiced in the art even before 2014. EX1046 at 399, 406-407. Indeed, it was well known in the art that a silicon nitride layer would act as a diffusion barrier for "heavy phosphorus diffusion" as well as perform its functions as an antireflection coating and surface passivation. EX1010, 291. This use of silicon nitride layer was known long before 2014. Chapter 7 of the 2002 Luque Handbook of Photovoltaics disclosed, for example, that "a key element is the silicon nitride layer, which serves as a masking layer for heavy phosphorus diffusion and plating, and also performs as an antireflection coating and surface passivator." EX1010, 291. In Luque, the silicon nitride layer was used as a diffusion mask in the context of a laser grooved buried-grid solar cell process. *Id*. The use of silicon nitride both a diffusion mask and antireflection coating and surface passivator is equally applicable here. In this case, Muller taught to cap the front side of the solar cell with a silicon nitride layer over the the boron ion implantation and aluminum oxide layer. EX1008, 266 and Fig. 3. Thus, when Li's front portion of the substrate is

replaced with an FFE with aluminum oxide layer and capped with a silicon nitride layer, as taught by Muller, the silicon nitride layer would prevent diffusion of the phosphorus into and cross-doping of the boron implanted front portion of the substrate with phosphorus, while still maintaining its function as an anti-reflection and passivation layer. No substantial change needs to be made with the combination. Thus, combining Li and Muller as described here would have been well within the level of ordinary skill in the art in 2014, would not have resulted in any unpredictable results and could have been readily accomplished without undue experimentation and with a reasonable expectation of success.

218. Finally, combining Li with the front-side boron FFE of Muller would not have changed Li's inherent disclosure of gettering metal impurities from the silicon substrate to the emitter region, because, as discussed above, the natural result of Li's process of doping the emitter region at 950°C would be to getter metal impurities from the silicon substrate, through the 1-2 nm thick silicon oxide dielectric layer, and into the N-doped and P-doped regions of the polysilicon layer. The Skilled Artisan would recognize that fabrication of the front side of the solar cells would have been independent of the back side of the solar cells. Certain steps such as implant doping of emitters or FSF/BSF, lithographic patterning of contact holes, and deposition of metal layers by evaporation, sputtering or screen printing

can be done on front and back surfaces independently of each other, and heating and annealing steps can be combined to save energy and costs.

219. The combination would simply have been the combination of prior art elements according to known methods to yield predictable results. Likewise, substituting Li's front doped portion with Muller's front doped portion would be simple substitution of one known element for another to obtain predictable results. It would further constitute use of a known technique (ion implantation of boron) to improve similar devices (Li'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.

D. The Combination of Li and Muller Disclosed All Elements of Claims 10, 13-15, 16, and 19

220. As I discussed above in ¶¶135-177, Li disclosed all elements of Claim 10, except for the dopant concentration of the front portion of the substrate. Li also disclosed the additional "polysilicon" element of Claims 15 and 19, as discussed in ¶¶183-184, 199-201186-198. The following discussions will focus on the front dopant concentration of Claim 10 and the additional elements recited in Claims 13-14, plus the "second metal contact" element of Claim 16.

1. Claim 10 – front dopant concentation

221. As I discussed above¶¶138-140, Li disclosed to dope the front portion of its substrate but does not disclose the dopant concentration to use. Using an "n-

type" silicon substrate similar to Li, Muller taught the benefits and advantages to a back contact solar cell of having the substrate's front portion be ion implanted with "boron doped front floating emitter" at a peak doping concentration of approximately 2×10^{18} cm^{-3}, and decreasing with depth into the substrate. EX1008, 267, 269. It would have been obvious to the Skilled Artisan to combine Li and Muller, as I discussed above in ¶¶210-219, to replace the phosphorous diffused front portion of Li with the ion-implanted boron-doped FFE at the dopant concentration taught by Muller because such combination would result in increased solar cell efficiency and better stability under UV illumination, as taught by Muller. Further, the Skilled Artisan would recognize that the ion-implanted FFE on the front is a portion of the silicon substrate because ion implantation does not deposit an extrinsic layer on the substrate, but rather implants boron ions into the substrate to form the FFE region.

222. Therefore, Muller's ion-implanted boron-doped FFE at the doping concentration of approximately 2×10^{18} cm^{-3} when substituted into the front portion of Li would satisfy this limitation. The inherent gettering effect observed under the processing conditions of Li, including when combined with King, Swanson-352, or Marvin, would still result in this alternative combination with Muller. The treatment of the front surface of the silicon substrate—whether with a FSF or an ion-implanted FFE—will not impede gettering into the backside emitter region.

2. Claims 10 and 16 - ”first emitter region” and “second emitter region”

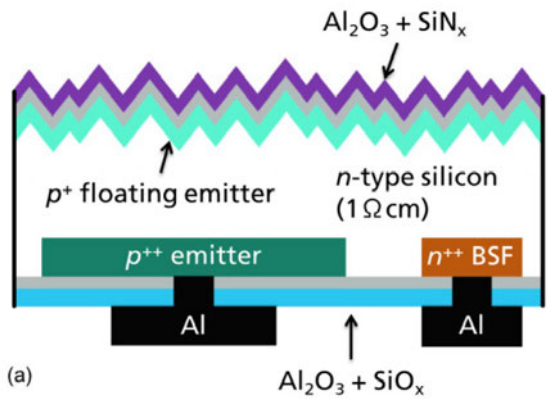
223. As I discussed above in ¶¶146-154, 186-191, Li disclosed a “first emitter region” and a “second emitter region” based on the usage of the term in the 315 Patent.

224. Muller’s descriptions of an “emitter” and “surface fields” are consistent with the common usage of these terms in the solar cell field. That is, “emitter” is usually used to refer to the doped region that has an opposite dopant polarity as the substrate, while “surface field” (either back or front) refers to the doped region that has the same dopant polarity as the substrate. However, as described in the 315 Patent, and as discussed above in ¶¶ 147-150, 204, the “p++ emitter” and “n++ BSF” regions on the backside of Muller would each be considered “emitter regions” as used by the 315 Patent. As described above with respect to the previous Li combinations, the P-type and N-type doped polysilicon regions in Li would be a “first emitter region” and “second emitter region,” as these are the same structure and arrangement as the oppositely doped P-type and N-type emitter regions (312, 314) described and claimed in the 315 Patent. As discussed above in ¶¶155-172, 186-193, each of Li’s polysilicon emitter regions would also necessarily and inevitably have metal impurities due to Li’s disclosed heating used to dope each region.

3. Claims 10 and 16 - metal contacts

225. As discussed above ¶¶173-177, 194-198, Li disclosed that first and second metal contacts are formed over the doped first and second emitter regions, respectively, of the back-contact solar cell.

226. Muller confirms that back-contact solar cells were known to include metal contacts formed over and connected to the N-doped and P-doped region of a back contact solar cell, as shown in Muller Fig. 3(a):



Muller specifically shows first and second metal contacts (each made of aluminum) positioned over and contacting the "p^{++} emitter" and the "n++ BSF" doped regions, respectively. Therefore, Muller would have confirmed to the Skilled Artisan that the "back-contact solar cell" of Li would similarly have a "first metal contact formed over the first emitter region," as claimed in Claim 10 of the 315 Patent, and a "second metal contact formed over the second emitter region," as claimed in Claim 16 of the 315 Patent.

227. To the extent that it is argued that that Li alone does not disclose the first and second metal contacts over the emitter regions, it would have been obvious to the Skilled Artisan to incorporate the positive and negative metal contacts of Muller over the doped emitter regions of Li, respectively, because they are both in the same particular field of back-contact solar cells and incorporation of such metal contacts was well known and also expressly recognized by Li as being part of any solar cell. Further, as seen from the many references I discussed for back-contact solar cells above, the Skilled Artisan would have known and recognized that two metallic contacts, each to contact one of the two emitter doped regions because positive and negative metal contacts are known to be necessary for a back-contact solar cell to perform its intended function, and therefore would have been motivated to employ them with the cell of Li.

4. Claim 13

228. Claim 13 recites: *"The solar cell of claim 10, wherein the portion of the silicon substrate comprises P-type dopants."*

229. In the combination of Li and Muller, the front portion of the silicon substrate would comprise ion-implanted boron, a P-type dopant (EX1005, ¶0037), because the boron-doped FFE, as taught by Muller would have replaced the diffused phosphorus doped front portion originally disclosed by Li, as discussed

above with respect to claim 10. Thus, the combination of Li and Muller satisfies the elements of claim 13.

5. Claim 14

230. Claim 14 recites: *"The solar cell of claim 10, wherein the portion of the silicon substrate comprises boron."* For the same reasons discussed in claim 13, the combination of Li and Muller disclosed the limitation of claim 14, that the front portion of the silicon substrate comprises boron because the combination uses the ion-implanted boron FFE of Muller for the back contact solar cell of Li.

VII. CLAIMS 10-15, 16, AND 19 WOULD HAVE BEEN OBVIOUS IN VIEW OF THE PREVIOUS COMBINATIONS, FURTHER IN VIEW OF HU AND RAMAPPA

231. In my opinion, any of the previous combinations in further view of Hu and Ramappa would have rendered Claims 10-15, 16, and 19 obvious.

232. I understand from counsel for CSI that Hu (EX1017) and Ramappa (EX1025) each qualifies as prior art, and I have been asked to assume them to be so.

233. The various combinations based on Li presented above disclose all limitations of the Claims 10-15, 16, and 19. To the extent it is disputed that claim 10's requirement that the "first emitter region having metal impurities" and claim 16's requirement that the "second emitter region having metal impurities" is inherently disclosed by Li alone, it would have been obvious to the Skilled Artisan

that such metal impurities would be present in the emitter regions due to gettering that occurs during Li's 950°C dopant diffusion step, as taught by Hu and Ramappa.

A. Hu (EX1017)

234. Hu is US Patent 4,053,335, entitled "Method of Gettering Using Backside Polycrystalline Silicon." EX1017(face). Hu issued October 11, 1977. EX1017(face). Accordingly, Hu issued decades before 2014.

235. Hu explained that heating a "semiconductor "body" and "polycrystalline layer" at 1000°C or less, results in "getterable impurities such as copper, lithium, sodium, potassium, iron, cobalt, nickel, chromium, and gold [diffusing] to, and becom[ing] trapped in, the polycrystalline silicon film." EX1017, 5:61-6:6. In particular, Hu described "gettering with a backside layer of polycrystalline silicon" to remove "unwanted impurities" from the semiconductor. *Id.* at Abstract. Hu described "deposition of a polycrystalline silicon film on a semiconductor wafer prior to any or some high temperature processing steps," after which "[t]he semiconductor body is then subjected to the normal semiconductor processing steps to form semiconductor devices on the surface opposite to the surface having the polycrystalline silicon layer." *Id.* Hu explained that "[d]uring these high temperature processing steps, unwanted impurities such as copper, iron, nickel, sodium and potassium ions move toward and into the polycrystalline silicon layer and thereby away from the semiconductor devices." *Id.*

B. Ramappa (EX1025)

236. Ramappa is a paper entitled "Diffusion of Iron in Silicon Dioxide." EX1025, 3773. Ramappa was published in 1999, years before 2014.

237. Ramappa observed that metal impurities such as iron "exhibit[] very high diffusivity (10^{-6} cm^2/s at 900°C) and solubility (2×10^{13} cm^{-3} at 900°C) in silicon." EX1025, 3773. Similarly, it noted that "[d]iffusion in SiO_2 of other metallic contaminants like Na, Au, Cu, Ni, Ag, Pd, and Ti have been studied." EX1025, 3773. Ramappa "present[ed] results on diffusion of iron in SiO_2 films grown on Si," showing that at the 950°C temperature used by Li, iron diffuses readily across even much thicker silicon dioxide layers (50-100nm) than the 1-2 nm layer used by Li. EX1025, 3773-3774, Fig. 1. I have added a red line to the Figure 1 of Ramappa reproduced below to show approximately where 1-2 nm thickness would be. And as seen from Figure 1 of Ramappa, at 950°C, iron would not be hindered at all by a silicon dioxide layer of 1-2 nm:

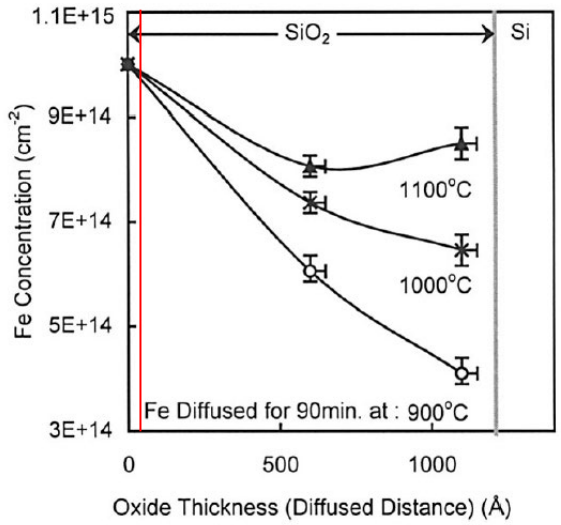


Figure 1. Iron concentration profile in SiO_2 following in-diffusion at temperatures of 900, 1000, and 1100°C for 90 min. Iron concentrations were measured by TXRF.

C. Motivation to Combine Li With Hu and Ramappa

238. As I discussed above in ¶¶87-92, integrating a gettering step into solar cell fabrication processes simultaneously with the diffusion step was well known in the art to yield advantages in solar cell performance due to the tendency of metal impurities to impact cell efficiency, particularly given the prevalence of multi-crystalline silicon substrates as of 2013 (over 65%). *See* EX1016, 696. It was known that multi-crystalline silicon substrates have substantial metal impurity concentrations (such as iron), as I discussed in ¶¶90-92. The Skilled Artisan would have had a strong motivation to getter metal impurities from the multicrystalline silicon substrate disclosed in Li to reduce their detrimental effect on the solar cell efficiency.

239. Incorporating the teachings of Hu and Ramappa using high temperature e.g., 900°C to 1,000°C gettering would have been obvious in view of

the similarities to Li's teaching to heat at 950°C. Specifically, Hu discloses gettering to a backside layer of polysilicon, just as Li also discloses a polysilicon layer on the backside. It would likewise be obvious to the Skilled Artisan that at the high temperature processing step disclosed by Hu and Li (*i.e.* above 900°C), the silicon dioxide layer would not hinder gettering, as shown by Ramappa, and thus would not deter the Skilled Artisan from gettering the metal impurities. Ramappa discusses the diffusivity of iron in silicon dioxide layers formed on silicon substrates and, based on its teachings, it would be apparent to the Skilled Artisan that iron would readily diffuse across the thin 1-2 nm silicon dioxide layer of Li into the doped polysilicon layer of Li, that is, into both doped polysilicon emitter regions of Li.

D. Reasonable Expectation of Success

240. The Skilled Artisan would have recognized that the combination of any of the above Li combinations with Hu and Ramappa would have been merely an arrangement of old elements (i.e., known gettering steps and temperatures) with each performing the same function it had been known to perform (the gettering of iron metal impurities into backside polysilicon layer) and yielding no more than what one would expect from such an arrangement (a solar cell with metal impurities being present in the backside polysilicon emitter regions).

241. The Skilled Artisan would have recognized from Hu and Ramappa that Li's description of heating to 950°C during the doping process (EX1005, ¶0045), would result in the gettering of metal impurities, such as iron, from silicon substrate, through the 1-2 nm dielectric layer, and into the two doped polysilicon emitter regions. Combining any of the above Li combinations with Hu and Ramappa as described here would have been well within the level of ordinary skill in the art as this would have required no material changes to the process of Li and therefore would have been done with a high expectation of success. It would also have been routine optimization for the Skilled Artisan to combine multiple heating steps into one single step for annealing such that the gettering and diffusion steps would all occur simultaneously, as was known in the art, and would have also conserved energy and cost. This would also have *not* resulted in any unpredictable results as seen from the teachings of Hu and Ramappa. Thus, the combination would simply have been the combination of prior art elements according to known methods to yield predictable results. Any adjustments, if needed at all, would have been routine and well within the level of skill of the Skilled Artisan.

E. Combining Hu and Ramappa With Any of the Previous Combinations Would Have Disclosed All Elements of the Challenged Claims

242. As I described above in ¶¶135-201, 220-230, the above combinations of King, Swanson-352, Marvin, or Muller with Li would have disclosed all

limitations of the Claims 10-15, 16, and 19. However, to the extent it is disputed that Li does not disclose Claim 10's requirement of *"a first emitter region having metal impurities ...*" and Claim 16's requirement of "*a second emitter region having metal impurities*," combining any of these combinations with the gettering teachings of Hu and Ramappa would have rendered a solar cell with these limitations obvious.

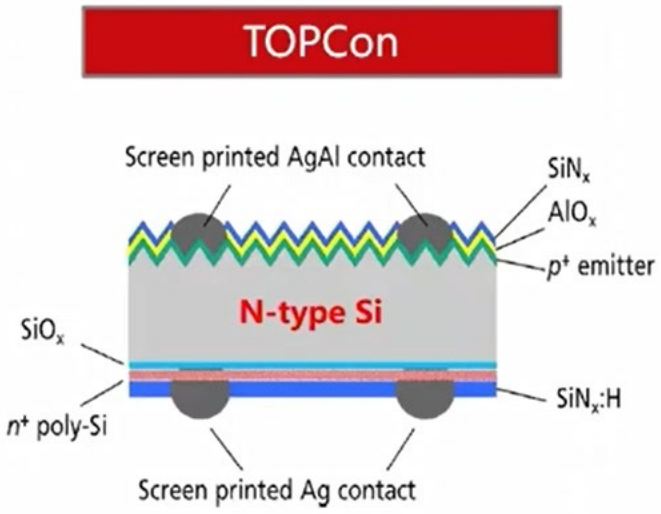
243. As discussed above, Hu and Ramappa confirm that Li's heating of the polysilicon material layer at 950°C during formation of the oppositely-doped polysilicon emitter regions would result in metallic impurities such as iron being gettered from Li's multicrystalline silicon substrate, through the 1-2 nm silicon dioxide layer, and into the doped emitter regions. Therefore, Hu and Ramappa in combination with Li would disclose these limitations.

VIII. SECONDARY CONSIDERATIONS

244. I am not aware of any objective evidence of non-obviousness that might support patentability of claims 10-15, 16, and 19 of the 315 Patent. I have not seen any evidence of commercial success attributable to the alleged invention. In fact, I understand that Maxeon does not contend that any of its current or prior products practice the inventions of the Asserted Claims, which include Claims 16 and 19. EX1070 at 8. This means to me that Maxeon has no product of its own

that it can point to as being commercially successful to support non-obviousness of the claims.

245. I understand that Maxeon has alleged that claims 16 and 19 are infringed by CSI's TOPCon solar cells. But based on my review of the schematic of CSI's TOPCon solar product that Maxeon has included in its complaint (reproduced below), CSI's TOPCon solar cell is a front contact solar cell (it has a metal contact of one polarity on the front side and a metal contact of the opposite polarity on the other side), and, notably, it does not have both positive and negative metal contacts on the backside of the solar cell, as required by Claims 16 and 19. CSI's TOPCon solar cell has the positive metal contact on the front side and the negative metal contact on the backside of the solar cell, and therefore cannot practice Claims 16 and 19, which are directed specifically to back-contact solar cells.



EX1013, 22.

246. Although the schematic shows two circular blocks labeled "Screen printed Ag contact" (singular) on the backside, these two blocks are in fact part of the same metal contact of negative polarity. They show up only as two blocks because the schematic is a cross-section diagram. When a front or back screen printed contact is viewed from the front or back, it is in fact a single metal contact of connected busbars and fingers. *See e.g.*, EX1011, 10-11 (Figures 6 and 7); EX1010, 276. And based on my understanding of the TOPCon structure, there is also no second doped region on the solar cell's backside polysilicon layer that can possibly form a "second emitter region," like in the 315 Patent.

247. Finally, there is no long and unfulfilled need for the claimed invention of Claims 16 and 19, as seen from the readily available teaching in the prior art of all aspects of solar cells according the claims of the 315 Patent. These teachings such as the optimal front dopant concentration for a back contact solar cell (King, Swanson-352, Marvin) or the gettering of metal impurities to the backside polysilicon of a silicon substrate (Hu), go back decades before 2014. Back-contact solar cell with backside polysilicon emitter region formed over a dielectric region was also well known and publicly disclosed even before 2014 (e.g., by Li (EX1005) and Swanson (EX1012)). These teachings demonstrate that the claimed invention simply followed conventional wisdom to reach results already predicted by the prior art.

APPENDIX A: Listing of the Claims 10-15 of the 315 Patent

APPENDIX B: List of Exhibits Considered

APPENDIX A

Listing of Claims 10-15 of the 315 Patent

Claim	Element
10[pre]	A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:
10[a]	a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3} and wherein the portion of the silicon substrate is formed at the front side of the solar cell;
10[b]	a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar;
10[c]	a first emitter region having metal impurities formed over the dielectric region; and
10[d]	a first metal contact formed over the first emitter region.
11	The solar cell of claim 10, wherein the portion of the silicon substrate comprises N-type dopants.
12	The solar cell of claim 10, wherein the portion of the silicon substrate comprises phosphorous.
13	The solar cell of claim 10, wherein the portion of the silicon substrate comprises P-type dopants.
14	The solar cell of claim 10, wherein the portion of the silicon substrate comprises boron.
15	The solar cell of claim 10, wherein the first emitter region comprises polysilicon.
16	The solar cell of claim 10, further comprising: a second emitter region having metal impurities formed over the dielectric region; and

	a second metal contact formed over the second emitter region.
19	The solar cell of claim 16, wherein the second emitter region comprises polysilicon.

APPENDIX B

List of Exhibits Considered

Exhibit #	Reference Name
1001	U.S. Patent No. 11,251,315 to Smith et al. ("315 Patent")
1002	File History of U.S. Patent Application No. 16/877,255
1003	Declaration of Sanjay Banerjee, Ph.D. Regarding U.S. Patent No. 11,251,315
1004	Curriculum Vitae of Sanjay Banerjee, Ph.D.
1005	U.S. Patent Pub. No. 2011/0214719, "Method of Fabricating a Back-Contact Solar Cell and Device Thereof." ("Li")
1006	King, Sinton and Swanson, "Studies of Diffused Phosphorous Emitters: Saturation Current, Surface Recombination Velocity, and Quantum Efficiency," IEEE Transactions On Electron Devices, Vol 37, No. 2 (Feb. 1990) ("King")
1007	Marvin and Froedge, "Interdigitated Back Contact Silicon Solar Cell Analysis and Design Recommendations for Space Use," AD-A220-414 (Sept. 30, 1989) ("Marvin-DTIC")
1008	Muller et al., "Ion Implantation for All-Alumina IBC Solar Cells with Floating Emitter," Energy Procedia 55 (2014), 265-271 ("Muller")
1010	Luque and Hegedus, Handbook of Photovoltaic Science and Engineering (2002) ("Luque")
1011	Neuhaus and Munzer, *Industrial Silicon Wafer Solar Cells*, Advances in OptoElectronics, 1-15, at 11 (2007) ("Neuhaus")
1012	U.S. Patent No. 7,468,485 to Swanson ("Swanson-485")
1013	Complaint, *Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.,* Case No. 2:24-cv-210 (E.D. Tex., filed March 25, 2024)
1014	U.S. Patent Pub. No. 2007/0256728
1015	U.S. Patent No. 4,234,352 ("Swanson-352")

Exhibit #	Reference Name
1016	Seibt et al., "Gettering in silicon photovoltaics: current state and future perspectives," phys. stat. sol. (a) 203, No. 4, 696–713 (2006) ("Seibt")
1017	U.S. Patent No. 4,053,335 to Hu ("Hu")
1018	Ferre, et al., Simultaneous gettering and emitter formation in multicrystalline-Si wafers by annealing phosphorus doped amorphous silicon compounds, Applied Physics Letters 98, 022102 (2011) ("Ferre")
1019	Vahanissi et al., Gettering of Iron in Silicon Solar Cells with Implanted Emitters, IEEE Journal of Photovoltaics (Volume: 4, Issue: 1, January 2014) ("Vahanissi")
1020	U.S. Patent Pub. No. 2010/0105190 A1 ("Tomas")
1021	Buonassisi, et al. "Transition metals in photovoltaic-grade ingot-cast multicrystalline silicon: Assessing the role of impurities in silicon nitride crucible lining material," Journal of Crystal Growth 287 (2006) 402–407 ("Buonassisi")
1022	2013 Renewable Energy Data Book, U.S. Department of Energy (2013) ("REDB-2013")
1025	Ramappa and Benley, Diffusion of Iron in Silicon Dioxide, Journal of the Electrochemical Society 146(1) 3773-3777 (1999) ("Ramappa")
1026	U.S. Patent Pub. No. 2006/0118868 A1 ("Yoshimura")
1028	Liu et al, Direct Observation of the Impurity Gettering Layers in Polysilicon-Based Passivating Contacts for Silicon Solar Cells, ACS Appl. Energy Mater. 2018, 1, 2275−2282 ("Liu-1")
1029	Liu et al, Effective impurity gettering by phosphorus- and boron-diffused polysilicon passivating contacts for silicon solar cells, Solar Energy Materials and Solar Cells 179 (2018) 136–141 ("Liu-2")
1035	Marvin and Froedge, "Analysis of Interdigitated Back Contact Silicon Solar Cells for Space Use," IEEE (1989) ("Marvin-IEEE")

Exhibit #	Reference Name
1036	Rohatgi et al, "High-Throughput Ion-Implantation for Low-Cost High Efficiency Silicon Solar Cells," Energy Procedia 15 (2012), 10-19 ("Rohatgi")
1040	NTIS Signed Attestation re: "Interdigitated Back Contact Silicon Solar Cell Analysis and Design Recommendations for Space Use" ("ADA220414")
1041	Kiyota et al., Phosphorus Direct Doping from Vapor Phase into Silicon for Shallow Junctions 141(8) 2241-2244 (August 1994) ("Kiyota")
1042	French, "Polysilicon: a versatile material for microsystems," Sensors and Actuators A 99 (2002) 3-12.
1043	Green, "Intrinsic concentration, effective densities of states, and effective mass in silicon," J. Appl. Phys. 67, 2944 (1990)
1044	Henry, "Limiting efficiencies of ideal single and multiple energy gap terrestrial solar cells," J. Appl. Phys. 51, 4494 (1980)
1045	Birkmire et al., "Harnessing the Sun with Thin-Film Photovoltaics," NREL (April 1999)
1046	Ghoshtagore, "Silicon Dioxide Masking of Phosphorus Diffusion in Silicon," Solid-State Elements Vol. 18 (1975)
1047	Muller et al., "Ion Implantation for All-Alumina IBC Solar Cells with Floating Emitter," Energy Procedia 55 (2014), 265-271, https://www.sciencedirect.com/science/article/pii/S1876610214013022 ("Muller Science Direct Webpage")
1070	Maxeon Disclosure of Asserted Claims and Infringement Contentions (dated 2024-07-12), *Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.,* Case No. 2:24-cv-210 (E.D. Tex.).