UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HANWHA SOLUTIONS CORPORATION,
Petitioner

v.

MAXEON SOLAR PTE. LTD.,
Patent Owner

Case IPR2024-01198
U.S. Patent No. 11,251,315

DECLARATION OF E. FRED SCHUBERT, PH.D. IN SUPPORT OF PATENT OWNER'S RESPONSE

Hanwha v. Maxeon, IPR2024-01198
Maxeon Ex. 2028

TABLE OF CONTENTS

I. Introduction....4
II. Summary of Opinions....4
III. Qualifications....5
IV. Documents Considered....9
V. Assumptions....11
A. Date of Invention....11
B. Person of Ordinary Skill in the Art....11
VI. Relevant Patent Law Standards....12
A. Obviousness....12
B. Inherency....14
C. Claim Construction....15
D. Standard of Proof....16
VII. The '315 Patent....16
A. Solar Cell Background....16
B. The '315 Patent's Novel Solar Cell Fabrication Technique....17
VIII. Claim Construction....18
A. "metal impurities"....18
1. A Goal of the '315 Patent Is to Transfer Undesired Metal Contaminants from the Substrate to the Emitters....19
2. The '315 Patent Uses "impurity" and "contaminant" Interchangeably....20
3. A Contaminant Is Commonly Understood to Be an Undesired Material....21
4. Disclaimer....22
B. All Other Claim Terms....23
IX. Petitioner Has Not Shown That Any Challenged Claim Is Unpatentable....23
A. Ground I....23

1. Claim 10 – Choi Does Not Disclose "metal impurities" 24
2. Claim 10 – The Proposed Choi-Istratov Combination Fails to Satisfy the "first emitter region" Limitation 26
3. Claim 10 – It Would Not Have Been Obvious to Implement Choi with the Claimed Doping Concentration.....31
4. Claims 13 and 14 – It Would Not Have Been Obvious to Implement a p-Type Dopant (For Example Boron) with All Other Claim Limitations.....48
5. Claim 16 – Ground I Fails to Satisfy the "second emitter region having metal impurities" 50
B. Ground II 52
C. Ground III 53
1. Claim 10 – The Proposed Cousins-Istratov Combination Fails to Satisfy the "first emitter region" Limitation 53
2. Claim 10 – It Would Not Have Been Obvious to Implement Cousins with the Claimed Doping Concentration.....54
3. Claims 13 and 14 – It Would Not Have Been Obvious to Implement a p-Type Dopant (For Example Boron) with All Other Claim Limitations.....56
X. Conclusion 57

I, E. Fred Schubert, Ph.D., declare as follows:

I. INTRODUCTION

1. I have been asked by counsel for Patent Owner Maxeon Solar Pte. Ltd. ("Patent Owner") to provide my opinions on certain matters raised in the Petition for Inter Partes Review in IPR2024-01198 (Paper No. 1, "the Petition") filed by Petitioner Hanwha Solutions Corporation ("Petitioner") with respect to U.S. Patent No. 11,251,315 ("the '315 patent"), the declaration of Zachary Holman, Ph.D. (Ex. 1003), the Decision Granting Institution of Inter Partes Review (Paper No. 17), the transcript of the deposition of Dr. Holman taken on May 1, 2025, and other related materials cited in this declaration. This declaration sets forth the opinions that I have reached to date regarding these matters.

2. I am not employed by Patent Owner or any affiliate or subsidiary thereof. I do not have a financial interest in Patent Owner.

3. My independent expert consulting services are being billed at my standard rate of $800/hr (plus reasonable expenses). My compensation is not contingent on the outcome of this matter or on the content of my review, analysis, or testimony.

II. SUMMARY OF OPINIONS

4. As set forth in detail below, in my opinion, claims 10-20 of the '315 patent are not unpatentable in view of the grounds set forth in the Petition.

III. QUALIFICATIONS

5. A true and correct copy of my *curriculum vitae* (CV) is included as Ex. 2029. The following is a brief summary of my relevant qualifications and professional experience.

6. I am currently an active tenured full Professor in the Department for Electrical, Computer, and Systems Engineering at the Rensselaer Polytechnic Institute (RPI) located in Troy, New York. My major faculty activities are teaching, research, intramural and extramural service, and consulting.

7. I received a Bachelor's Degree in Electrical Engineering from the University of Stuttgart, Germany, in 1978. I received a Master's Degree in Electrical Engineering from the University of Stuttgart in 1981. I then joined the Max Planck Institute for Solid-State Research, Stuttgart, as a Member of the Scientific Staff, and, from 1981 to 1985, conducted research for which I received a Ph.D. degree in Electrical Engineering from the University of Stuttgart.

8. In 1985, subsequent to my tenure at the Max Planck Institute, I joined AT&T Bell Laboratories in Holmdel and Murray Hill, New Jersey, initially as a post-doctoral Member of Technical Staff. About two years later, in 1988, I became a Member of Technical Staff, Principal Investigator, and Member of Management. I worked at AT&T Bell Laboratories for 10 years, until 1995.

9. In 1995, I joined academia. My first position was at Boston University (Boston, MA), where I worked as a full professor for seven years. At Boston University, I directed the Semiconductor Devices Research Laboratory and co-directed (with Professor Jan G. Smits) the Silicon Integrated Circuit Processing Facility.

10. In 2002, I joined Rensselaer Polytechnic Institute (RPI) as a distinguished professor, the Wellfleet Senior Constellation Professor with appointments in the Department for Electrical, Computer, and Systems Engineering and the Department for Physics, Applied Physics and Astronomy. During my tenure at RPI, I held various leadership positions, including Head of the Future Chips Constellation and Director of the Smart Lighting Engineering Research Center (Smart Lighting ERC) that was funded by the U.S. National Science Foundation at a volume of $40 million for over 10 years.

11. I am named as inventor or co-inventor of 39 U.S. patents and have co-authored more than 300 publications. I authored the books “Doping in III-V Semiconductors” (1993), “Delta Doping of Semiconductors” (1996), “Physical Foundations of Solid-State Devices” (2015 and 2022) and the first, second and third editions of “Light-Emitting Diodes” (2003, 2006 and 2018); the latter book is known as a standard textbook in the field of LEDs, and the book has been translated into Russian, Japanese and Korean. My publications have been well

recognized by the technical community as illustrated by the more than 45,000 citations that my publications have received.

12. I received several awards for my technical contributions. They include: Senior Member IEEE (1993); Literature Prize of Verein Deutscher Elektrotechniker for my book "Doping in III-V Semiconductors" (1994); Fellow SPIE (1999); Alexander von Humboldt Senior Research Award (1999); Fellow IEEE (1999); Fellow OSA (2000); Boston University Provost Innovation Award (2000); Discover Magazine Award for Technological Innovation (2000); R&D 100 Award for RCLED (2001); Fellow APS (2001); RPI Trustees Award for Faculty Achievement (2002 and 2008); Honorary Membership in Eta Kappa Nu (2004); 25 Most Innovative Micro- and Nano-Products of the Year Award of R&D Magazine (2007); and Scientific American 50 Award (2007).

13. My general expertise is in the field of electrical engineering and applied physics including semiconductor materials, semiconductor physics, processing, and devices.

14. I have worked on multiple aspects of solar cell technology. My research, teaching, and consulting activities included electrical aspects of solar cells, optical aspects of solar cells, as well as manufacturing aspects of solar cells. My work activities in solar cells are reflected in my publication activities that include multiple publications on anti-reflection coatings.

15. My work activities on the electrical aspects of solar cells focused on the doping of solar cells including the employment of highly doped regions and doping with a concentration gradient to promote carrier transport over the pn junction barrier and over the contact barriers to demonstrate solar cells with a high efficiency. The base materials of solar cell materials I developed included single-crystal silicon, poly-crystalline silicon, as well as III-V semiconductors. I have conducted research on ohmic metal-to-semiconductor contacts having an insulating interface layer (such as TiO_2, SiO_2 and Si_3N_4) that de-pins the Fermi level, passivates the semiconductor surface, and allows for the tuning of the Schottky barrier height by selection of metals with suitable metal work functions.

16. My work activities on the optical aspects of solar cells included the design and fabrication of low-reflectivity optical coatings that minimize Fresnel reflection losses. The anti-reflection coatings included multiple layers having a carefully designed refractive index sequence, so as to minimize optical reflections over a broad wavelength range, as is desirable for the broad spectral band of solar radiation (ranging from the infrared to the ultraviolet).

17. My work activities on the manufacturing aspects of solar cells included ohmic contacts made by diffusion rather than implantation processes. Furthermore, my activities included manufacturing feasibility studies for graded-index optical coatings that possess a high degree of porosity, which may reduce the

mechanical strength of the coatings. Finally, my activities included manufacturing efficiency considerations, such as throughput considerations as well as reliability considerations.

18. As Director and Principal Investigator of the Smart Lighting Engineering Research Centre, funded by the US National Science Foundation, I have directed research on LEDs for use in intelligent or "smart" lighting systems. Such smart lighting systems have functionalities that go beyond lighting and include, for example, the tuning of the color temperature, as well as communication with lighting sources.

IV. DOCUMENTS CONSIDERED

19. In preparing this declaration and in forming the opinions set forth in this declaration, I reviewed the documents cited in this declaration, including the following:

Paper / Exhibit	Description
Paper 3	Petition for Inter Partes Review of U.S. Patent No. 11,251,315
Paper 17	Decision Granting Institution of *Inter Partes* Review
Ex. 1001	U.S. Patent No. 11,251,315 ("the '315 patent")
Ex. 1002	File History of U.S. Patent No. 11,251,315
Ex. 1003	Declaration of Dr. Zachary Holman Regarding Claims 10-20 of U.S. Patent No. 11,251,315
Ex. 1006	U.S. Pub. No. 2014/0311567 to Choi et al. ("Choi")
Ex. 1007	U.S. Patent No. 8,207,444 to Cousins ("Cousins")
Ex. 1008	Marvin and Froedge, "Interdigitated Back Contact Silicon Solar Cell Analysis and Design Recommendations for Space Use," Space Systems Division Air Force Systems Command (1989) ("Marvin")

Paper / Exhibit	Description
Ex. 1010	Granek, "High-Efficiency Back-Contact Back-Junction Silicon Solar Cells," Dissertation ("Granek")
Ex. 1011	U.S. Pub. No. 2013/0240029 to Smith ("Smith")
Ex. 1012	Istratov, et al., "Gettering in Silicon-on-Insulator Wafers: Experimental Studies and Modelling," Semicond. Sci. Technol. 20 (2005), pp. 568-575 ("Istratov")
Ex. 2002	Lamers et al., "Towards 21% Efficient N-CZ IBC Based on Screen Printing," *26th European Photovoltaic Solar Energy Conference and Exhibition*, (2011) ("Lamers")
Ex. 2003	Desa et al., "Optimization of p-type Screen Printed Interdigitated Back Contact Silicon Solar Cell with Aluminum Back Surface Field," *International Journal of Engineering & Technology IJET-IJENS*, 14(2) (2014) ("Desa")
Ex. 2005	Procel et al., "Analysis of the Impact of Doping Levels on Performance of Back Contact – Back Junction Solar Cells," 4th International Conference on Silicon Photovoltaics, SiliconPV 2014, Italy, 2014, pp 128-132, ScienceDirect ("Procel")
Ex. 2030	McGraw-Hill Dictionary of Scientific and Technical Terms, 6th ed. (2003)
Ex. 2031	Merriam-Webster's Collegiate Dictionary, 11th ed. (2006)
Ex. 2033	Coletti, G., "Sensitivity of State-of-the-Art and High Efficiency Crystalline Silicon Solar Cells to Metal Impurities," Prog. Photovolt: Res. Appl. 2013; 21, pp. 1163-1170
Ex. 2034	Vossier, A., et al., "Is Auger Recombination the Ultimate Performance Limiter In Connector Solar Cells?" Applied Physics Letters 97, 193509 (2010)
Ex. 2035	Korte, L., et al., "Surface Photovoltage Investigation of Recombination at the a-Si/c-Si Heterojunction," Thin Solid Films 517, pp. 6396-6400 (2009)
Ex. 2036	Cuevas, A., et al., "Extraction of the Surface Recombination Velocity of Passivated Phosphorus-Doped Silicon Emitters" ("Cuevas")
Ex. 2037	Transcript of deposition of Zachary Holman, Ph.D. taken May 1, 2025

Paper / Exhibit	Description
Ex. 2038	https://www.ioffe.ru/SVA/NSM/Semicond/Si/electric.html (accessed 2025-05-20)

V. ASSUMPTIONS

A. Date of Invention

20. I have been asked to assume that the date of the inventions of the claims of the ’315 patent was December 22, 2014.

B. Person of Ordinary Skill in the Art

21. I have been asked to assume that a person having ordinary skill in the art (POSITA) is as described in the Petition, *i.e.*, a person that had “(1) an advanced degree in electrical engineering, mechanical engineering, applied physics, chemistry, materials science, or a related discipline and (2) at least one year of experience designing, developing, or researching the design and/or manufacture of solar cells or related technologies” or, alternatively, “(1) a bachelor’s degree in one of the aforementioned disciplines and (2) at least two years of experience designing, developing, or researching the design and/or manufacture of solar cells or related technologies.”

22. At the time of the invention of the claims of the ’315 patent, I possessed at least such knowledge and experience. Further, I was aware of the understandings and capabilities of a person having the skill level described above.

VI. RELEVANT PATENT LAW STANDARDS

23. I have relied upon the following understandings of the applicable legal standards in reaching my opinions set forth in this declaration.

A. Obviousness

24. I have been informed that a patent claim is invalid as being obvious in view of the prior art if the differences between the patented subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time of the invention to a person having ordinary skill in the art. In making a determination of obviousness, I understand that the following factors are analyzed: (i) the scope and content of the prior art; (ii) the differences, if any, between the prior art and the claims at issue; (iii) the level of ordinary skill in the pertinent art; and (iv) objective evidence of non-obviousness, if any exists.

25. I have been informed that the following rationales are some of the acceptable bases for the conclusion that a claim is obvious: (i) the claimed invention is simply a combination of prior art elements joined according to known methods to yield predictable results; (ii) the claimed invention is a simple substitution of one known element for another to obtain predictable results; (iii) the claimed invention uses known techniques to improve similar devices (methods, or products) in the same way; (iv) the claimed invention was "obvious to try" because it was a choice from a finite number of identified, predictable solutions, with a

reasonable expectation of success; (v) there is known work in one field of endeavor that would have prompted variations of it for use in either the same field or a different one based on design incentives or other market forces, and the variations would have been predictable to a POSITA; or (vi) there is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art references or to combine prior art reference teachings to arrive at the claimed invention.

26. I have been informed that in order for a patent claim to be considered obvious, at the time the invention was made, each and every limitation of the claim must be present within the prior art, or within the prior art in combination with the general knowledge held by a POSITA, and that such a person would have a reasonable expectation of success in combining these teachings to achieve the claimed invention. I also understand that the reason to select and combine features, the predictability of the results of doing so, and a reasonable expectation of success of doing so may be found in the teachings of the prior art themselves, in the nature of any need or problem in the field that was addressed by the patent, in the knowledge of a POSITA in the field at the time, or within the common sense or creativity possessed by a POSITA. There need not be an express or explicit suggestion to combine references.

27. I understand that substituting one known element for another known element may have been obvious when it leads to reasonably predictable results.

28. I understand that a combination of elements may have been obvious when a POSITA has a good reason to pursue the combination, which is among a finite number of known options within his or her technical grasp, and leads to reasonably expected results.

29. A prior art reference may teach away when a POSITA would be discouraged from following the path set out in the reference or would be led in a direction divergent from the path that was taken in the claimed invention. The mere disclosure of more than one alternative does not necessarily constitute a teaching away from alternatives that are not disclosed when the prior art does not criticize, discredit, or otherwise discourage the solution claimed in the alleged invention. Similarly, a prior art reference that merely expresses a general preference for one option does not necessarily teach away from all other options.

B. Inherency

30. I have been informed that a reference may disclose a limitation either explicitly or inherently. When a reference does not disclose a limitation explicitly, the doctrine of inherency may be relied upon only when the reference necessarily would have included or resulted in the unmentioned feature or quality. The fact

that a certain thing may result—or even probably would result—from a given set of circumstances is not sufficient to render the result inherent.

31. I have been informed that inherency is not proven by showing that a particular feature would be more cost-effective. Stated differently, a reference does not inherently disclose a feature if implementing an embodiment of that reference in an allegedly cost-effective manner.

32. I have been informed that inherency is not proven by showing that an undetectable or unrecognized *de minimis* quantity may result.

C. Claim Construction

33. I understand that patent claim terms are generally given their ordinary and customary meaning as understood by a POSITA when read in the context of the specification and prosecution history. Two exceptions are when (1) the patentee acts as their own lexicographer, or (2) the patentee disavows the full scope of the claim term.

34. I also understand that, in construing the claims, the analysis should focus on the words of the claims. However, patent claims are not read in a vacuum and should instead be read in view of the specification and prosecution history, i.e., the back-and-forth correspondence between the patent applicant and the U.S. Patent and Trademark Office. I further understand that the patent specification is the single best guide to the meaning of a claim term. Thus, a construction that is

not supported by the specification should be rejected, even if that construction is plausible, if divorced from the specification. However, it is improper to read limitations from the specification into a claim absent a clear indication in the intrinsic record that the patentee intended the claims to be so limited. To conclude, the interpretation to be given a claim term can be determined and confirmed only with a full understanding of what the inventors actually invented and intended to envelop with the claim.

D. Standard of Proof

35. I understand that the standard to prove unpatentability is by a preponderance of the evidence, which means more likely than not.

VII. THE ’315 PATENT

A. Solar Cell Background

36. When a photon impinges upon a solar cell, it may separate an electron from the remainder of an atom. This creates a floating electron (negatively charged) and a floating hole (positively charged). If the electron and hole are collected by emitters before combining, a voltage difference can be achieved, thereby permitting electric current.

37. An important consideration in solar cell design is carrier “lifetime,” which refers to the time during which an electron (or hole) lasts by itself before recombining with its oppositely-charged counterpart. Techniques that increase

lifetime are the passivation of surfaces and interfaces, the doping of near-surface regions, and the minimization of unwanted contaminants.

B. The ’315 Patent’s Novel Solar Cell Fabrication Technique

38. The ’315 patent discloses a novel solar cell and method of manufacturing a solar cell. Among other things, the ’315 patent discloses four example processes of manufacturing a solar cell where two parameters were varied: the dopant concentration and the temperature of a heat treatment step. The results of those processes are summarized in Figure 11 of the ’315 patent.

39. In Example Processes A and C, a dopant concentration of 2×10^{18} cm^{-3} was used. In Example Processes B and D, a dopant concentration of 4×10^{18} cm^{-3} was used. In Example Processes A and B, the heat treatment step occurred at a temperature less than 900°C. In Example Processes C and D, the heat treatment step occurred at a temperature greater than 900°C. (Figure 11 includes a typographical error in the rows for Example Processes C and D. The value in the “Temp” column should be “> 900 deg-C.”)

40. The best results were achieved from Example Process C. In that process, unwanted impurities were found to have been gettered from the substrate to a polysilicon layer. Further, the surface passivation was found to be good. Accordingly, a 0.5% increase (“+0.5 % abs.”) in efficiency above the baseline was

achieved. Based on Figure 10 of the '315 patent, this corresponds to a relative efficiency increase of about 0.5% / 24% = 2.1%.

VIII. CLAIM CONSTRUCTION

A. "metal impurities"

41. I have been asked to opine on the proper construction of the term "metal impurities." That term appears in challenged claims 10 and 16.

42. In my opinion, a POSITA would have understood the term to mean "undesired foreign metals." Within the context of this construction, an "undesired" metal is one that would be deleterious to the solar cell.[1] A POSITA would understand what metals are deleterious with reasonable certainty. For example, the presence of iron, nickel, or chromium in a semiconductor substrate would accelerate premature recombination and thus would be undesired. On the other hand, a dopant that is purposefully introduced, such as a donor or acceptor dopant introduced into a region that is meant to conduct electricity or to prevent recombination would not be undesired. Further, for purposes of this construction, and within the context of claims 10 and 16, "foreign" means different than the material that forms the first emitter region (typically silicon doped with donors or

[1] Accordingly, another suitable construction for "metal impurities" is "deleterious foreign metals."

acceptors[2]) (claim 10) and the second emitter region (claim 16). Specifically, the construction should not include purposefully introduced dopants, such as Al and Ga, which are well-known dopants in Si. This opinion is based on the following.

43. Generally, in the solar cell field, "impurities" can refer either to (1) an undesired material (undesired trace substances) within another material or (2) any material (any trace substances) within another material. These meanings are of different scopes, i.e., the second meaning is broader and subsumes the first. In my opinion, both meanings of "impurities" are plain and ordinary, and the term is commonly used in the solar cell field to refer to both meanings.

44. A POSITA would have understood that the inventors of the '315 patent use "impurities" to have the first plain and ordinary meaning. This is evident from the following.

1. A Goal of the '315 Patent Is to Transfer Undesired Metal Contaminants from the Substrate to the Emitters

45. The '315 patent recognizes that certain metal impurities in the substrate impede efficiency. '315 patent at 5:1-7 (observing that metal impurities can be sources of recombination resulting in lower solar cell efficiency). Fe (iron),

[2] It is well known that the group-III elements boron, aluminum, gallium and indium are acceptor dopants in silicon, whereas the group-V elements nitrogen, phosphorus, arsenic, antimony and bismuth are donor dopants in silicon.

Ni (nickel), and Cr (chromium) are examples of such unwanted deleterious impurities. (’315 patent at 4:65-5:1) Accordingly, a goal of the ’315 patent is to increase efficiency by “getter[ing] impurities to the emitter region.” ’315 patent at Abstract. Stated differently, a central purpose of the ’315 patent is to move undesired foreign metal atoms from the substrate to a region where they are less deleterious. This is consistent with the meaning of “metal impurities” as undesired foreign metals.

2. The ’315 Patent Uses “impurity” and “contaminant” Interchangeably

46. The ’315 patent equates an impurity and a contaminant. During his deposition, Dr. Holman stated that “contaminant” has a negative connotation (“Typically contaminant sounds like it has a negative connotation.” Ex. 2037 (Holman Depo. Tr.) at 114:8-9.) I agree with Dr. Holman in this regard. The negative connotation is reinforced by the usage of “gettering” which refers to the trapping or binding of contaminants in places where they are less harmful. In stark contrast, “dopant” does not have a negative connotation.

47. First, the ’315 patent states that “[a]s referred throughout, contaminants and/or impurities can be used interchangeably.” ’315 patent, 5:8-9. The term “throughout” includes the claims of the ’315 patent.

48. Second, the ’315 patent describes the same reference numbers as both contaminants and impurities. ’315 patent at 4:65-66 (“[T]he silicon substrate 202

can have contaminants and/or impurities 220."), 6:57-60 ("In an example, 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."), 8:16-19 ("In an example, impurities and/or contaminants 520, e.g. metal impurities and/or contaminants, can be located in the second emitter region 512 as shown.").

49. By contrast, the '315 patent does not equate an impurity and a dopant (which is desired and is purposefully introduced). Accordingly, intentionally added group III metal dopants (such as Al and Ga) and Group V metal dopants (such as Bi) are not unwanted impurities.

3. A Contaminant Is Commonly Understood to Be an Undesired Material

50. In the solar cell field, a contaminant is understood to be a material that has deleterious effects and is thus undesired.

51. The McGraw-Hill Dictionary of Scientific and Technical Terms (Ex. 2030) defines the verb "contaminate" as "To render unfit or to soil by the introduction of foreign or ***unwanted material***." That definition is proper in the solar cell field, i.e., a POSITA would similarly understand the action of to "contaminate" as the introduction of an undesired foreign material. A similar understanding of the noun contaminant would similarly apply, i.e., an undesired foreign material that is introduced into another material.

52. The general understanding of "contaminant" is consistent with dictionary definitions. The Merriam-Webster's Collegiate Dictionary (Ex. 2031) includes the following definitions for "contaminate": "to soil, stain, corrupt, or infect by contact or association," "to make inferior or impure by admixture," and "to make unfit for use by the introduction of unwholesome or ***undesirable elements***." Ex. 2031 at p. 269. That same dictionary defines "contaminant" as "something that contaminates." *Id.* Accordingly, a contaminant would be understood to include undesirable elements.

53. That the '315 patent uses the expression "and/or" does not suggest impurity and contaminant are alternatives. The '315 patent explicitly declares that "contaminants ***and/or*** impurities can be used interchangeably." '315 patent, 5:8-9 (emphasis added). In view of this, a POSITA would understand that the patentee uses "and/or" to show equivalence between contaminants and impurities, not to distinguish the two.

4. Disclaimer

54. Although I do not believe that "impurity" has only one plain and ordinary meaning and that such meaning broadly encompasses any material (whether beneficial and desired or deleterious and undesired), even if that were the case, in my opinion, the inventors of the '315 patent clearly and unmistakably use "metal impurities" in a narrower sense, i.e., to refer to only those metals that are

undesired and foreign to a host material. For example, transition metals such as Fe, Ni, or Cr are undesired metal impurities in Si, whereas elements such as B, Al, and Ga (acceptors in Si) and P and As (donors in Si) are desired dopants in Si. To conclude, it is beneficial to distinguish between dopants (desired and intentionally introduced) and contaminating impurities (undesired and not intentionally introduced). Not making this distinction would in my view result in a misunderstanding of the ’315 patent. For example, the ’315 patent does neither teach nor claim the gettering of dopants.

B. All Other Claim Terms

55. For all other claim terms, I have been asked to apply the plain and ordinary meaning of the terms of the challenged claims as those terms would have been understood by a POSITA at the time of the invention (i.e., in 2014).

IX. PETITIONER HAS NOT SHOWN THAT ANY CHALLENGED CLAIM IS UNPATENTABLE

A. Ground I

56. Ground I is unavailing because it fails to show satisfaction of two limitations of claim 10: “a first emitter region having metal impurities formed over the dielectric region” and “a portion of the silicon substrate has a dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3}.” Because all other challenged claims depend from claim 10, the entirety of Ground I fails.

Ground I suffers from additional shortcomings with respect to claims 13, 14, and 16, as discussed below.

1. Claim 10 – Choi Does Not Disclose "metal impurities"

57. Under the proper construction of "metal impurities," i.e., "undesired foreign metals," Choi fails to disclose the feature "a first emitter region having metal impurities." Petitioner contends that Choi's second conductive type area 34 corresponds to the "first emitter region" of claim 10. Petition at 54. However, the dopants that are added to Choi's second conductive type area are not undesired foreign metals. Rather, they are dopants that are purposefully introduced. Ex. 1006 (Choi) at ¶ [0037]. In particular, a POSITA would understand that such dopants include n-type and p-type dopants that provide n-type and p-type conductivity, respectively. A POSITA would understand well-established differences between desired dopants and undesired contaminating impurities with the former ones providing electrical conductivity and the latter ones being "sources of recombination, resulting in poor lifetime" as taught in the '315 patent ('315 patent, 5:3-4). Dopants in Si (a group-IV element) are selected from group III and V and include B, Al, Ga and In (group-III) as well as P, As, Sb and Bi (group-V). Some of these dopants, for example Al, Ga, In and Bi, are metals. Dopants and contaminating metal impurities have diametrically opposing characteristics (desired versus undesired) and a POSITA would distinguish between them, and not

categorize them as the same type of impurity as Petitioner appears to suggest. Choi's substrate region has a first conductivity type (for example, n-type), whereas Choi's second conductive type region 34 has a second conductivity type (for example, p-type). In combination, the two regions form a pn-junction that serves to separate photo-generated electron-hole pairs thereby generating a photovoltage. I note the dopants in Choi's region 34 establish the second conductivity type and cause the solar cell to function properly.

58. I finally note that Dr. Holman makes multiple statements about the "emitter" of a solar cell. During his deposition, he stated: "And I note that in this field, the word emitter [...] is typically understood to have the opposite doping of the absorber, which [...] is a silicon wafer, also referred to sometimes as the 'substrate' [...]" (Ex. 2037 (Holman, Depo. Tr.) at 19:6-13) In his Declaration, he states: "In the field of solar cell technology, 'emitter' usually refers to the region or layer that is oppositely doped from the substrate." (Ex. 1003 (Holman Decl.), para. 58) However, Dr. Holman is contradicted by his own reference, the Choi reference, which states: "**The base area 110 may have an n-type impurity as the first conductive-type dopant**. As a result, the second conductive type area 34 [...] may be a p-type. [...] As a result, the **first conductive type area 32 serving as an emitter** [...]" (Emphasis added) (Ex. 1006, Choi, para. [0026])

2. Claim 10 – The Proposed Choi-Istratov Combination Fails to Satisfy the "first emitter region" Limitation

59. Petitioner states, "To the extent Patent Owner contends that the claimed 'metal impurities' must be elements other than Group III or V elements, Choi in combination with Istratov teaches and renders obvious a first emitter having metal impurities." Petition at 55. I understand that Patent Owner has not argued that "metal impurities" necessarily must be metals other than Group III or V elements. A POSITA would not understand the claimed "metal impurities" to include metal dopants such as Al, Ga, In, and Bi.

60. Regardless, I disagree with the suggestion that "Choi in combination with Istratov teaches and renders obvious a first emitter having metal impurities." Petition at 55. Petitioner does not clearly explain what it contends "Choi in combination with Istratov" is. Nevertheless, I disagree that a POSITA would have been motivated to incorporate the teachings of Istratov in Choi for the following reasons.

a. Istratov Is Not Analogous Art

61. Istratov is not related to solar cell technology. Instead, it relates to silicon-on-insulator (SOI) and separation by implanted oxygen (SIMOX) technology in connection with silicon integrated circuits, not solar cells. Silicon integrated circuits do not involve optics. In fact, light is prevented from entering integrated circuits because light is detrimental to integrated circuits. A POSITA

would understand that integrated circuits are encapsulated in opaque packages to shield the integrated circuit from light. In contrast, solar cells are designed to absorb light. Further, Istratov employs a buried oxide (BOX) layer whereas Choi employs a tunneling oxide layer. The tunnelling oxide relies on electrical conductivity by way of the tunneling effect (and would not function without tunneling), whereas Istratov's BOX layer is an insulating layer and does not permit tunneling. Ex. 1012 (Istratov) at p. 568 ("The BOX layer not only provides electrical isolation between the top Si layer and the substrate . . .").

62. Istratov teaches BOX oxide thickness values of at least 200 nm. Ex. 1012 (Istratov) at Figs. 2, 3 (disclosing BOX oxide thicknesses of 200 nm and 1300 nm, respectively). Choi teaches tunnel oxide thickness values of "0.5 nm to 5 nm (for example, 1.0 nm to 4 nm)." Ex. 1006 (Choi) at ¶ [0034]. Thus, Choi's tunnel oxide thicknesses are 40 to 2,600 times thinner than Istratov's BOX oxide thicknesses.

63. Finally, Istratov gives no indication that it is related to solar cell technology. Accordingly, Istratov is not analogous to the '315 patent.

b. Istratov's Goals Are Opposite to Those of the '315 Patent

64. Istratov is directed at gettering impurities from a device layer to a silicon substrate. Ex. 1012 (Istratov) at p. 568 ("The BOX layer . . . introduces a barrier for diffusion of metal impurities from the device layer to the gettering sites

in the substrate. This barrier may render inefficient the traditional gettering techniques, which use intentionally introduced precipitation / segregation sites for metals in the bulk of the wafer or on its back surface.").

65. Istratov teaches "gettering sites in the substrate" and "intentionally introduced precipitation / segregation sites for metals in the bulk of the wafer or on its back surface" so that metal contaminants are extracted from the "device layer" and are gettered at "gettering sites in the substrate." Istratov states: "Buried oxide, which separates the device area from the substrate in silicon-on-insulator (SOI) wafers, forms a diffusion barrier for transition metals in silicon. The impact of this barrier on the efficiency of traditional gettering techniques for iron and copper is evaluated using computer modelling." (Istratov, Abstract) That is, Istratov investigates if the thick BOX barrier layer would negatively impact the extraction of unwanted impurities from the device layer to getter them in the substrate.

66. In contrast, the '315 patent teaches to extract metal contaminants (such as Fe, Ni, or Cr) out of the substrate to getter them in the thin poly-Si layer above the tunneling oxide. Extracting metal contaminants (such as Fe, Ni, or Cr) from the substrate increases the carrier lifetime in the substrate thereby improving the solar cell efficiency.

c. It Would Not Have Been Obvious to Implement Istratov in Choi

67. Petitioner fails to show that gettering would have been required in Choi. A POSITA would not have been motivated to modify Choi by implementing a procedure similar to Istratov's experiment described in Section 4 to Istratov. Petitioner fails to show that Choi includes metal impurities in its silicon substrate 10 much less that the level of any such impurities would be high enough that would prompt the need for gettering.

68. In this regard, I note that Dr. Holman opines that "It was known by the earliest possible priority date that wafer manufacturing and subsequent device fabrication on the wafer ***could*** introduce metal impurities into silicon-based semiconductor devices" and that "[g]ettering was ***only required*** in solar cells with ***significant*** metal impurity levels in the wafer." Ex. 1003 (Holman Dec.) at ¶ 83. In that passage, Dr. Holman seems to recognize that a significant level of metal impurities—such that gettering would be required—was not inevitable in 2014. I agree. It was known that silicon wafers could be cleaned after sawing to remove impurities that were introduced during such sawing. *See, e.g.*, Ex. 1084 at 2 ("After etching, the wafer is cleaned to remove metal and organic contaminants that would cause an increase of surface and bulk recombination during the following high-temperature process steps."). Similarly, it was known that silicon wafers with low contaminant concentrations could be employed. For example, Ex.

2033 discloses a silicon wafer with iron in only one part per 100 billion (caption of Figure 3, noting iron concentration of 5×10^{11} cm^{-3}). I note that Petitioner's theories are based on hindsight. That is, in my opinion, a POSITA would not have thought to combine the teachings of Choi and Istratov unless first made aware of the invention of the '315 patent and then directed to arrive at a combination that would include all of the elements of the '315 patent claims.

69. Further, even if Istratov's teachings were incorporated into Choi, it would result in the movement of impurities originally in Choi's first and second conductive regions 32, 34 into Choi's semiconductor substrate 10. Petitioner has not provided any alleged motivation for that, and I am not aware of any. Further, such a process would result in the opposite of what claim 10 requires because it would remove impurities from Choi's first and second conductive regions 32, 34.

70. Further, a POSITA would hesitate to subject the solar cell of Choi to the elevated temperatures and prolonged times that Istratov discloses in connection with the experiments undertaken in Section 4, i.e., 1020°C for 8 hours (for iron) or 690°C for 5 hours (for copper) and 1150°C for 2 hours (for copper). *See* Ex. 1012 (Istratov) at 570-571. Such a severe heat treatment may negatively impact the front surface field of Choi by causing the dopants to disperse throughout the silicon substrate. Additionally, the high annealing temperature of Istratov could negatively affect the thin tunneling oxides in Choi and possibly dissolve them.

71. I understand that Dr. Holman has suggested that the temperatures and times of Istratov could be adjusted to effectuate gettering in Choi because Choi's tunneling layer 20 is thinner than Istratov's BOX layer. Ex. 2037 (Holman Depo. Tr.) at 93:17-94:20. However, Dr. Holman presumes both that a POSITA would have found the need to getter impurities from Choi's silicon substrate and that there is a certain temperature-time combination that would not have had a deleterious impact on Choi. A POSITA would not understand that either premise was valid, and Dr. Holman (and Petitioner) fail to establish either premise.

3. Claim 10 – It Would Not Have Been Obvious to Implement Choi with the Claimed Doping Concentration

a. Petitioner Misreads Marvin

72. Petitioner errs in alleging that implementing the doping concentration of Marvin would satisfy the claim requirement of "a portion of the silicon substrate has a dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3}." In fact, Marvin teaches that the preferred dopant concentration for an implementation similar to Petitioner's proposed combination is 5×10^{18} cm^{-3}.

73. Marvin teaches, "In the low radiation environment, the minority and majority carrier collection regions should be of comparable width, with thicknesses of 0.9 μm and 3.0 μm, respectively. The FSF should be an approximately 0.5 μm step with doping concentration of 5E18 cm^{-3}." Ex. 1008 (Marvin) at p. 25. A POSITA would understand that 5E18 is another way of expressing 5×10^{18}. Further,

a POSITA would understand that the sentence that begins "The FSF should be . . ." is also subject to the introduction of the preceding sentence, i.e., "In the low radiation environment." Marvin states that a terrestrial application is one example of a low radiation environment. Specifically, Marvin states that "[i]n cases where radiation exposure is not present as the result of shielding or terrestrial use . . ." Ex. 1008 (Marvin) at p. 16. Thus, while low radiation does not necessarily mean terrestrial (because a space-based application can be shielded), a terrestrial application is low radiation.

74. By contrast, Marvin's observations regarding dopant concentrations of 1×10^{17} to 1×10^{18} cm^{-3} pertain to a high radiation environment. Specifically, Marvin's conclusion states, "In a high radiation environment, a different design is used to maximize the EOL performance. . . . The FSF is graded over 15 μm with a peak doping concentration of 1E17 to 1E18 cm^{-3}." Ex. 1008 (Marvin) at p. 25. A POSITA would understand that 1E17 is another way to express 1×10^{17} and 1E18 is another way to express 1×10^{18}. Further, a POSITA would understand that the sentence "The FSF is graded over 15 μm with a peak doping concentration of 1E17 to 1E18 cm^{-3}" describes part of the "different design" that Marvin found near-optimal in a high radiation environment. A POSITA would understand that a high radiation environment includes, for example, an unshielded space application. For example, Marvin states, "For space use, where radiation is present . . ." Ex. 1008

(Marvin) at 16. (I understand that Dr. Holman testified that his proposed combination of Choi and Marvin was in the context of a one-sun (non-concentrator) and terrestrial application. Ex. 2037 (Holman Depo. Tr.) at 33:17-21, 41:15-19.)

75. I understand that Dr. Holman believes that the second paragraph on page 15 of Marvin supports the contention that Marvin recommends a dopant concentration of below 1×10^{18} cm^{-3}. Ex. 2037 (Holman Depo. Tr.) at 34:6-18. I disagree. Marvin's Conclusion section is unambiguous—it instructs that 5×10^{18} cm^{-3} should be used for the terrestrial environment. Furthermore, Marvin's paragraph on page 15 relates to abrupt doping profiles that have limited practical value.

76. Further, a POSITA would understand that Marvin relies heavily on numerical simulations. Whereas experimental results are primary sources of information that generally cannot be disputed, modelling device behavior by means of theoretical simulations such as a "two-dimensional numerical simulation" are secondary sources of information. This is because simulations depend on parameters that are frequently only vaguely known. *See* Ex. 1021 (King) at p. 365 (noting that surface recombination velocity is "strongly dependent on technological factors, some of which are difficult to control [such as] surface roughness, surface contamination, oxidation temperature, ambient gases during oxidation, and

postoxidation annealing"). A device whose properties are "strongly dependent on technological factors, some of which are difficult to control" cannot be simulated with assured reliability. Thus, a POSITA would understand that Marvin's simulations have limited meaningfulness. This is especially true since Marvin's simulations are two-dimensional, which is less realistic than a three-dimensional simulation would be (actual devices are of course three-dimensional). In this context, I note that Dr. Holman suggested that numerical simulations can be "garbage." Ex. 2037 (Holman Depo. Tr.) at 150:1.

77. It appears that Petitioner also fails to appreciate that much of Marvin's teachings relate to concentrator solar cells. Marvin discusses, for example, a "100 sun Air Mass 1.5" cell, Ex. 1008 (Marvin) at Abstract, which receives light (typically concentrated by a convex lens) that is 100 times more intense than regular sunlight. In such conditions, carrier generation is significantly higher, such that Auger recombination is more of a consideration than in a one-sun application. A POSITA would have known that Auger recombination is proportional to the carrier concentration (specifically $R_{\text{Auger}} \propto n^2p$ for the "eeh" Auger process, and $R_{\text{Auger}} \propto np^2$ for the "ehh" Auger process, where n and p are the electron and hole concentrations, respectively). *See* Ex. 2034 at p. 1 ("In principle, Auger recombination should constitute the ultimate limiting mechanism for concentrator photovoltaic performance as optical concentration, and hence current densities, are

raised to progressively higher values."). Thus, a POSITA would understand that Auger recombination is more significant in concentrator solar cells than in non-concentrator solar cells. Accordingly, statements made on Auger recombination in the context of concentrator solar cells cannot be readily applied to non-concentrator solar cells.

78. Further, a POSITA would have been aware of the significant differences between conventional solar cell configurations (such as Marvin) and TOPCon (tunnel oxide passivation contact) solar cells (such as Choi). Thus, a POSITA would have understood that Marvin's teachings are not equally applicable to TOPCon solar cell configurations.

b. Granek Does Not Teach that a Dopant Concentration of Less than 2×10^{18} cm^{-3} Is Preferred

79. Granek includes both simulation results and empirical results. Among the two, a POSITA would assign greater weight to the latter. As I discuss above in the context of Marvin, simulations in general, and those for solar cells in particular, are known to have limited accuracy. In part, this is due to the unpredictability of the technology. For example, surface recombination velocity, a relevant parameter, is "strongly dependent on technological factors, some of which are difficult to control [such as] surface roughness, surface contamination, oxidation temperature, ambient gases during oxidation, and postoxidation annealing." Ex. 1021 (King) at p. 365. Granek's one-dimensional simulations are even less reliable than two-

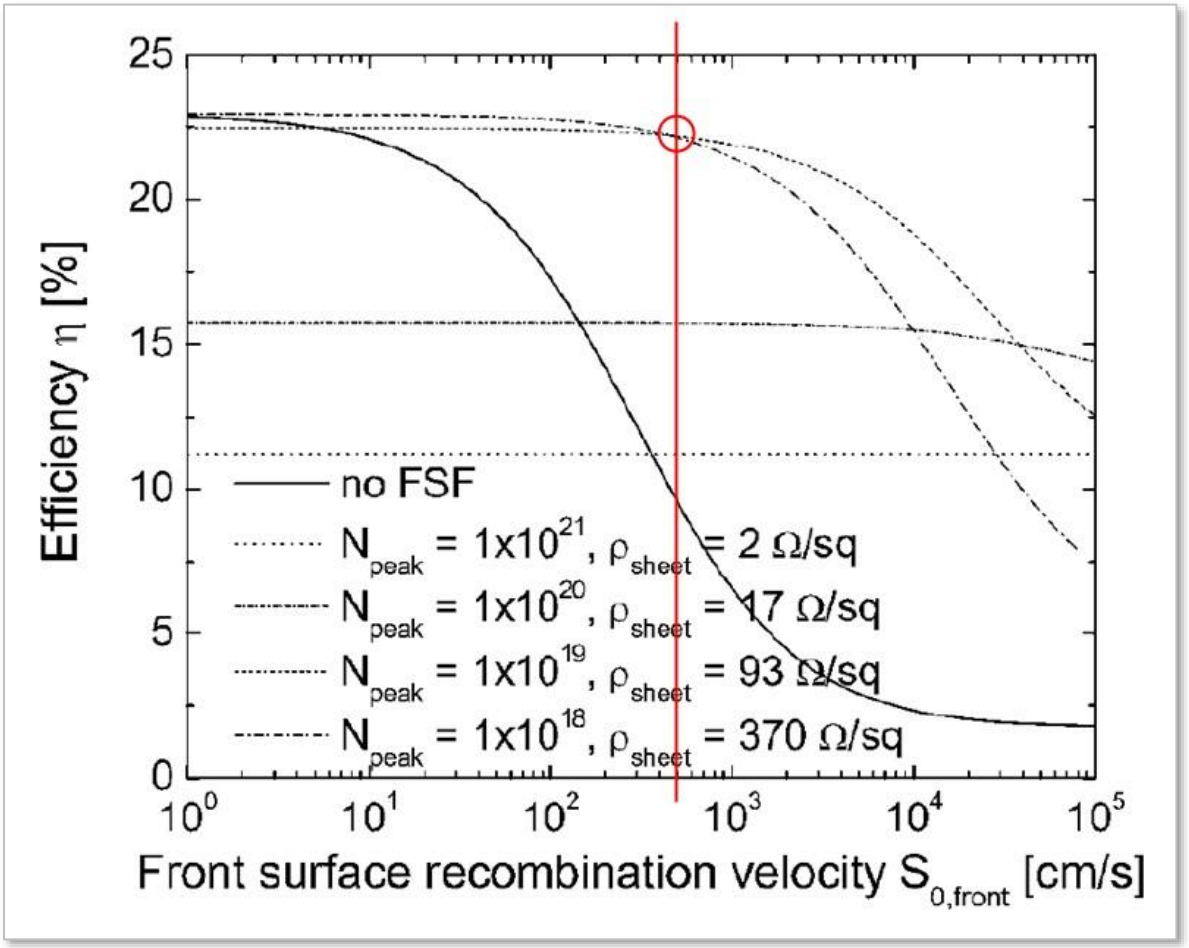
dimensional or three-dimensional simulations would be. Thus, in order to better understand the results of certain conditions, empirical results are generally given more weight. In this context, I note that Dr. Holman suggested that numerical simulations can be "garbage." Ex. 2037 (Holman Depo. Tr.) at 150:1.

80. Figure 7-1 of Granek does not teach that 1×10^{18} cm^{-3} is the preferred dopant concentration. Rather, the figure shows general trends at dopant concentrations of round values, i.e., 0, 1×10^{18}, 1×10^{19}, 1×10^{20}, and 1×10^{21} cm^{-3}. A POSITA would understand that in implementing a dopant concentration in Choi, they would not be limited to one of those specific values but instead could choose whichever value was optimal in view of other design parameters.

81. Additionally, Figure 7-1 was the result of a one-dimensional simulation. Ex. 1010 (Granek) at p. 120. A POSITA would understand that simulations in general do not always accurately reflect real-world results and that a one-dimensional simulation has the readily apparent weakness that only one spatial dimension is taken into account. For example, lateral transport and the collection of carriers in the emitter regions cannot be taken into account in one-dimensional simulations.

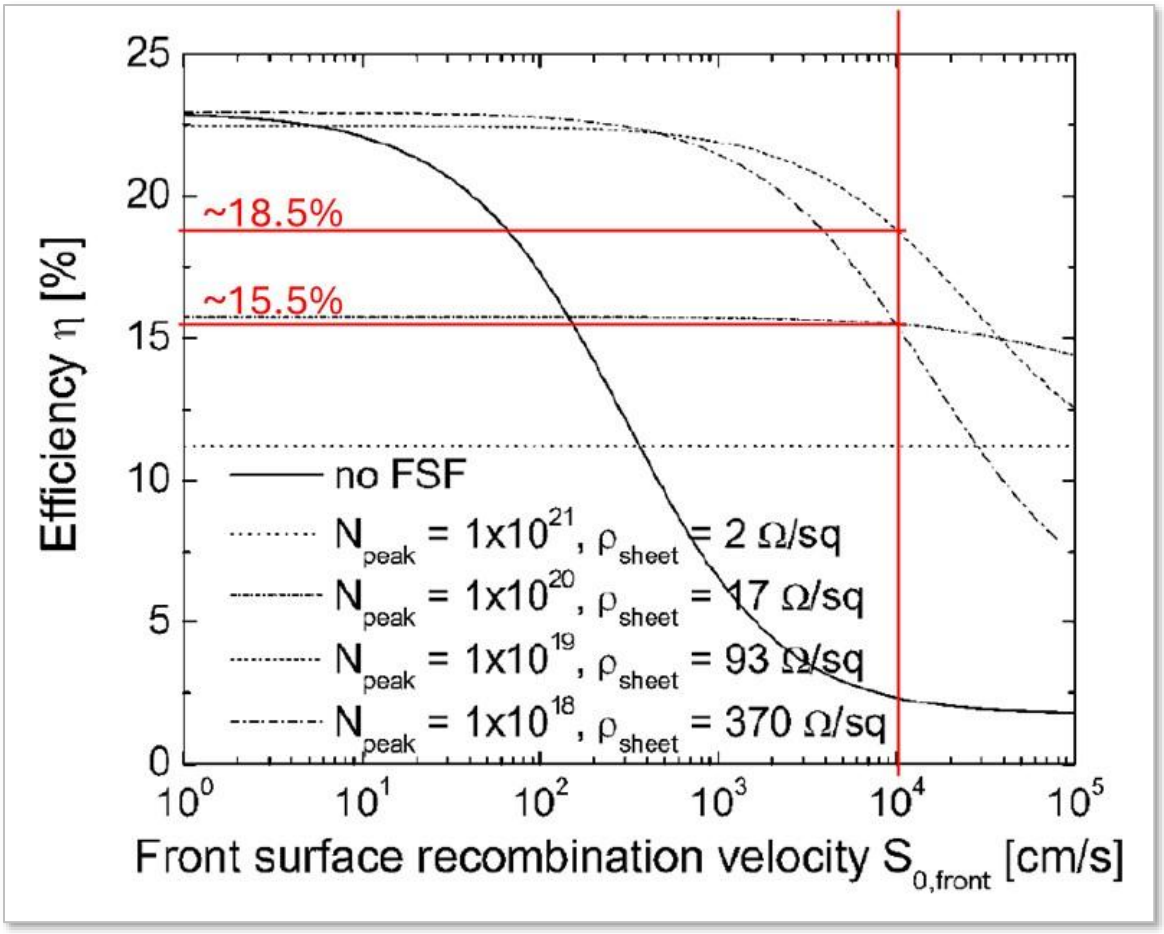
82. Further, among those concentrations that were simulated, the results of the dopant concentration of 1×10^{19} cm^{-3} are superior to those of 1×10^{18} cm^{-3}. In particular, Figure 7-1 shows that for all values of front surface recombination

velocity greater than approximately 500 cm/s, the efficiency using 1×10^{19} cm^{-3} is higher than the efficiency using 1×10^{18} cm^{-3}. This is shown in the annotated figure below.



Ex. 1010 (Granek) at Fig. 7-1 (annotated).

83. Further, the difference in efficiency is appreciable at many surface recombination velocities. For example, at a recombination velocity of 10^4 (10,000) cm/s, the simulated efficiencies for 1×10^{19} cm^{-3} and 1×10^{18} cm^{-3} are approximately 18.5% and approximately 15.5%, respectively.



Ex. 1010 (Granek) at Fig. 7-1 (annotated).

84. This difference (approximately 3% absolute and 19.4% relative) is roughly one-fifth of the efficiency at 1×10^{18} cm^{-3} and is significant. That is, the efficiency increases by 19.4% (relative percentage) when increasing the doping from 1×10^{18} cm^{-3} to 1×10^{19} cm^{-3}. A relative percentage change compares the change in percentage to the reference percentage. Thus, a relative percentage change may be much greater than an absolute percentage change. By contrast, the difference in the simulated efficiencies at low front surface recombination velocities is negligible. In fact, the separation between the two curves is likely

smaller than the unavoidable uncertainties associated with the simulation, such as the uncertainty of parameters entering the simulation and the inherent deficiencies in one-dimensional and two-dimensional simulations, which are less accurate than three-dimensional simulations. (Granek states, "A direct measurement of the surface recombination velocity S and surface saturation current density J_{0s} is not possible." Ex. 1010 (Granek) at p. 35.)

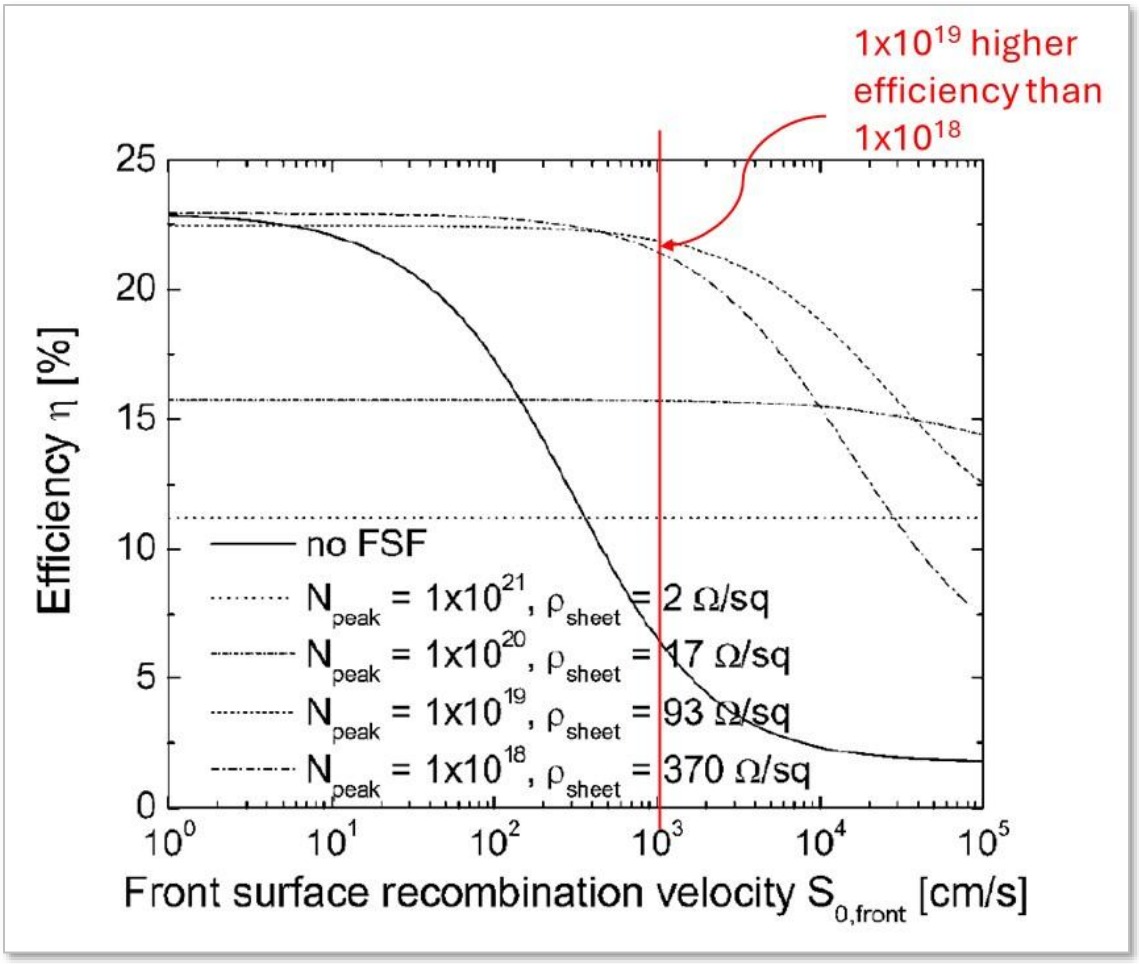
85. Further, a POSITA would be skeptical of Figure 7-1 of Granek. The figure suggests that at low recombination velocities, a solar cell without a front surface field (FSF) would have an efficiency similar to those with doping concentrations of 1×10^{18} cm^{-3} or 1×10^{19} cm^{-3}. However, the suggestion that good results could be obtained without an FSF layer is contrary to well-accepted experimental results that have firmly established the usefulness of an FSF layer. As a result, a POSITA would recognize that at least the region of Figure 7-1 with low surface recombination velocities has limited (if any) relevance.

86. For these reasons, a POSITA would not expend the cost in attempting to achieve such a very low surface recombination velocity when the simulations suggested only marginal (if any) benefits.

87. That a POSITA would try to avoid the cost required to achieve a very low front surface recombination velocity is especially true since the surface recombination velocity "is strongly dependent on technological factors, some of

which are difficult to control." Ex. 1021 (King) at p. 365. In particular, the following variables impact surface recombination velocity: "surface roughness, surface contamination, oxidation temperature, ambient gases during oxidation, and postoxidation annealing." *Id.* Generally, efforts to control those variables to reduce surface recombination velocity (e.g., reduce surface roughness, reduce surface contamination, etc.) involve additional cost.

88. Granek's assessment that an FSF layer would not be needed for a surface recombination velocity of 10^0 cm/s (that is, 1 cm/s), and given that it is very common for solar cells to use an FSF layer, shows that such a low surface recombination velocity (10^0 cm/s) is simply unrealistic. A typical surface recombination velocity is 10^3 cm/s. For example, Ex. 2035 investigated high-efficiency solar cells and in performing simulations used a recombination velocity of 1,000 cm/s because that is "a typical value for an oxide-covered c-Si surface," i.e., a crystalline silicon substrate. Ex. 2035 at p. 6397. Also, Marvin assumes a surface recombination velocity of 10^3 cm/s. Ex. 1008 (Marvin) at p. 10 ("Front surface recombination velocity" is "1E3 cm/s"). Granke's Figure 7-1 simulation reveals that at such a recombination velocity, 1×10^{19} cm^{-3} yields a higher efficiency than 1×10^{18} cm^{-3}. This is shown in the annotated figure below.



Ex. 1010 Granek at Fig. 7-1 (annotated).

89. With respect to experimental results (which are favored over simulations as I discuss above) Granek teaches dopant concentrations greater than 2×10^{18} cm^{-3}. First, in Section 4, Granek teaches that an "optimal" dopant concentration is 5×10^{18} cm^{-3}. In particular, Granek states as follows:

> The front side is textured with random pyramids and passivated with a lightly doped ($N_{peak} = 5\times10^{18}$ cm^{-3}) and deeply diffused (1.4 μm) phosphorus front surface field (FSF). The sheet resistance of the FSF (ρ_{FSF}) equals 148 Ω/sq. The diffusion profile of the FSF was

optimized to achieve an optimum front side passivation quality. The presence of the phosphorus doped front surface field (FSF) is one of the key features of the developed device design.

Ex. 1010 (Granek) at p. 46.

90. Similarly, in Section 7, Granek discloses that among solar cells that were manufactured, the highest efficiency was obtained when a dopant concentration of 3.8×10^{18} cm^{-3} was used. Ex. 1010 (Granek) at pp. 126 (showing that profile FSF5 used 3.8×10^{18} cm^{-3}, 132 (showing 20.8% efficiency for FSF5).

91. In view of these disclosures, a POSITA would be dissuaded from adopting a doping concentration of less than 2×10^{18} cm^{-3}.

c. <u>The Appropriate Dopant Concentration for Choi Would Depend on Design Parameters</u>

92. A POSITA would understand that the appropriate dopant concentration to employ in Choi would depend on design parameters. Examples of such parameters are the radiation environment (e.g., whether the solar cell will be used in an unshielded space environment or a terrestrial environment), whether the solar cell will be used in a concentrator configuration, the thickness of oxide passivation layers, and the shape of the dopant profile (e.g., whether a Gaussian or error function profile is used). Petitioner fails to provide a set of parameters that would lead a POSITA to employ a dopant concentration of less than 2×10^{18} cm^{-3}. Instead, Petitioner appears to suggest that a POSITA would simply use numbers

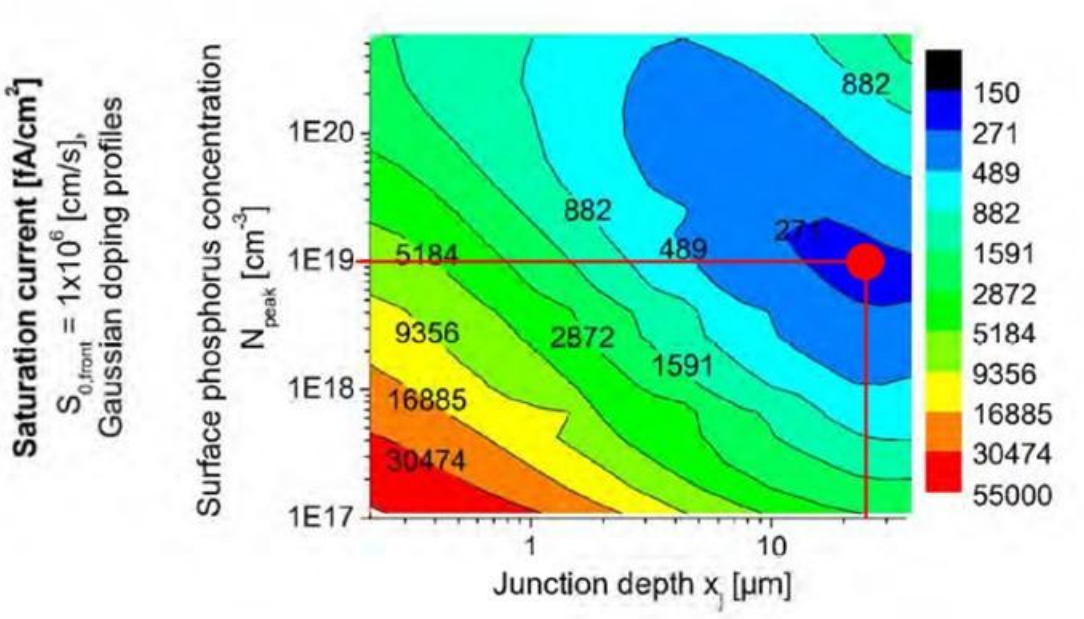
that appear in portions of Granek and/or Marvin. I disagree with Petitioner's contention that a POSITA would have done so.

93. I understand that Petitioner and Dr. Holman argue that Figure 7-3 of Granek suggests a doping concentration of less than 2×10^{18} cm^{-3}. Petition at 29-30; Ex. 1003 (Holman Dec.) at ¶ 149. I disagree. As an initial matter, a POSITA would understand that saturation current is a secondary figure of merit and that efficiency is the primary figure of merit. Thus, a POSITA would not adopt a dopant concentration to reduce saturation current when that dopant concentration would not be optimal with regards to efficiency.

94. Further, Petitioner and Dr. Holman rely on only the lower half of Figure 7-3 of Granek. The one-dimensional simulation results of the lower half of Figure 7-3 assume a front surface recombination velocity proposed by Cuevas. Ex. 1010 (Granek) at p. 122 (caption of Fig. 7-3); *see also id.* at 42 (showing recombination velocity as function of dopant concentration according to parameterization of Cuevas). However, Petitioner fails to show that Cuevas's parameterization would apply to Choi (or Cousins). Further, Cuevas notes that the parameterization is subject to "several sources of uncertainty." Ex. 2036 at p. 3. Cuevas proceeds to identify those sources of uncertainty: "This includes not only the error in the measurements of J_0 and the dopant profile but also the assumed energy bandgap narrowing and minority carrier lifetime, especially for deeply

diffused samples." Ex. 2036 at p. 3. Choi (and Cousins) are devoid of disclosure that suggests that the conditions that would lead to Cuevas's parametrization, e.g., that contamination is negligible, are present. *See* Ex. 1021 (King) at p. 1 ("When contamination is negligible and all processing parameters are the same, however, definite trends in the dependence of s [surface recombination velocity] on N_{surf} can be observed."). A POSITA would understand that fabricating a solar cell in a controlled research environment is different from fabricating a solar cell in an industrial environment and that the cost required to ensure negligible contamination may not be justified in an industrial environment.

95. Petitioner and Dr. Holman do not address the top portion of Figure 7-3 of Granek. This figure shows that the lowest saturation current, when surface recombination velocities are 1×10^6 cm/s, is obtained with a dopant concentration of approximately 1×10^{19} cm^{-3} and a junction depth of approximately 25 μm.



Ex. 1010 (Granek) Fig. 7-3 (partial, annotated).

d. Other References Teach a Dopant Concentration Higher than the Claimed Range

96. As further confirmation that the appropriate dopant concentration is influenced by design parameters, many references that post-date Granek and Marvin teach dopant concentrations greater than 2×10^{18} cm^{-3}. Dr. Holman discussed these references during his deposition; however, I disagree with many of his assertions in this regard for the following reasons.

97. With respect to Lamers (Ex. 2002), Dr. Holman argued that, under the conditions of Choi, Lamers's disclosure of a "lightly doped and shallow front surface field" applies. Ex. 2037 (Holman Depo. Tr.) at 146:16-21. Dr. Holman appears to believe that a "lightly doped" front surface field will have a dopant concentration less than Lamers's recommendation of 3×10^{18} cm^{-3}. I disagree. A

POSITA would not believe that "lightly doped" excludes a doping concentration of 3×10^{18} cm^{-3}. Indeed, Granek states that 5×10^{18} cm^{-3} is "lightly doped." Ex. 1010 (Granek) at p. 46 ("The front side is textured with random pyramids and passivated with a light doped ($N_{peak} = 5\times10^{18}$ cm^{-3}) and deeply diffused (1.4 μm) phosphorus front surface field (FSF).").

98. Furthermore, I note that Petitioner's reading of Lamers is selective and unsupported by Lamers. First, Lamers states: "The IBC cells require a rear surface passivation solution for three different surfaces: the highly doped p-type emitter, the highly doped n-type back surface field and the lightly doped n-type base." (Lamers, page 1) Second, Lamers's Figure 1 discloses an "n^+ FSF" and n^+ BSF" indicating that both are highly n+-doped. Third, Lamers states: "Recombination in the FSF should be minimal and the optimal doping level was found to be 3.10^{18} atoms/cm^2 [...] Under these circumstances, a lightly doped and shallow FSF, with a high resistance in combination with good surface passivation, will give the highest cell output [5]. [...] It can be seen that the J_{SC} is optimal for dopants at 3.10^{18} atoms/cm^3 for a wide variety of S as it shows that for **this doping level the processing is most stable** in terms of surface passivation." Ex. 2002 at p.2. To summarize, Lamers discloses that the "optimal doping level" is 3×10^{18} atoms/cm^3, that the FSF region should be "n^+ FSF" (where "n^+" in the art refers to a highly doped layer) and that "Jsc is optimal for dopants at 3.10^{18} atoms/cm^3."

99. With respect to Desa (Ex. 2003), Dr. Holman argues that the reference does not actually disclose a front surface field because the substrate of Desa is a p-type and that the dopants are n-type. Ex. 2037 (Holman Depo. Tr.) at 147:20-149:12. However, Desa itself considers the n-type doped region a "front surface field." For example, on page 70, Desa states, "The solar cell parameters used for simulation have been listed in Table 1." Ex. 2003 at p. 70. That table indicates that notwithstanding the wafer being p-type the "Front Surface Field" uses phosphorus (an n-type) dopant. Ex. 2003 at p. 80. Desa also uses "front surface field" throughout. Ex. 2003 at pp. 70, 71. Dr. Holman also suggests that the Figure 5(c) reflects "garbage" modelling results because he doubts the accuracy of the efficiency values at the 1×10^{21} cm^{-3} doping concentrations. Ex. 2037 (Holman Depo. Tr.) at 149:13-150:3. However, Dr. Holman did not provide any reason to doubt the efficiency value at 1×10^{19} cm^{-3}, Ex. 2037 (Holman Depo. Tr.) at 150:7-14, and I am not aware of any reason to doubt that value either (at least any more than the modelling results of Marvin and Granek upon which Petitioner relies).

100. With respect to Procel (Ex. 2005), Dr. Holman had no direct complaints. Instead, he noted that in a near contemporaneous paper, the authors of the Procel paper published another paper in which they used a doping concentration of 1×10^{18} cm^{-3}. Ex. 2037 (Holman Depo. Tr.) at 152:20-153:22. However, in the paper that Dr. Holman referenced (Ex. 1040), the authors

"performed a study of rear side geometry." Ex. 1040 at p. 15 (Abstract). The aim of their work was "to improve the physical understanding of the impact of different rear geometries on the performance of BC-BJ solar cells by a systematic simulation analysis." *Id.* For such purposes, the authors used a doping concentration of 1×10^{18} cm^{-3} for the front surface field for all such simulations. *Id.* Thus, the aim of Ex. 1040 was not to find optimal front surface field doping concentrations as it was in Ex. 2005. Ex. 1040 thus does not cast doubt on the pertinent results of Ex. 2005.

4. Claims 13 and 14 – It Would Not Have Been Obvious to Implement a p-Type Dopant (For Example Boron) with All Other Claim Limitations

101. I disagree with Petitioner's contention that it would have been obvious to implement Choi with a p-type dopant in the substrate (as claim 13 requires), for example boron (as claim 14 requires) with all of the other limitations of those claims. Both claims 13 and 14 ultimately depend from claim 10. Thus, each claim incorporates all limitations of claim 10, including the requirement that "a portion of the silicon substrate has a dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3}."

102. A central error in Petitioner's theory for claims 13 and 14 is failing to appreciate that a change from an n-type dopant (such as phosphorus) to a p-type dopant (such as boron) would require an adjustment of the doping concentration to

achieve similar results. Stated differently, a POSITA would understand that simulations or empirical results for an n-type dopant would not inform the appropriate doping levels of a p-type dopant.

103. The differences between p-type and n-type dopants is revealed by, for example, Granek. Figure 3-6 purports to depict relationships between dopant concentration and surface recombination velocity for each of phosphorus (n-type) and boron (p-type). Ex. 1010 (Granek) at p. 42. Taking just two examples, the surface recombination velocity at a dopant concentration of 10^{18} cm^{-3} is approximately 70 cm/s for phosphorus and over 2,000 cm/s for boron. At a concentration of 10^{21} cm^{-3}, the surface recombination velocity for phosphorus is approximately 100,000 cm/s and for boron is approximately 22,000 cm/s. I note that in Si, the electron mobility is more than twice as high as the hole mobility, so that electron transport cannot be equated to hole transport. (see, for example, Ex. 2038, https://www.ioffe.ru/SVA/NSM/Semicond/Si/electric.html)

104. Yet another reason not to change the dopant polarities is that n-type Si has many benefits over p-type Si. Some are enumerated in Granek at pp. 48-49. I agree that those benefits are correct and that a POSITA would have recognized them as benefits to using n-type Si. Accordingly, these benefits to n-type Si would have been further weight against changing to p-type as Petitioner's theory requires.

5. *Claim 16 – Ground I Fails to Satisfy the "second emitter region having metal impurities"*

105. Ground I, the only ground used for claim 16, fails to show the unpatentability of claim 16. Claim 16 recites, among other things, "a second emitter region having metal impurities formed over the dielectric region."

106. My opinions with respect to this limitation are similar to those I present above with respect to the limitation "a first emitter region having metal impurities." Specifically, Choi fails to disclose a "second emitter region having metal impurities" because the dopants that Choi discloses are not undesired foreign metals but are instead desired dopants. Further, reliance on Istratov is misplaced because Choi does not disclose that its substrate has metal impurities, and it would not have been inherent that Choi's substrate has metal impurities. Still further, putting those shortcomings aside, a POSITA would understand that employing the temperatures and times of Istratov would adversely impact the solar cell of Choi, and Petitioner (and Dr. Holman) have failed to show that there would be a time-temperature combination that could both achieve gettering without negatively impacting the solar cell of Choi.

107. I disagree with Petitioner's allegation that Choi's first conductive type area 32 corresponds to this limitation. Petition at 59. Petitioner states, "Further, as explained above (§X.A.2.iv), to the extent Patent Owner argues that the claimed invention includes any metal or any source of metal, a POSITA would also have

understood that Choi's second conductive type area 34 is doped with metal impurities." Petition at 59. As an initial matter, I understand that Patent Owner has not argued that "metal impurities" is that broad. Indeed, I believe "metal impurities" is not that broad and instead refers only to undesired foreign metals.

108. Thus, I disagree with Petitioner's suggestion that follows, i.e., that dopants in Choi's second conductive type area 34 correspond to "metal impurities" of claim 16. In Section X.A.2.iv of the Petition—cited in the above excerpt of the Petition—Petitioner states that "Choi teaches that each of the first and second conductive type areas 32, 34 is doped with either p- or n-type impurities in different embodiments" and that "because a POSITA would have understood that at least bismuth, aluminum, gallium, and indium are metals, a POSITA would have understood that Choi's first and second conductive type areas 32, 34 are doped with metal impurities." Petition at 54. However, the dopants in Choi's first and second conductive type areas 32, 34 are not undesired foreign metals. Rather, they are purposefully introduced. Ex. 1006 (Choi) at ¶¶ [0036]-[0037]. A POSITA would understand that dopants, including Al, Ga, In and Bi, are intentionally introduced to provide the desired n-type or p-type conductivity whereas metal impurities such as Fe, Ni, or Cr are contaminants that deteriorate carrier lifetime and solar cell efficiency by means of deep-level assisted recombination known in the art as SRH recombination (Shockley-Read-Hall recombination). To put wanted

dopants and unwanted metal impurities into the same category would be contrary to the spirit and word of the ’315 patent (as discussed in detail above). I note that basic principles of semiconductor doping have been discussed in textbooks such as the textbook “Doping in III-V semiconductors” authored by myself and published by Cambridge University Press (Cambridge UK) in 1993. The benefits of dopants are that the conductivity type (n-type and p-type) as well as the magnitude of the conductivity (e.g. low, medium, and high) can be determined by proper selection of the doping element (e.g. boron or phosphorus) and its concentration. Without dopants, the field of solar cells would not exist. Without contaminating metal impurities, the efficiency of solar cells would improve. To summarize, dopants serve a useful purpose, whereas contaminating foreign metal impurities do not.

109. I also disagree with Petitioner’s alternative suggestion, i.e., that Choi in combination with Istratov renders obvious the “second emitter region having metal impurities” for the same reasons that I presented above with respect to the “first emitter region” limitation of claim 10.

B. Ground II

110. Ground II addresses only claim 18, which depends from claim 16, which in turn depends from claim 10. Ground II is premised on the notion that Ground I shows the unpatentability of claim 16. Petition at 66 (incorporating Section X.A.8, which addresses claim 16). That section in turn incorporates

Section X.A.2, which addresses claim 10. Petition at 58. Because the Petition fails to show that claim 10 is unpatentable under Ground I, the Petition necessarily fails to show that claim 18 is unpatentable under Ground II.

C. Ground III

1. Claim 10 – The Proposed Cousins-Istratov Combination Fails to Satisfy the "first emitter region" Limitation

111. The proposed Cousins-Istratov combination suffers from many of the same deficiencies that I note above with respect to the proposed Choi-Istratov combination. Indeed, Petitioner cross-references its discussion of the Choi-Istratov combination in its brief section addressing a purported motivation to combine Cousins and Istratov. Petition at 70 (citing Section X.A.1.ii of Petition). With respect to the limitation "first emitter region having metal impurities," the Petition fails to show that the substrate 101 of Cousins would include metal impurities, i.e., undesired foreign metals. Petitioner thus failed to show that any such impurities would be in a concentration sufficient to prompt a POSITA to implement a gettering step. Indeed, Cousins is assigned to SunPower Corporation. Ex. 1007 (Cousins) at Field [73]. SunPower was known to employ high-quality silicon wafers. Ex. 1084 at 11 ("SunPower is using wafers with lifetimes greater than 1 millisecond and a thickness of 200 μm."). Petitioner also failed to show that any gettering step could be employed without adversely impacting the solar cell of

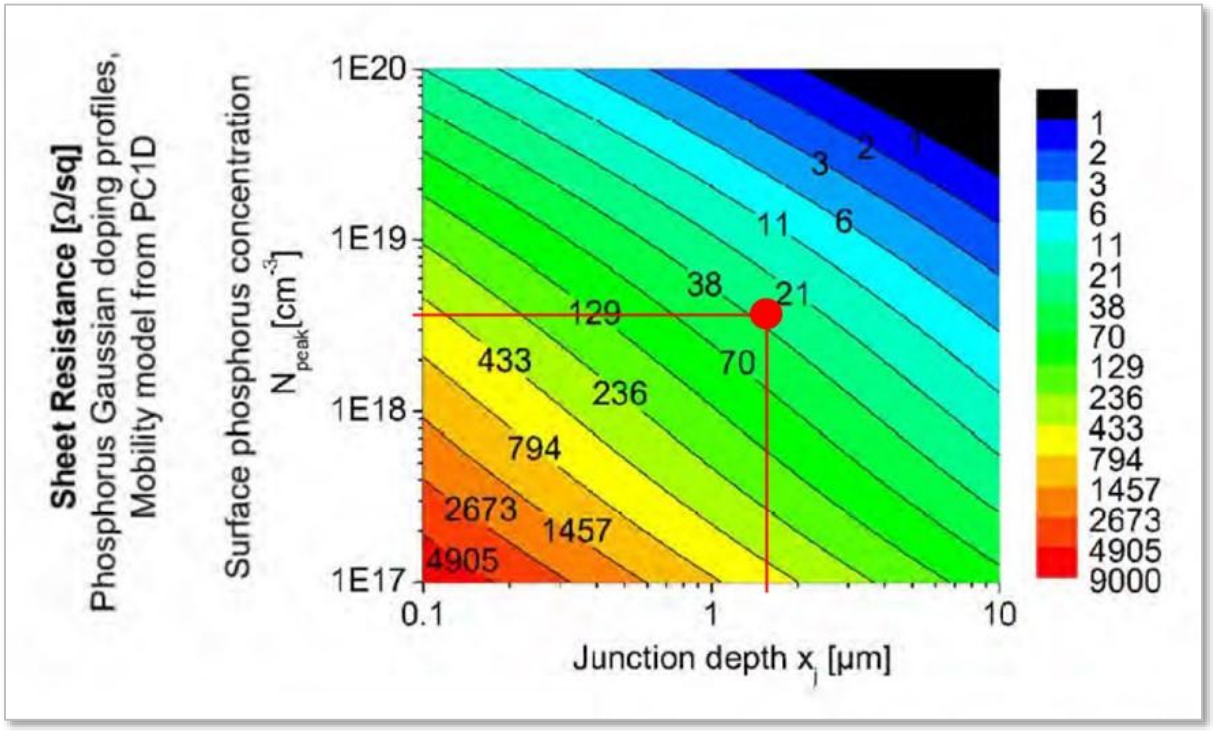
Cousins. (Petitioner does not allege that Cousins alone discloses the "first emitter region having metal impurities" limitation.)

2. Claim 10 – It Would Not Have Been Obvious to Implement Cousins with the Claimed Doping Concentration

112. For reasons similar to those presented above in Section IX.A.3 with respect to Choi, Petitioner fails to show that it would have been obvious to implement Cousins with a dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3}. In particular, Marvin teaches that 5×10^{18} cm^{-3} is preferred for terrestrial environments, Granek's empirical results reveal dopant concentrations above 2×10^{18} cm^{-3} were optimal and yielded highest efficiencies, and the simulation results of Granek—although not fully reliable—point toward a dopant concentration of greater than 2×10^{18} cm^{-3}.

113. I understand that Petitioner has argued that Figure 7-4 of Granek reveals that Cousins's disclosure of a sheet resistance of "100 to 500 Ω/sq" is "compatible" with a dopant concentration of less than 2×10^{18} cm^{-3}. Petition at 68-69; *see also* Ex. 1003 (Holman Dec.) at ¶ 365. Petitioner's reliance on Figure 7-4 for that proposition is flawed. Figure 7-4 reflects simulated results, and as I have stated previously a POSITA would understand that such results deviate from actual solar cell devices. Indeed, Granek itself reveals the imprecision of the simulations of Figure 7-4. For example, Table 7-1 of Granek (page 126) indicates that a sample with a Gaussian doping profile having a concentration of 3.8×10^{18} cm^{-3} and

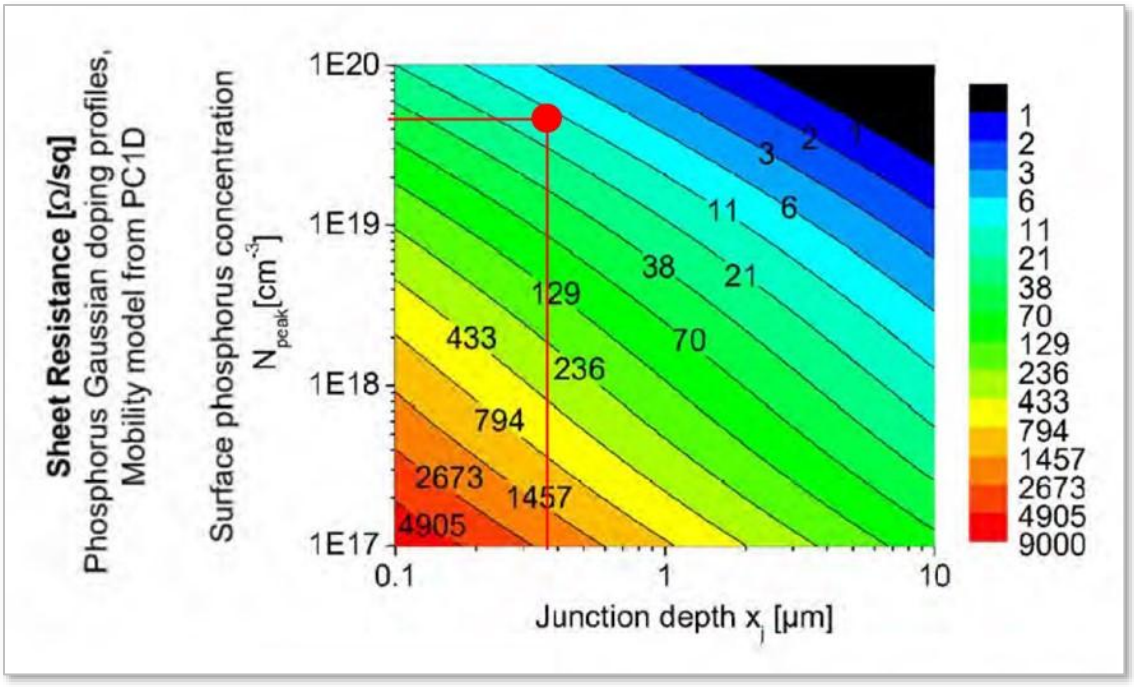
a junction depth of 1.44 µm yielded a sheet resistance of 148 Ω/sq. Ex. 1010 (Granek) at p. 126. However, Figure 7-4 predicts a sheet resistance under those conditions of less than 38 Ω/sq.



Ex. 1010 (Granke) at Fig. 7-4 (annotated).

114. Thus, the simulation and empirical results differ by a factor of approximately four.

115. The difference is even more stark when error function profiles are examined. Plotting the data from FSF4 in Table 7-1, i.e., a dopant concentration of 4.5×10^{19} cm^{-3} and a junction depth of 0.38 µm on Figure 7-4 indicates an expected sheet resistance of less than 21 Ω/sq.



Ex. 1010 (Granek) at Fig. 7-4 (annotated).

116. However, the actual sheet resistance was measured as 353 Ω/sq. Ex. 1010 (Granek) at p. 126. In this regard, I disagree with Dr. Holman's suggestion that the teachings of Figure 7-4 of Granek (which are imprecise simulations even when a Gaussian profile is assumed) are "still relevant" when an error function profile is used. *See* Ex. 2037 (Holman Depo. Tr.) at 140:12.

3. Claims 13 and 14 – It Would Not Have Been Obvious to Implement a p-Type Dopant (For Example Boron) with All Other Claim Limitations

117. For reasons similar to those presented above in Section IX.A.4 with respect to Choi, beyond Petitioner's failure to show that the claimed dopant concentration would have been obvious in Cousins, Petitioner's failure to do so with a p-type dopant (such as boron) is even more pronounced. Specifically, even

if it would have been obvious to implement Cousins with a doping concentration of 1×10^{18} cm^{-3} based on certain select teachings of Granek, it would not have been obvious to disregard the fact that the disclosures of Granek upon which Petitioner (and Dr. Holman) rely were specific to using the dopant of phosphorus (an n-type dopant). Marvin does not aid Petitioner because that reference teaches a dopant concentration of 5×10^{18} cm^{-3}, which is outside of the claimed range.

118. Further, I disagree with Petitioner's allegation that "as of the filing date of the '315 patent [2014], p-type wafers were more common and cheaper than n-type wafers." Petition at 77. Granek states otherwise: "Phosphorus doped n-type silicon has received increased interest in the PV research community in recent years, due to ***shortage of the p-type silicon feedstock*** and due to its high minority carrier lifetime." Ex. 1010 at p. 48 (emphasis added). I agree that there was a shortage of p-type silicon in 2014, contrary to Petitioner's argument.

X. CONCLUSION

119. In my opinion, based on my review of the '315 patent, the materials referenced above, and my knowledge of what a POSITA would have known at the time of the invention, Petitioner fails to show that any challenged claim is unpatentable.

120. I declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true and that

these statements were made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Date: May 21, 2025



E. Fred Schubert, Ph.D.