UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HANWHA SOLUTIONS CORPORATION,

Petitioner,

v.

MAXEON SOLAR PTE. LTD.,

Patent Owner.

Case No. IPR2024-01198

U.S. Patent No. 11,251,315

REPLY DECLARATION OF DR. ZACHARY HOLMAN REGARDING U.S. PATENT NO. 11,251,315

HANWHA v. MAXEON
IPR2024-01198
HANWHA 1089

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

I. INTRODUCTION

1. My name is Zachary Charles Holman.

2. I am making this declaration at the request of Hanwha Solutions Corporation ("HSC" or "Petitioner") as an independent expert consultant in this proceeding before the United States Patent and Trademark Office and to address and respond to the arguments made in the Patent Owner's Patent Owner Response ("POR," Paper 29) and the declaration submitted by Dr. E. Fred Schubert (Ex.2028) ("Schubert Declaration") in support of the POR. I previously submitted a Declaration in support of the Petition, dated August 8, 2024 (Ex.1003) ("First Declaration").

3. As stated in my First Declaration, I am being compensated for my work on this matter at my standard hourly consulting rate of $500 per hour. My opinions are based on my own views and understanding of the prior art, the knowledge of a person of ordinary skill in the art ("POSITA"), and the '315 patent. My compensation is not dependent on and in no way affects the substance of my statements, opinions, or conclusions in this declaration, and it is also not dependent on any testimony I give or on the outcome of this proceeding.

4. As also stated in my First Declaration, I have no financial interest in Petitioner or Patent Owner. I similarly have no financial interest in the '315 patent, and I have had no contact with the named inventors of the '315 patent.

II. MATERIALS CONSIDERED

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

6. Since preparing my First Declaration, I have reviewed Patent Owner's Preliminary Response ("POPR," Paper 9), the declaration submitted by Dr. David L. Carroll in support of the POPR (Ex.2001), the Board's Institution Decision ("ID," Paper 17), the POR, and the Schubert Declaration. I have also reviewed documents cited by Dr. Schubert in his declaration, and the transcript of Dr. Schubert's deposition held on July 15, 2025 ("Schubert Deposition") (Ex.1090). I have further reviewed and considered both the declaration submitted by Dr. David L. Carroll in support of Patent Owner's POR (Ex.1091) in *Canadian Solar Inc. v. Maxeon Solar*

[1] I also signed an errata with respect to my deposition transcript for my First Declaration. *See* Ex.1123.

Ltd., IPR2024-01038 (P.T.A.B.) ("CSI proceeding"),[2] and the transcript of Dr. Carroll's deposition held on June 18, 2025 in that proceeding (Ex.1092). I have also reviewed and considered the declarations submitted by Dr. Douglas Ruby in support of Patent Owner's PORs in *Hanwha Solutions Corporation v. Maxeon Solar Pte. Ltd.*, IPR2024-01199 (P.T.A.B.), and *Hanwha Solutions Corporation v. Maxeon Solar Pte. Ltd.*, IPR2024-1203 (P.T.A.B.), and the transcript of Dr. Ruby's deposition held on July 31, 2025 (Ex.1136-Ruby-Tr.).[3]

III. SUMMARY OF OPINIONS

7. For the reasons discussed at length in my First Declaration, it is my opinion that there is nothing inventive about claims 10-20 ("Challenged Claims") of the '315 patent. As detailed herein, it remains my opinion that the prior art renders obvious the Challenged Claims of the '315 patent.

[2] The CSI proceeding was filed by Canadian Solar, Inc. against claims 10-16 and 19 of the same '315 patent. Ex.1091-Carroll-CSI-Decl., ¶¶4, 21.

[3] Similar to my First Declaration, various annotations have been added to the figures and diagrams in this report. All these annotations as well as emphasis to text are added unless noted otherwise.

8. Nothing in the POR, the Schubert Declaration, the Schubert Deposition, the POPR, or Dr. Carroll's declaration in support of the POPR changes my opinions set forth in my First Declaration. As my First Declaration and this Reply Declaration explain, I have interpreted the '315 patent and the prior art references consistent with the knowledge and understanding of a POSITA without the use of hindsight. In this Reply Declaration, I respond to areas of dispute raised by Dr. Schubert and Patent Owner and questions raised in the Board's ID.

IV. QUALIFICATIONS AND EXPERIENCE

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

V. RELEVANT LEGAL STANDARDS

10. In my First Declaration, I set forth the applicable principles of patent law that counsel provided to me, which I incorporate by reference here. Ex.1003-Decl., ¶¶19-34.

11. For purposes of this Reply Declaration, I have been informed about certain additional aspects of the law that are relevant to my opinions. My understanding of these additional aspects of the law was provided to me by counsel.

A. Claim Construction

12. I understand that the terms of a patent claim are generally given their plain and ordinary meaning. This is the meaning that the term would have to a POSITA as of the time of the alleged invention.

13. As my First Declaration explains, I was informed and I understand that the words used in a patent's claims and the context in which the words are used in the claims are highly relevant to determine a word's meaning and that the words of a claim are to be interpreted in the context of the entire patent, including the patent's claims, its specification, and its figures. I further understand that, while claims are interpreted in light of the written description, it is improper to import into a claim limitations from the written description that are not part of the claim.

14. I have been informed that there are two exceptions to the general rule that the terms of a patent claim are generally given their ordinary and customary meaning: (1) when a patentee sets out a definition and acts as their own lexicographer, or (2) when a patentee disavows the full scope of a claim term either in the specification or during prosecution. I understand that, to act as its own lexicographer, a patentee must clearly set forth a definition of the disputed claim term other than its plain and ordinary meaning and must clearly express an intent to redefine the term. Regarding disavowal, I understand that a specification or

prosecution history must include expressions of manifest exclusion or restriction, representing a clear disavowal of claim scope.

B. Indefiniteness

15. I have been informed and understand that a claim is invalid if, at the time the alleged invention was made, its language, read in light of the specification and the prosecution history, fails to inform, with reasonable certainty, those skilled in the art about the scope of the invention. I understand that, to be sufficiently definite, a claim, when read in light of the specification and prosecution history, must provide objective boundaries to those of skill in the art.

VI. LEVEL OF ORDINARY SKILL IN THE ART

16. As I explain in my First Declaration, a POSITA as of the claimed priority date of the '315 patent would have had (1) an advanced degree in applied physics, chemistry, electrical engineering, materials science, mechanical engineering, or a related discipline and (2) at least one year of experience designing, developing, or researching the design and/or manufacture of solar cells or related technologies. Alternatively, a POSITA would have had (1) a bachelor's degree in one of the aforementioned disciplines and (2) at least two years of experience designing, developing, or researching the design and/or manufacture of solar cells or related technologies. Additional work experience may compensate for less formal

education, and vice versa. Dr. Schubert does not contest my definition of a POSITA and applies it in his declaration. Ex.1090-Schubert-Tr., 54:14-21; Ex.2028-Schubert-Decl., ¶¶21-22.

17. Dr. Schubert does not dispute that I have the qualifications and experience necessary to assess the '315 patent based on the perspective of a POSITA. Ex.1090-Schubert-Tr., 54:22-55:7; Ex.1003-Decl., ¶41; Ex.2028-Schubert-Decl., ¶¶21-22.

18. Notably, Dr. Schubert's expertise is principally in light-emitting diodes, and Dr. Schubert's experience with silicon solar cells is principally in researching antireflective coatings, which is unrelated to the issues here. Ex.2028-Schubert-Decl., ¶13; Ex.2001-Carroll-Decl., ¶¶16, 21-22; *see generally* Ex.2029-Schubert-CV; Ex.1090-Schubert-Tr., 32:14-35:8. During his deposition, Dr. Schubert testified that he had "not heard of" PC1D, which is the most common and popular simulation software for solar cells. Ex.1090-Schubert-Tr., 187:5-9; *see, e.g.*, Ex.1135-PVLighthouse; Ex.1129-Clugston, 207. On the other hand, Patent Owner's expert, Dr. Ruby, testified that PC1D is free software he uses for numerical modeling of a solar cell and it has been around "certainly since 1985." Ex.1136-Ruby-Tr., 71:21-73:3.

19. Dr. Carroll was originally Patent Owner's expert in this proceeding and submitted a declaration in support of Patent Owner's POPR, stating he is a POSITA with respect to the '315 patent. Ex.2001-Caroll Decl., ¶31. Dr. Carroll is also Patent Owner's expert in the CSI proceeding. Ex.1091-Carroll-CSI-Decl., ¶¶4, 21; Ex.1092-Carroll-CSI-Tr., 4:18-5:4. I note that Dr. Schubert testified that he was not aware that Dr. Carroll is Patent Owner's expert in the CSI proceeding, nor has Patent Owner shown him Dr. Carroll's declaration. Ex.1090-Schubert-Tr., 59:18-60:4.

VII. OVERVIEW OF THE '315 PATENT

20. Contrary to Dr. Schubert's assertion that "[t]he '315 patent discloses a novel solar cell and method of manufacturing a solar cell," Ex.2028-Schubert-Decl., ¶38, the '315 patent describes a solar cell design that purportedly increases a solar cell's efficiency[4] by using two well-known concepts. Specifically, the '315 patent claims that a solar cell's efficiency can be improved by (a) creating a doped layer at

[4] Patent Owner incorrectly describes "efficiency" as "the ratio of ***energy*** that is output by a solar cell relative to the amount of ***energy*** in the sunlight that it receives." POR, 2-3. In the field of solar cells, efficiency is defined as the ratio of the ***power*** that is output by the solar cell to the ***power*** it receives from sunlight. Power is the time derivative of energy; they are not the same.

the front side of the solar cell, and (b) a heating process that getters metal impurities into the emitter[5] region of the solar cell. Ex.1001-USP315, 4:55-64 ("a dopant region 216 can be formed on a surface 204 of silicon substrate 202 ... to dope the surface 204 … to repel charge carriers and prevent and/or reduce recombination at the surface 204 of the solar cell," and the dopant region 216 formed on the "surface 204, can be on a front side … of the solar cell"), 5:1-5 ("Metal impurities can be detrimental to the electrical conduction of the solar cell as these impurities can be sources of recombination, resulting in poor lifetime, surface passivation and/or lower solar cell efficiency."). Both techniques were well known before the priority date of the '315 patent.

[5] I note that Dr. Schubert refers to both regions for collecting electrons and holes as "emitters." However, as I explain in my opening declaration, in the field of solar cells, "emitter" typically refers to the region(s) that is oppositely doped from the substrate and is used to collect minority carriers only (i.e., for collecting holes in n-type solar cells—those made with n-type wafers—or for collecting electrons in p-type solar cells).

VIII. CLAIM CONSTRUCTION

21. My First Declaration does not propose a construction of any claim term of the Challenged Claims and applies each term's plain and ordinary meaning as would have been understood by a POSITA at the time of the alleged invention. Ex.2037-Holman-Tr., 120:18-19. I also reserved the right to respond if Patent Owner proposed an express claim construction in this proceeding. Ex.1003-Decl., ¶127. Patent Owner and Dr. Schubert have proposed a construction of the term "metal impurities."

22. Dr. Schubert proposes a construction for "metal impurities" of "undesired foreign metals." Ex.2028-Schubert-Decl., ¶42. I disagree with Dr. Schubert that this is a proper construction of "metal impurities."

23. "Impurities" is a term of art in the semiconductor and solar fields and has a single, well-understood plain and ordinary meaning. At the time of the alleged invention, a POSITA would have understood the plain and ordinary meaning of "impurities" to be any element that is foreign to the element(s) of a host material. For example, in a silicon wafer, a POSITA at the time of the alleged invention would have understood the term "impurity" to mean any non-silicon atom, including intentionally introduced dopants. Ex.2037-Holman-Tr., 110:19-111:4; 113:18-114:4; 115:2-6; 119:21-120:6.

24. For example, the Wiley Electrical and Electronics Engineering Dictionary, published in 2004, defines "impurity" as "[a] substance whose presence within another [substance] reduces or eliminates the purity of the latter." As an example, it explains that "[t]he presence of an impurity in a crystal can change its properties significantly, as seen in the use of dopants in semiconductors." Ex.1109-Wiley-Dictionary, 363-64. Similarly, the Dictionary of Electronics and Electrical Engineering defines "impurity" as "[f]oreign atoms in a semiconductor that are either naturally occurring or deliberately introduced." Ex.1108-EE-Dictionary, 299. The semiconductor and solar fields are closely related and share terminology (*see* below ¶70).

25. Likewise, a POSITA would have understood the term "metal" to mean an element that typically appears in nature as metallic. Accordingly, in the context of the '315 patent, the plain and ordinary meaning of "metal impurities" is any non-silicon atom that is a metal. Ex.2037-Holman-Tr., 111:4-9.

26. Publications in the semiconductor field consistently use "impurities" to include intentionally introduced dopants, including textbooks authored by Dr. Schubert himself. For example, the Preface of Dr. Schubert's 1993 textbook *Doping in III-V Semiconductors* provides a history of the usage of the term "impurities" in the semiconductor field and concludes that "the term 'impurities' is used for

unintentional as well as intentional foreign atoms in the semiconductor." Ex.1105-Schubert-1993, xvi (Preface). Dr. Schubert's 1996 textbook *Delta Doping of Semiconductors* also uses the term "impurity" to include intentionally introduced dopants. Ex.1106-Schubert-1996, 3-4 ("All impurities, shown as dark circles in the inset to Fig. 1.1, occupy substitutional lattice sites in the host semiconductor."); *id*. Fig. 1.1 (referring to the dark circles in the inset of Fig. 1.1 as "Dopants"):

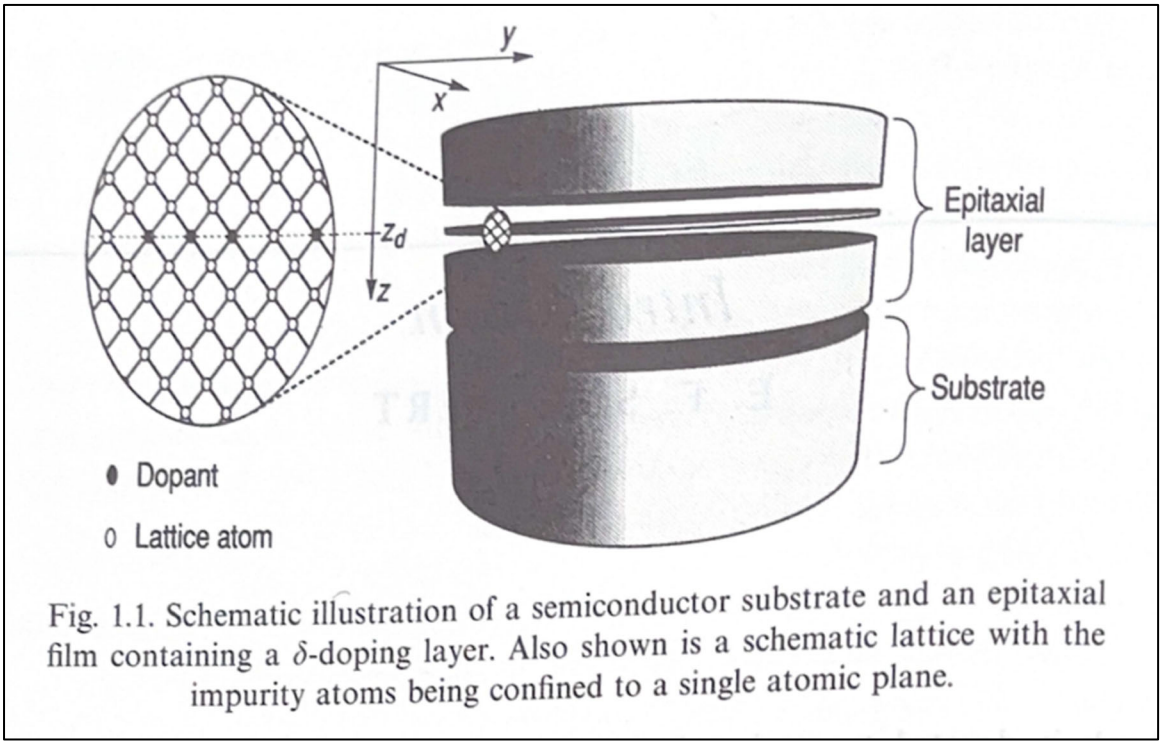


Fig. 1.1. Schematic illustration of a semiconductor substrate and an epitaxial film containing a δ-doping layer. Also shown is a schematic lattice with the impurity atoms being confined to a single atomic plane.

Other textbooks use "impurities" to include intentionally introduced dopants. For example, the 2006 textbook *Solid State Electronic Devices* explains that, "[i]n addition to the intrinsic carriers generated thermally, it is possible to create carriers

in semiconductors by purposely introducing impurities into the crystal." Ex.1107-Streetman, 81.

27. The McGraw-Hill Dictionary of Scientific and Technical Terms, cited by Patent Owner, also illustrates that "impurity" as used in the semiconductor field includes intentionally introduced dopants. POR, 14 (citing Ex.2030-McGraw-Hill, 1058). It defines "impurity semiconductor" as "[a] semiconductor whose properties are due to impurity levels produced by foreign atoms," Ex.2030-McGraw-Hill, 1058. Further, while the same dictionary provides a definition of "impurities" in the generic field of "Science and Technology" of "[a]n undesirable foreign material in a pure substance," it also gives a definition for the specific field of solid-state physics of "[a] substance that, when diffused into semiconductor metal in small amounts, either provides free electrons to the metal or accepts electrons from it." Ex.2030-McGraw-Hill, 1058.[6]

28. Dr. Schubert asserts that "impurities" has two plain and ordinary meanings in the solar field. Ex.2028-Schubert-Decl., ¶43. First, Dr. Schubert

[6] The dictionary explains that "Solid-State Physics" refers to the branch of physics centering on the physical properties of solid materials, usually crystalline materials, which includes semiconductors. Ex.1134-McGraw-Hill-2, xiii.

acknowledges that "impurities" refers to "any material within…another material," with which I agree, as explained above. However, I disagree that "impurities" has a second plain and ordinary meaning of "an undesired material (undesired trace substances) within another material." As explained above, texts and publications in the semiconductor and solar fields consistently define "impurities" as any element that is foreign to the element(s) of a host material, including intentionally introduced dopants. Publications in the field do not use the term "impurities" to mean only an undesired material within another material, and Dr. Schubert does not cite to any publications giving the term that meaning.

29. In the context of the '315 patent, a POSITA would not understand "metal impurities" as recited in the claims to have a meaning other than the plain and ordinary meaning discussed above, including "undesired foreign metals." The '315 patent states that "[a]s referred throughout, contaminants and/or impurities can be used interchangeably." Ex.1001-USP315, 5:8-9. Interchangeability does not suggest equivalence. Rather, it suggests that where one word appears, the other word may also be used. Ex.1133-Merriam-Webster. For example, while lenses having different focal lengths can be used interchangeably with the same camera, that does not mean that they are equivalent. Unlike "impurities," the term "contaminant" does not have a well-established meaning in the semiconductor or solar fields, Ex.2037-

Holman-Tr., 114:6-7; 121:14-16; 124:11-13, and a POSITA would not equate "contaminants"—which does not have a well-understood meaning in the field—with "impurities"—which does.

30. Further, a POSITA would not understand "impurities" to be synonymous with "contaminants" as used in the '315 patent because the specification uses those terms inconsistently. For example, it states that "[i]n an embodiment, the silicon substrate 202 can have contaminants and/or impurities 220, for example metal contaminants and/or metal impurities, such as iron, nickel and/or chromium among others," Ex.1001-USP315, 4:65-5:1, and it is unclear whether "iron, nickel and/or chromium" are examples of "contaminants," "impurities," or both. Elsewhere, the '315 patent states that "[i]n 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," Ex.1001-USP315, 6:57-60, and it is unclear whether "metal impurities 320 and/or metal contaminants" are examples of "impurities," "contaminants 320," or both. In view of the '315 patent's inconsistent usage of "contaminants" and "impurities," a POSITA would understand that "contaminants" and "impurities" have different meanings in the context of the '315 patent, and would apply the plain and ordinary meaning of "impurities."

31. As explained above in paragraph 14, I have been informed by counsel that a patentee may provide its own express definition of a claim term that is different from its plain and ordinary meaning by clearly setting forth a definition of the claim term other than its plain and ordinary meaning and clearly expressing an intent to redefine the term. In my opinion, the patentee did not do so in the '315 patent. A POSITA would not understand the specification's statement "as referred throughout, contaminants and/or impurities can be used interchangeably" to clearly express an intent to redefine the term "impurities" to mean "contaminants." Using terms "interchangeably" does not mean that the two terms are equivalent. For example, in the semiconductor field, one can use different dopants, such as boron and aluminum "interchangeably" to generate excess holes in a silicon substrate, but that does not mean that they are the same thing—they are still different elements with unique properties. Further, Patent Owner's POR does not argue that the '315 patent sets forth an express definition of "impurities" other than its plain and ordinary meaning.

32. Further, as noted above, the '315 patent uses the terms "contaminants" and "impurities" inconsistently, which would also suggest to a POSITA that the patentee did not clearly express an intent to redefine the term "impurities." In addition, Dr. Schubert contends that his proposed construction is one of two "plain and ordinary" meanings of "impurities." While I disagree with Dr. Schubert that

"impurities" has a second plain and ordinary meaning of "an undesired material within another material," Dr. Schubert does not suggest why the patentee would have favored one of those definitions over the other or offer an opinion that the patentee intended to define the term different from its plain and ordinary meaning. *See* Ex.2028-Schubert-Decl., ¶¶43-44.

33. Dr. Schubert's observation that the '315 patent describes the same reference numbers in the drawings as both "contaminants" and "impurities" does not support his proposed construction. Ex.2028-Schubert-Decl., ¶48. As explained above, the plain and ordinary meaning of "impurities" is any element that is foreign to a host element, including both intentionally and unintentionally introduced elements. Referring to "contaminants" as "impurities" is not inconsistent with that meaning and would not suggest to a POSITA that the meaning of "impurities" is limited to the definition of "contaminants," in the same way that referring to a Corvette as a car does not mean that the term "car" encompasses only Corvettes.

34. Patent Owner's observation that Figure 1 refers to both contaminants and dopants does not support its proposed construction either. POR, 16. A POSITA would have recognized that the dopants referred to in Figure 1 are also "impurities." Further, a POSITA reading the '315 patent would have recognized that the patentee knew how to distinguish between impurities that behave as dopants and impurities

that may be contaminants when it intended to do so, and chose not to do so in the claims.

35. I also understand that a patentee may depart from the plain and ordinary meaning of a claim term by disavowing the full scope of the term either in the specification or during prosecution by including expressions of manifest exclusion or restriction, representing a clear disavowal of claim scope. In my opinion, the patentee did not do so in the '315 patent with respect to the term "impurities." For similar reasons as above, a POSITA would not understand the statement "as referred throughout, contaminants and/or impurities can be used interchangeably" to express manifest exclusion or restriction of the term "impurities" to exclude intentionally introduced dopants.

36. In addition, the prosecution history demonstrates that, not only did the patentee not disavow the full scope of the plain and ordinary meaning of "impurities," the patentee and the Examiner understood "impurities" to include intentionally introduced dopants. During prosecution of U.S. Patent No. 9,520,507 (from which the '315 patent claims priority), the Examiner rejected claims reciting "a first emitter region having metal impurities" based on U.S. Patent App. Pub. No. 2013/0247981. Ex.1036-USPA935FH, 42, 76; Ex. 1110 ("Yelundur"). Like Choi, Yelundur discloses an emitter, which it explains could be doped with p- or n-type

impurities, including boron, gallium, indium, aluminum, phosphorus, antimony, or arsenic. Ex.1110-Yelundur, [0053], [0055]. In response, the patentee did not argue that Yelundur does not disclose the claimed "metal impurities" but instead added a new claim limitation to avoid the prior art, and that limitation did not purport to narrow the "metal impurities" limitation. Ex.1036-USPA935FH, 98. In view of this prosecution history, a POSITA would understand that the patentee understood "impurities" as claimed in the '315 patent to have its plain and ordinary meaning, including intentionally introduced dopants, because the patentee did not dispute that a reference that described an emitter region having metallic dopants disclosed the "metal impurities" limitation.

37. Dr. Schubert suggests that a POSITA would understand "metal impurities" as recited in the claims to mean "undesired foreign metals" because "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." Ex.2028-Schubet-Decl., ¶45. I disagree. While the '315 patent explains, for example, that "[a] gettering process can be used to trap the metal impurities in the emitter regions, reducing recombination," Ex.1001-USP315, 5:12-14, a POSITA would not understand the meaning of "impurities" as recited in the claims to necessarily refer to a gettering process. The claims do not refer to gettering or otherwise specify where the claimed

metal impurities in the emitter region originate from. Therefore, the claims encompass a solar cell where no undesired foreign metals were gettered from the substrate to the emitter, as long as there were also metal impurities (including "undesired foreign metals") in the emitter. Accordingly, the solar cell structure in claim 10 does not necessarily achieve a reduction in recombination due to a gettering process, and a POSITA would not understand "impurities" as recited in the claims to be limited to impurities removed from the substrate to the emitter via gettering.

38. Further, if Dr. Schubert's proposed construction of "metal impurities" applied, then the claims would not inform a POSITA of the scope of the claimed invention with reasonable certainty. A POSITA would not understand under what conditions metals in the emitter are "desired" or "undesired" under Dr. Schubert's proposed construction. For example, in some circumstances even intentionally introduced dopants can have undesirable effects, such as inducing recombination, depending on the concentration, and Dr. Schubert agrees. Ex.2037-Holman-Tr., 125:11-18; Ex.1090-Schubert-Tr., 53:19-54:6. Conversely, in some circumstances, unintentional inclusion of metal impurities can be desirable and have beneficial effects, such as doping, again depending on the concentration. Ex.2037-Holman-Tr., 126:13-17. The '315 patent provides no guidance at what concentrations metals in the emitter are "desirable" or "undesirable" under Dr. Schubert's proposed

construction, and a POSITA would not understand the scope of the claims with reasonable certainty under that construction.

39. In addition, a POSITA would not understand with reasonable certainty what elements constitute "undesired foreign metals" under Dr. Schubert's proposed construction. The '315 patent provides only an exemplary list of three elements that are "contaminants and/or metal impurities": iron, nickel, and/or chromium. Ex.1001-USP315, 4:67-5:1. However, other elements are found in silicon solar cells *both* desirably and undesirably. For example, while aluminum was commonly used as a dopant in 2014, it was also a known impurity that could be unintentionally introduced in silicon wafers during the refining process and cause recombination. Ex.1119-Coletti-2012, 80. As explained above, the term "contaminants" lacks a well-established meaning in the semiconductor and solar fields, and if the definition of "impurities" were substituted with "contaminants," as Dr. Schubert appears to suggest, a POSITA would not understand with reasonable certainty what other elements are encompassed by Dr. Schubert's proposed construction of "undesired foreign metals."

IX. CLAIMS 10-17 AND 19-20 ARE INVALID AS OBVIOUS OVER CHOI, GRANEK OR MARVIN, AND OPTIONALLY ISTRATOV (GROUND I)

A. Choi Discloses "a First Emitter Region" and "a Second Emitter Region Having Metal Impurities"

40. As explained above in paragraph 23, the plain and ordinary meaning of "impurities" in the semiconductor and solar fields is any element that is foreign to the element(s) of a host material, including intentionally introduced dopants.

41. As I explain in my First Declaration, Choi teaches a "first conductive type area 32" and a "second conductive type area 34," Ex.1003-Decl., ¶255, that correspond to the claimed "second emitter region" and "first emitter region," respectively. *Id*. ¶¶266, 307. Further, Choi teaches that the first and second conductive type areas may be doped with n- or p-type impurities, including, among other elements, bismuth, aluminum, gallium, and indium, which a POSITA would have understood are metals. *Id*. ¶¶267-268.

42. Thus, under the plain and ordinary meaning of "metal impurities," a POSITA would have understood that Choi's first and second conductive type areas have metal impurities. *Id*. ¶¶268, 308.

43. Neither Patent Owner nor Dr. Schubert disputes that Choi discloses first and second emitter regions having metallic foreign elements. They argue only that Choi does not disclose first and second emitter regions having metal impurities under

their proposed construction of "metal impurities" as "undesired foreign metals." POR 21-22; Ex.2028-Schubert-Decl., ¶57. As explained above in paragraphs 28-30, I disagree that "undesired foreign metals" is the proper construction of "metal impurities," and therefore I disagree with Patent Owner and Dr. Schubert that Choi does not disclose first and second emitter regions having metal impurities.

B. Choi in View of Istratov Renders Obvious "a First Emitter Region" and "a Second Emitter Region Having Metal Impurities"

1. Silicon Solar Cell Wafers in 2014 Had Metal Impurities that Needed to be Gettered

44. As of 2014, metal impurities in silicon wafers were a pressing concern in the solar industry because they were known sources of recombination that lead to poor minority carrier lifetime, short diffusion length, and reduced solar cell efficiency. Ex.1003, ¶¶93, 205, 207; Ex.2037-Holman-Tr., 91:17-20; Ex.1047-Istratov-2000, 491; Ex.1033-Perichaud, 316; Ex.1093-Liu, 136; Ex.1094-Macdonald, 033523-1; Ex.1139-Shabani, 179. Dr. Schubert agrees that impurities are sources of recombination that lead to poor lifetime, as taught by the '315 patent. Ex.2028-Schubert-Decl., ¶57.

45. A POSITA as of 2014 would have understood that silicon wafers used for solar cell fabrication contain metal impurities, particularly iron, at levels that

adversely affect solar cell performance and for which gettering is needed, as explained below in paragraphs 48-57, 63-69.

46. Metal impurities could be incorporated into silicon wafers from the silicon feedstock and also from solar cell fabrication. Ex.1120-Coletti-2011, 3 ("It is clear that impurities are introduced and removed during most of the steps of the production chain."); Ex.1047-Istratov-2000, 491; Ex.1033-Perichaud, 315-316; Ex.1095-Seibt, 696.

47. The figure below shows "the main sources of impurities along the overall production chain of crystalline silicon PV modules." Ex.1120-Coletti-2011, 3-4 (Fig. 1.1).

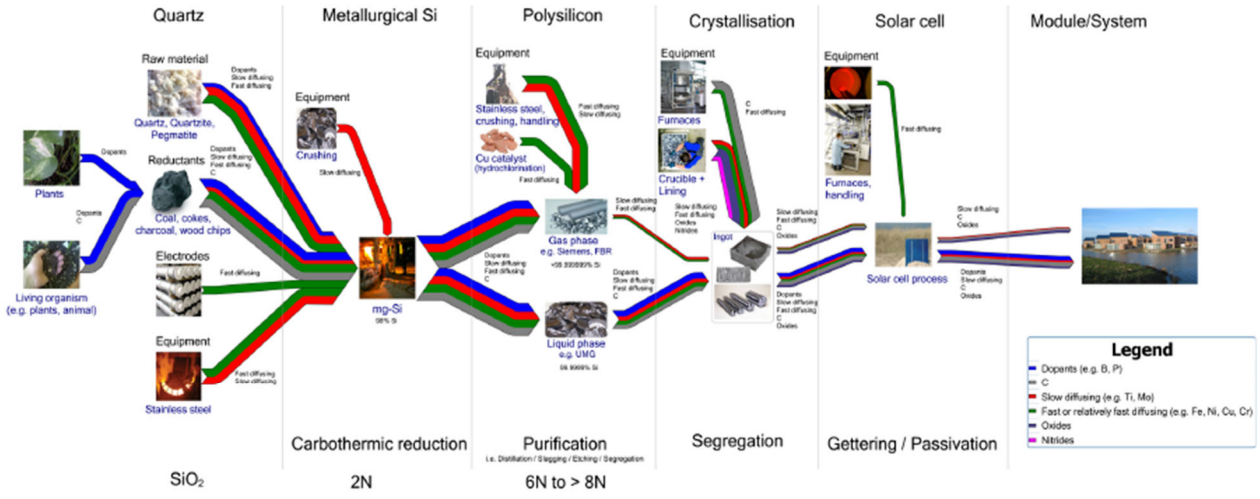


Figure 1.1 *Impurity sources and refinement scheme.*

Ex.1120-Coletti-2011, 4 (Fig. 1.1). The production of silicon wafers from the raw materials is shown in the first four columns: "Quartz," "Metallurgical Si," Polysilicon," and "Crystallization." Ex.1120-Coletti-2011, 4 (Fig. 1.1). The fifth column shows solar cell fabrication, which typically included gettering. Ex.1120-Coletti-2011, 4 (Fig. 1.1). The sources of "[f]ast or relatively fast diffusing" metal impurities, which include iron ("Fe"), nickel ("Ni"), copper ("Cu"), and chromium ("Cr") impurities, are shown in green in the figure. Ex.1120-Coletti-2011, 3-4 (Fig. 1.1).

a. Presence Of Metal Impurities In Silicon Wafers

48. As shown in the figure above (¶47), the production of silicon feedstock introduces "[f]ast or relatively fast diffusing (e.g., Fe, Ni, Cu, Cr)" impurities through numerous sources. Ex.1120-Coletti-2011, 3-4. The impurities could be introduced through the "raw material used for the production of silicon feedstock," which is "mainly quartzite and/or lumpy quartz." Ex.1119-Coletti-2012, 80. The raw materials could contain impurities such as iron, aluminum, titanium, calcium, and cobalt. Ex.1120-Coletti-2011, 3.

49. Another "important" "source of impurities" is "the carbon-based reducing agents used for the carbothermic production of silicon [], which contain" "metallic impurities in different amounts." Ex.1119-Coletti-2012, 80. It was known

as of 2014 that "[t]he electrodes and the construction materials of the furnace itself introduce iron, chromium, nickel as well as other metals." Ex.1119-Coletti-2012, 80.

50. The silicon at this stage then "require additional purification" to "be deemed usable for photovoltaic applications." Ex.1119-Coletti-2012, 80. The purification processes could introduce additional impurities, for example, iron, nickel, and chromium. Ex.1119-Coletti-2012, 80. Afterwards, the "crystallization techniques and methods" could introduce further metal impurities. Ex.1119-Coletti-2012, 82.

51. Silicon wafers used for solar cell fabrication were known to typically contain significant levels of metal impurities, particularly transition metals, as of 2014.[7] Ex.1094-Macdonald, 033523-1 ("Transition-metal impurities … are relatively common in photovoltaic-grade materials."); Ex.1093-Liu, 136 ("[i]mpurities such as transition metals are commonly found in silicon wafers for solar cells"); Ex.1003-Decl., ¶83; Ex.2037-Holman-Tr., 90:2-91:20, 97:20-98:4. Dr. Carroll, who was Patent Owner's original expert in this IPR (*see* above ¶6), agrees that in 2014, the solar industry used lower-quality silicon substrates than the

[7] Iron, copper, chromium, and nickel are examples of transition metals.

microelectronics industry. Ex.1092-Carroll-CSI-Tr., 25:2-26:18 ("In 2014 you would have used a lower-quality silicon to make the panels."), 29:3-14 (metal impurities in low-quality silicon substrates for solar "would include … nickel, iron, cobalt, moly and so forth"). Dr. Carroll testified that the silicon feedstock used for most solar cell fabrication came from silicon rejects from the microelectronics industry due to cost pressures. Ex.1092-Carroll-CSI-Tr., 25:12-16; *see* Ex.1033-Perichaud, 316.

52. Dr. Carroll referenced typical overall metal impurity concentrations of greater than 10^{15} cm^{-3}. Ex.1092-Carroll-CSI-Tr., 29:3-14. Another study by the same researchers as Istratov reports that iron levels alone were about "2.5×10^{13} cm^{-3}" for typical "silicon wafers for solar cells." Ex. 1047-Istratov-2000, 492.

53. In addition to being present at high concentrations, iron was known as of 2014 to be particularly detrimental to silicon solar cell performance. Iron was described as a "lifetime killer[]" due to its effects on carrier lifetime and solar cell efficiency. Ex.1119-Coletti-2012, 94-96; Ex.1047-Istratov-2000, 489; Ex.1137-Laades, 382-383. The following graph shows several types of metal impurities that negatively impact carrier lifetime, with iron ("Fe") and iron-boron ("FeB") impurities causing low carrier lifetime. Lines on the left side in the graph correspond

to particularly harmful impurities, though all the impurities plotted in this graph are in fact quite harmful.

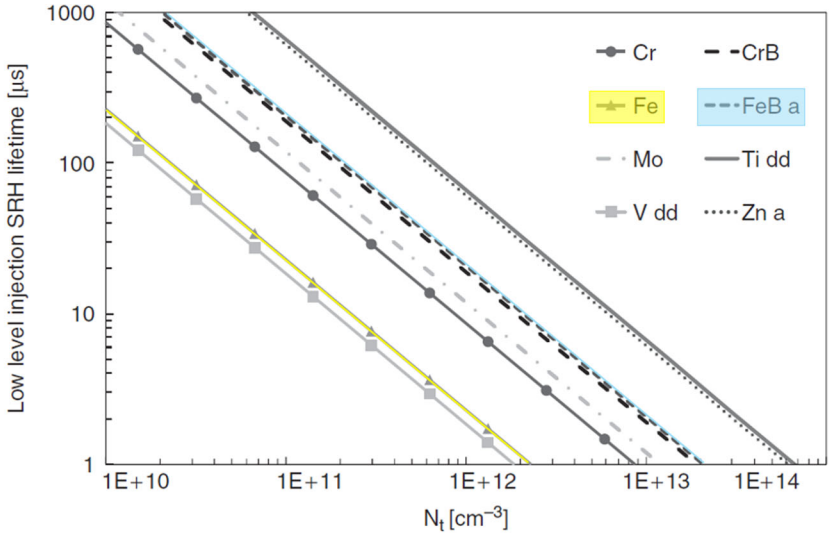


Figure 3.7 *SRH lifetime of several impurities in Si as a function of defect concentration at low injection level for a bulk resistivity of 1Ω cm. In the legend a) means acceptor and dd) double donor [1].*

Ex.1119-Coletti-2012, 95 (Fig. 3.7). The left portion of the graph shows that even at low concentrations, Fe and FeB impurities cause significant decreases in carrier lifetime.

54. The following graph shows the monotonic recombination lifetime decrease with increasing iron concentration for monocrystalline p-type wafers in particular.

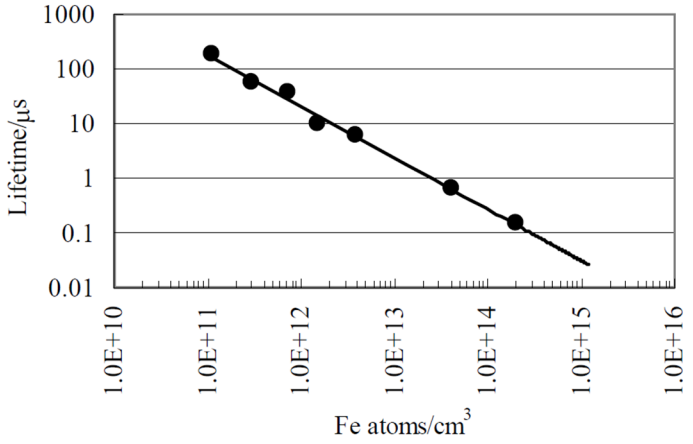


Fig. 7 Recombination lifetime versus Fe concentration for 10 Ωcm p-type wafers.

Ex.1139-Shabani, 183 (Fig. 7).

55. Metal impurities were present in significant amounts in the types of silicon substrates contemplated by Choi and Cousins: monocrystalline silicon and multicrystalline silicon wafers. Ex.1006-Choi, [0024]-[0025]; Ex.1007-Cousins, 2:44-49.

56. As of 2014, monocrystalline silicon wafers typically contained transition metals. Ex.1120-Coletti-2011, 6 (Table 1.1). Iron was an abundant contaminant, present at levels around 10^{13}-10^{14} cm^{-3} in solar-grade monocrystalline silicon. Ex.1139-Shabani, 183 (Table 2); Ex.1137-Laades, 384. It was known that even low levels of iron, *e.g.*, around 10^{12} cm^{-3}, reduce the diffusion length in monocrystalline silicon wafers, and lower diffusion lengths reduce solar cell efficiency. Ex.1120-Coletti-2011, 38-39. Copper was found to be present at levels around 10^{13}-10^{14} cm^{-3} in solar-grade monocrystalline silicon. Ex.1139-Shabani, 183

(Table 2). Chromium, barium, selenium, silver and zinc were other major contaminants. Ex.1137-Laades, 384. It was known that the other major metal impurities besides iron also decrease the carrier lifetime of monocrystalline silicon wafers. Ex.1137-Laades, 385.

57. Solar-grade multicrystalline wafers were similarly "known to contain [particularly] high transition metal concentrations." Ex.1064-Istratov-2004, 4474. Overall metal impurities in solar-grade multicrystalline silicon wafers were reported to be as "high as 10^{13}-10^{16} cm^{-3}." Ex.1100-Buonassisi, 402. For iron alone, iron impurities were present at levels around "10^{14}-10^{16}" cm^{-3} in multicrystalline silicon. Ex.1095-Seibt, 696; Ex.1127-Hofstetter-2011, 158 ("in most mc-Si materials total as-grown Fe [i.e., iron] concentrations as high as 10^{14}-10^{16} cm^{-3} are usually found"); Ex.1097-Hajjiah, 1-2 ("The typical concentration of iron [Fe] in commercial multi-crystalline silicon ingots has been reported to be in the range of 10^{13}–10^{15} cm^{-3} as determined by neutron activation analysis"). Other transitions metals such as nickel and copper were also present at high concentrations. Ex.1094-Macdonald, 033523-6 ("Maximum concentrations of 3.8×10^{14}, 3.7×10^{12}, and 2.8×10^{15} cm^{-3} were detected near the top of the ingot for Fe, Co, and Cu, respectively" in "a photovoltaic-grade multicrystalline silicon ingot"); Ex.1139-Shabani, 180 ("the major metal impurities in cast solar grade multi-crystalline (mc) silicon are Al, Fe, Ni and Cu with

concentration ranges of 10^{12} to 10^{15} atoms/cm^3, [and] medium levels metal impurities are Ti, Cr, Mn and Co ranging from 10^{10} to 10^{13} atoms/cm^3"). The majority of commercial solar cells used p-type multicrystalline wafers, which were known to have high sensitivity to impurities. Ex.1031-Bultman, 69; Ex.2037-Holman-Tr., 77:22-78:11, 156:9-12.

b. Metal Impurities Introduced By Solar Cell Fabrication

58. As my First Declaration explains, by 2014 it was known that, in addition to wafer manufacturing, subsequent device fabrication on the wafer could introduce metal impurities into silicon-based semiconductor devices, including solar cells. Ex.1003-Decl., ¶83; *e.g.*, Ex.1033-Perichaud, 316; Ex.1138-Liu-2022, Abstract ("further contamination during device fabrication is commonly found, especially in mass production environments"); Ex.1136-Ruby-Tr., 147:7-14 (testifying that "when you introduce a silicon wafer to a high temperature operation" for solar cell fabrication, "contaminants can be driven into the silicon, thereby creating recombination centers and reducing cell efficiency"). Metal impurities could be introduced during solar cell fabrication through process equipment, through chemicals and gases, or during handling between processing steps. Ex.1047-Istratov-2000, 491; Ex.1122-Saito, 82 ("The source of metal contaminants are

mainly categorized in three factors: process machines, materials and chemicals & gases.").

59. Metal impurities can be introduced from "processing equipment" such as etching baths, furnaces, chemical vapor deposition (CVD) equipment, and wafer handlers. Ex.1047-Istratov-2000, 491, 493; Ex.1122-Saito, 82. During wafer manufacturing, silicon ingots are cut into blocks and then wafers, typically with a wire saw. Ex.1120-Coletti-2011, 8. This sawing process causes mechanical damage to the wafer surface and can introduce metal impurities below the surface. Ex.1120-Coletti-2011, 8. Additionally, "[c]ross contamination from wafer to wafer, or from the furnace, can also take place during high temperature processes." Ex.1120-Coletti-2011, 9.

60. During processing, metal impurities can also be introduced "from chemicals (for example, gases, wet chemistry, photoresist, water)." Ex.1047-Istratov-2000, 491. After the wafers are cut, etching is used to remove impurities from the surface of the wafer. Ex.1120-Coletti-2011, 8. If surface impurities are not properly removed, they can "contaminate chemical baths employed in solar cell manufacturing," resulting in cross contamination of the wafers. Ex.1119-Coletti-2012, 84. Gas delivery systems were also known sources of metal impurities. Ex.1047-Istratov-2000, 491.

61. Metal impurities can also be introduced "from handling between these steps (by wafer carriers [or] even from the ambient air)." Ex.1047-Istratov-2000, 491.

62. Metal impurity contamination during device fabrication continues to be a problem in solar cell fabrication. Ex.1138-Liu-2022, Abstract ("[F]urther contamination during device fabrication is commonly found, especially in mass production environments. Metallic impurities are ubiquitous and abundant[.]"). Iron was known to be particularly "difficult to eliminate on a production line," even years after 2014. Ex.1047-Istratov-2000, 489.

c. Gettering Was Needed in Solar Cell Fabrication, Particularly to Reduce Iron Impurities

63. As of 2014, gettering was a commonly used process during solar cell fabrication for reducing the metal impurity concentration and improving solar cell performance. Ex.1003-Decl., ¶¶84-89. Both Dr. Schubert and Dr. Carroll agree. Ex.1090-Schubert-Tr., 118:17-119:12, 119:21-120:3; Ex.1091-Carroll-CSI-Decl., ¶38 ("[i]n 2014," gettering to "remove [] impurities" was a "common way[] of reducing such impurities"); Ex.1092-Carroll-CSI-Tr., 71:8-10.

64. Indeed, since the early 1960s, gettering had been a known way to reduce the harmful effects of metal impurities in silicon-based semiconductor devices. Ex.1003-Decl., ¶¶85-86; Ex.1139-Shabani, 188-189. A 2004 publication

by the same researchers as Istratov reported: "Gettering of transition metals by a layer of polycrystalline silicon (polysilicon) deposited on the back side of silicon wafers has been widely used by the silicon industry as a means to remove transition metals from the wafer and improve the minority carrier lifetime." Ex.1064-Istratov-2004, 4472.

65. Dr. Carroll and I agree that gettering was "necessary" for solar cell fabrication as of 2014. Ex.1092-Carroll-CSI-Tr., 25:2-27:4 (because "the silicon solar industry typically uses a lower grade of silicon," "post processing," i.e., "so-called gettering" that "take[s] place as part of the solar cell fabrication process," "is necessary"). Publications from the 2000s describe gettering as "a prerequisite for the production of efficient solar cells" and needed during solar cell fabrication to improve the bulk electrical properties of silicon wafers and silicon solar cell devices. Ex.1095-Seibt, 696; Ex.1033-Perichaud, 316. In 2014 and beyond, it was still a prerequisite for solar cell fabrication. Ex.1138-Liu-2022, Abstract ("Gettering … is therefore an essential aspect of the cell fabrication process.").

66. Dr. Schubert reads my testimony out of context to assert as if I admitted that gettering was ***not*** necessary for solar cell fabrication if using wafers with less than "significant level[s] of metal impurities." Ex.2028-Schubert-Decl., ¶¶67-68. I note that Dr. Schubert's opinion that gettering was not required for solar cell

fabrication differs from Dr. Carroll's opinion that gettering ***was*** "necessary." Ex.2028-Schubert-Decl., ¶68; Ex.1092-Carroll-CSI-Tr., 25:2-27:4. As I explained above in paragraphs 48-62, solar-grade wafers as of 2014 typically contained significant levels of metal impurities, and solar cell fabrication typically introduced additional metal impurities on the production lines. The levels of metal impurities in silicon solar cell materials were known to negatively affect solar cell performance, as explained above in paragraphs 44-45, 53, 56. Gettering was thereby necessary for solar cell fabrication as of 2014.

67. Due to the prevalence of iron and copper in silicon semiconductor devices, Istratov evaluates "the efficiency of traditional gettering techniques for iron and copper." Ex.1012-Istratov, 568; Ex.2037-Holman-Tr., 90:13-91:6.

68. Iron and copper were known to be relatively fast or fast diffusing impurities in silicon and thus particularly sensitive to gettering. Ex.1119-Coletti-2012, 93-94, 96. On the other hand, metal impurities such as titanium, molybdenum, and vanadium are slow diffusers and thus less sensitive to gettering. Ex.1119-Coletti-2012, 93-94. As the figure below show, "[a]t 840 °C, which is the typical temperature for [phosphorus] diffusion," the diffusivity of iron and copper through silicon is much higher than it is for titanium.

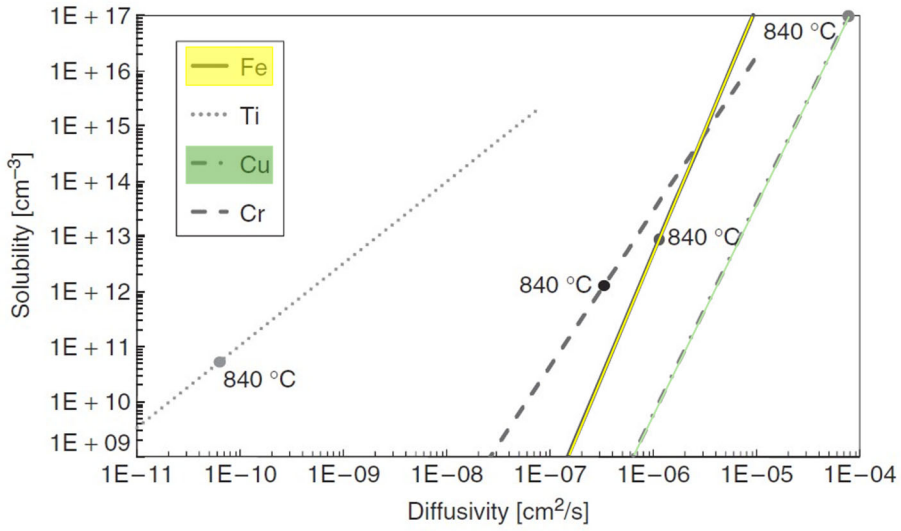


Figure 3.6 *Solubility versus diffusivity for representative metals. The dots represent the solubility and diffusivity at 840°C, which is the typical temperature for P-diffusion [1].*

Ex.1119-Coletti-2012, 93 (Fig. 3.6).

69. Iron was known to be a "relatively fast diffusing impurity": at 840 °C, the diffusivity of iron was approximately 1×10^{-6} cm^2/s, and at 1000 °C, its diffusivity was approximately 2.6×10^{-6} cm^2/s. Ex.1119-Coletti-2012, 85, 93 (Fig. 3.6); Ex.1120-Coletti-2011, 34. Therefore, a POSITA would have understood that the concentrations of iron and copper in silicon wafers and silicon solar cell devices can be effectively reduced by gettering during solar cell fabrication.

2. Istratov Is Analogous Art

70. As my First Declaration explains, Istratov and the '315 patent are in the same field of silicon semiconductor devices, which encompasses solar cells. Ex.1003-Decl., ¶203; Ex.2037-Holman-Tr., 54:1-6. Dr. Schubert asserts in his

declaration that because Istratov is in the field of integrated circuits, it is not related to solar cell technology. Ex.2028-Schubert-Decl., ¶61. But during his deposition, Dr. Schubert testified that silicon integrated circuits and solar cells are in the same field, that "solar cells are made of semiconductors," and that knowledge from the semiconductor field "is applicable" and "useful for the design, manufacturing, and operation of solar cells." Ex.1090-Schubert-Tr., 49:18-50:5, 52:2-53:1, 57:12-18. Patent Owner's own patents recognize that "[s]olar cells … may be fabricated on a semiconductor wafer using semiconductor processing technology." Ex.1102-USP053, 1:25-28. I note that Dr. Schubert's deposition testimony and Patent Owner's own patents contradict Patent Owner's assertion and Dr. Schubert's declaration that "silicon integrated circuits" are "not in the same field as … solar cell devices." POR, 24; Ex.2028-Schubert-Decl., ¶61.

71. Dr. Schubert asserts that "Istratov gives no indication that it is related to solar cell technology." Ex.2028-Schubert-Decl., ¶63. A POSITA would have understood that Istratov's gettering technique could be applied to solar cell fabrication. An earlier publication from the same researchers as Istratov states they were researching "techniques for gettering of iron" and "the effect of iron on [silicon] devices, including integrated circuits, power devices, and ***solar cells***." Ex.1047-Istratov-2000, 489.

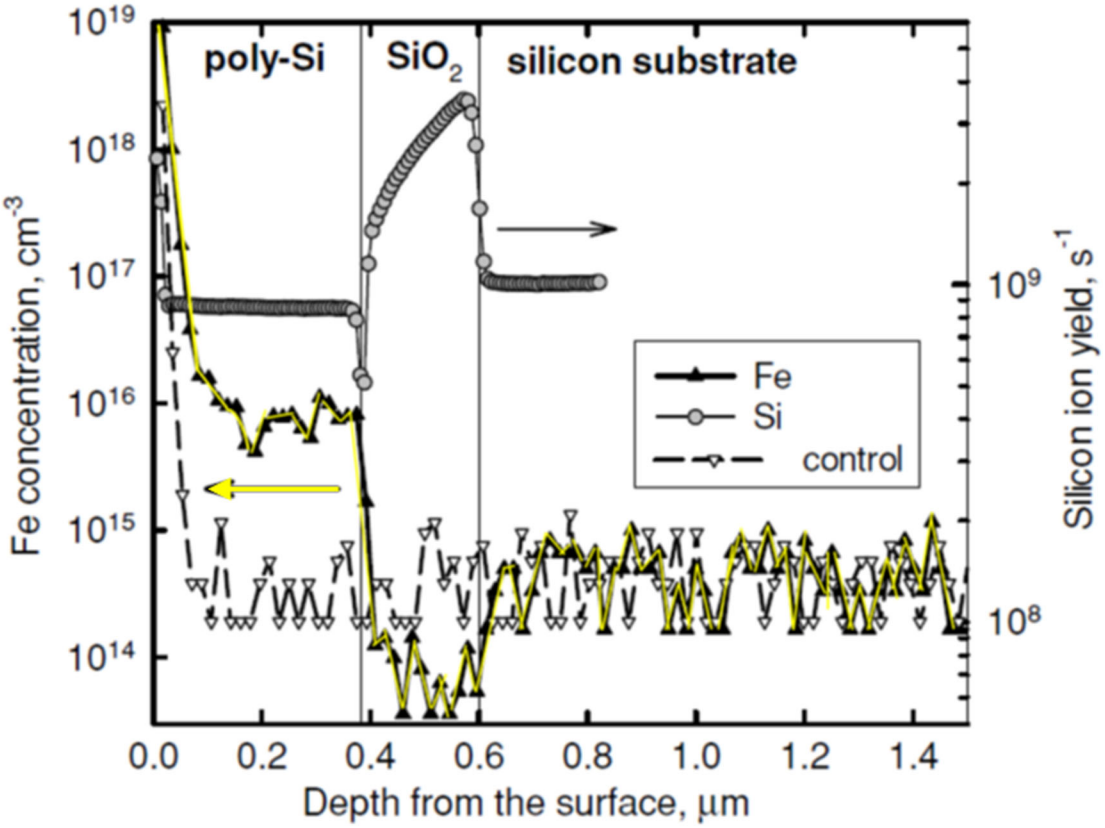
72. I disagree with Dr. Schubert's assertion that Istratov and the '315 patent have "opposite" "goals." Ex.2028-Schubert-Decl., 27. The '315 patent describes "techniques for improving the fabrication process, reducing the cost of manufacturing and increasing the efficiency of solar cells" by reducing recombination caused by metal impurities present in silicon substrates through gettering. Ex.1001-USP315, 1:35-39, 4:65-5:25. Istratov is also directed to improving device efficiency by reducing recombination caused by metal impurities through gettering. Ex.1012-Istratov, 569; Ex.2037-Holman-Tr., 104:2-105:9; Ex.1090-Schubert-Tr., 137:8-11. Other publications by Istratov describe these same goals. *See, e.g.*, Ex.1047-Istratov-2000, 491 (in "photovoltaics, iron contamination provides recombination centers which reduce … the solar cell efficiency"); Ex.1096-Istratov-2003, 6553 ("transition metals … are known to be highly recombination active in silicon" and responsible for "efficiency degradation of solar cells," and "gettering can reduce the amount of metal contaminants in the cells").

73. Dr. Schubert's arguments regarding Istratov's gettering direction—that Istratov is solely "directed at gettering impurities from a device layer to a silicon substrate"—misread Istratov. Ex.2028-Schubert-Decl., ¶¶64-65. Like the '315 patent, Istratov's experiments and simulations evaluate the gettering of metal impurities ***from*** the substrate ***through*** the oxide layer and ***into*** the polysilicon layer.

Ex.1012-Istratov, 570-572 ("iron can diffuse through the BOX layer ***from the substrate to the devices***"); Ex.2037-Holman-Tr., 81:8-13, 83:9-84:1, 84:13-18.

74. For gettering iron in its poly-Si/SiO_2/Si structure, Istratov introduces "[i]ron contamination" "by scratching the backside of the sample (i.e., the side opposite to the side on which poly-Si/SiO_2 was deposited)."[8] Ex.1012-Istratov, 570; *see* above ¶59. Dr. Schubert and I agree that iron was introduced into Istratov's poly-Si/SiO_2/Si structure through the silicon substrate. Ex.1090-Schubert-Tr., 138:20-139:19. Istratov shows the sample "annealed" at elevated temperature such that iron from the substrate moved through the silicon dioxide layer and into the polysilicon layer. Ex.1012-Istratov, 570 (Fig.2). Istratov's Figure 2 below shows the resulting profile of iron:

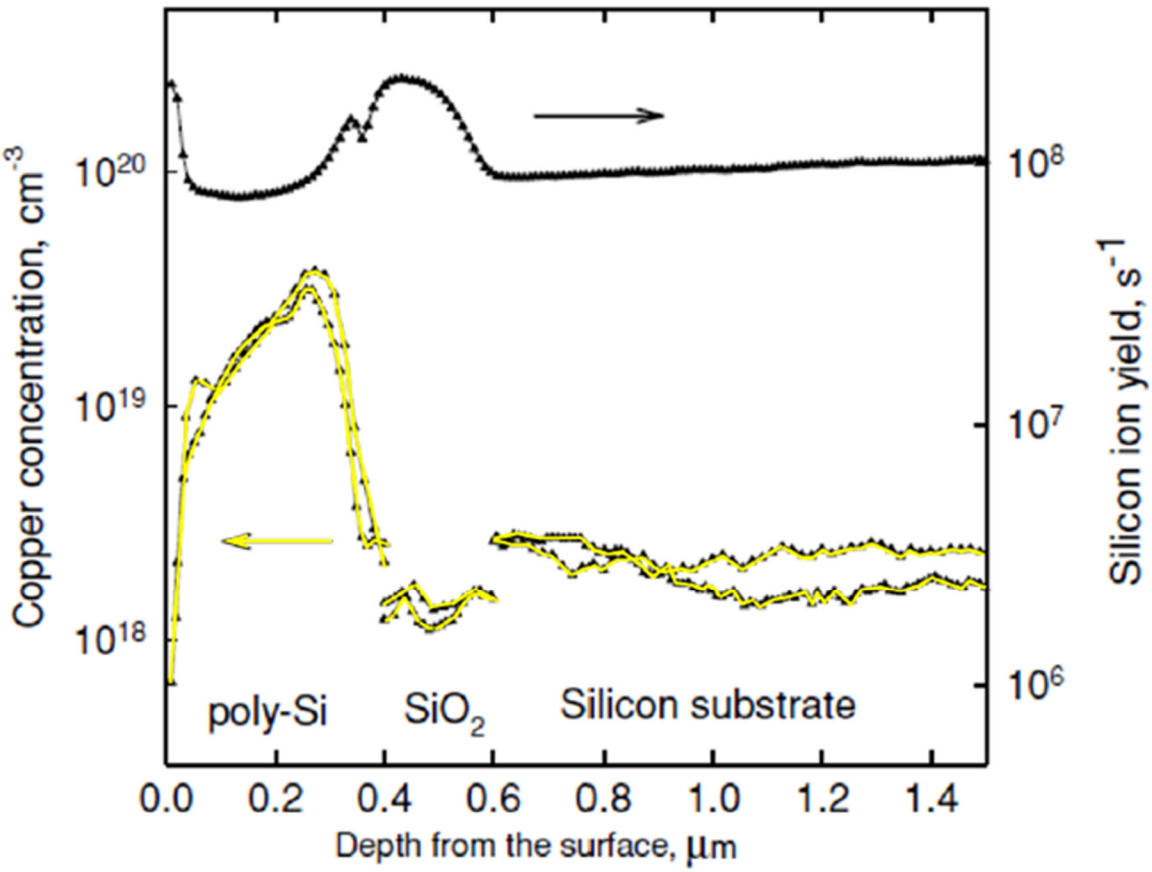
[8] Istratov's test structure is composed of a polysilicon ("poly-Si") layer covering a silicon dioxide ("SiO_2") layer that is grown on a silicon ("Si") substrate. Ex.1012-Istratov, 569-571.



Ex.1012-Istratov, 570, Fig.2. Dr. Schubert agrees that Istratov's Figure 2 shows iron moved from the silicon substrate through the silicon dioxide layer and into the polysilicon region. Ex.1090-Schubert-Tr., 139:20-140:16, 142:8-143:1.

75. For gettering of copper in its poly-Si/SiO_2/Si structure, Istratov introduces "[c]opper contamination" on "the backside of the wafer with a copper wire." Ex.1012-Istratov, 571. Dr. Schubert and I agree that copper was introduced into Istratov's poly-Si/SiO_2/Si structure through the back side of the silicon substrate. Ex.1090-Schubert-Tr., 140:17-141:5. Istratov then studied the diffusion of that copper at elevated temperatures. Ex.1012-Istratov, 571. As Dr. Schubert

confirms, Istratov reports that copper moved from the silicon substrate through the silicon dioxide and into the polysilicon region, as Figure 5 below shows. Ex.1090-Schubert-Tr., 142:19-143:1, 150:5-10.



Ex.1012-Istratov, 571, Fig.5.

76. I further disagree with Dr. Schubert's misreading of Istratov's gettering direction because when conducting gettering, one cannot selectively control the direction in which metal impurities diffuse. Rather, after heating, metal impurities in a solar cell diffuse throughout the semiconductor and become "trapped" in regions

in which the metal impurities have a relatively higher solubility. Ex.1033-Perichaud, 316-318.

77. Finally, Patent Owner misrepresents my testimony by asserting I "overlooked Istratov's purpose" and failed to consider "Istratov's introduction." POR 25. I testified that I "did consider" Istratov's Introduction and that I "read Istratov in its entirety." Ex.2037-Holman-Tr., 83:4-5. Patent Owner is referring to this statement from Istratov's introduction section, which Patent Owner's counsel asked me about during my deposition:

> The BOX layer not only provides electrical isolation between the top Si layer and the substrate, but also introduces a barrier for diffusion of metal impurities from the device layer to the gettering sites in the substrate.

Ex.1012-Istratov, 568; POR, 25 (citing Ex.2037-Holman-Tr., 81:5-84:1). As I explained during my deposition, this statement from Istratov's introduction describes "previous work in the state of the field … as is typical in introduction sections." Ex.2037-Holman-Tr., 82:7-84:1. Istratov's experiments and simulations gettered metal impurities ***from*** a silicon wafer ***through*** an oxide layer ***into*** a polysilicon layer. Ex.2037-Holman-Tr., 81:5-16, 83:9-18.

3. A POSITA Would Have Been Motivated to Combine Choi and Istratov with a Reasonable Expectation of Success

78. I disagree with Dr. Schubert's suggestion that certain differences between Choi's and Istratov's oxide layers would have undermined the combination

of Choi with Istratov. Despite the differences between Choi and Istratov's oxide thicknesses (0.5-5 nm versus 197 nm, respectively) and thus susceptibility to charge carrier transport (tunneling versus insulating, respectively), Ex.2028-Schubert-Decl., ¶¶61-62, the metal impurities were successfully gettered through Istratov's oxide layer, as I explained above in paragraphs 74-75. Istratov's disclosure of gettering through its much thicker oxide layer demonstrates the same could be achieved in a significantly thinner oxide layer such as Choi's, which would have a lower diffusion barrier. *See* Ex.1090-Schubert-Tr., 146:16-147:3 ("If the oxide layer thickness is decreased, then the thickness of the diffusion barrier is lower."). Istratov's disclosure of successful gettering would have encouraged a POSITA to implement gettering in Choi's solar cell. Ex.1003-Decl., ¶213.

79. I also disagree that implementing Istratov's gettering process would have been detrimental to Choi's solar cell. Ex.2028-Schubert-Decl., ¶¶69-71. Neither Dr. Schubert nor Patent Owner has cited to any evidence that Choi's tunnel oxide layer could "potentially dissolve," that Choi's dopants from the front surface field could potentially "disperse throughout the silicon substrate," or that "impurities originally in Choi's first and second conductive regions" could potentially migrate into Choi's substrate. POR, 28; Ex.2028-Schubert-Decl., ¶¶69-71. Gettering was

routinely used in solar cell fabrication as of 2014, as I explained above in paragraphs 63-65 and in my First Declaration. Ex.1003-Decl., ¶¶84-89.

80. A POSITA would have adapted Istratov's gettering process for Choi's solar cell structure by lowering the temperature and/or processing time to avoid any detrimental impacts. Ex.2037-Holman-Tr., 85:3-86:2. A POSITA would have known to lower the temperature and/or processing time because the oxide layer through which metal impurities are gettered is much thinner in Choi's solar cell (*see* above ¶78). As Dr. Schubert acknowledges, "Choi's tunnel oxide thicknesses are 40 to 2,600 times thinner than Istratov's [] oxide [layer] thicknesses." Ex.2028-Schubert-Decl., ¶62. A thinner oxide layer such as Choi's requires less thermal energy to diffuse through.

81. Dr. Schubert suggests that there may not be a "temperature-time combination that would not have had a deleterious impact on Choi." Ex.2028-Schubert-Decl., ¶71. It was within the level of ordinary skill for a POSITA as of 2014 to calculate an appropriate temperature and time for gettering. Gettering simulation tools were available as early as 2003. These tools simulated "contamination and gettering processes" for studying the influence of parameters such as "temperature and time of process, type of impurity … and initial concentration" on gettering efficiency. Ex.1125-delCanizo-2003, 993, 995. More

sophisticated gettering simulation tools were available by 2010 to optimize gettering processes. *See generally* Ex.1126-Hofstetter-2010.

82. It was well known as of 2014 that iron is a relatively fast diffuser and copper is a fast diffuser, as explained above in paragraphs 68-69. An earlier publication from the same researchers as Istratov reported:

> [T]he diffusivity of iron in silicon dioxide is about 10^{-14} to 10^{-15} cm^2/s at 1000°C …. The diffusion coefficient in the range of 10^{-14} cm^{-3} implies that iron would diffuse through a 10-nm oxide within several minutes at 1000°C, i.e., a thin silicon dioxide layer will not keep iron from diffusion into the bulk unless the anneals are very short or the oxide layer is very thick.

Ex.1047-Istratov-2000, 495. Thus, for Choi's solar cell, which had an even thinner tunnel oxide thickness of 0.5-5 nm, iron would diffuse through Choi's tunnel oxide within a lesser amount of time than the "several minutes" reported at 1000 °C. Ex.1006-Choi, [0034]; Ex.1047-Istratov-2000, 495.

C. Choi in View of Marvin or Granek Renders Obvious the Claimed Front Dopant Concentration

83. As my First Declaration explains, numerous prior art publications in addition to Marvin and Granek disclose that the desired dopant concentration in a region near the substrate's surface was around 1×10^{18} cm^{-3} due to balancing surface and Auger recombination. Ex.1003-Decl., ¶¶79-82, 193; *e.g.*, Ex.1021-King, 367, 369; Ex.1030-Swanson-352, 4:45-51; Ex.1040-Procel, 15. Additionally, a 1981 publication by Chin et al. discloses a "front n^+-doped IBC cell [] designed with a

doping gradient penetrating below the front surface as shown in Fig. 9" (e.g., a front surface field ("FSF"), as shown below), which was "introduced to suppress the surface recombination." Ex.1103-Chin, 111 (Abstract), 113. Figure 9 shows the "optimum front surface concentration" was about "10^{18}/cm^3." Ex.1103-Chin, 114.

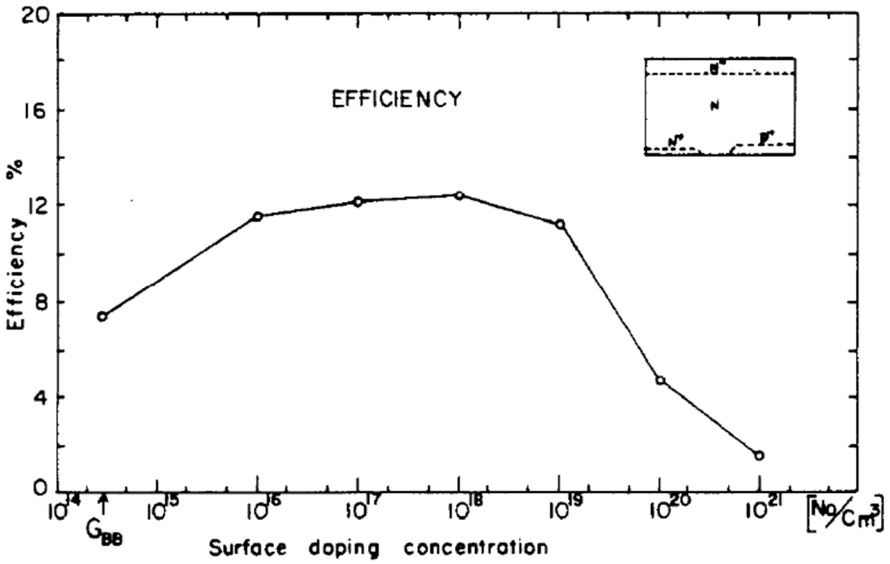


Fig. 9. The conversion efficiency of a front doping gradient IBC cell vs surface doping concentration showing that the optimum surface doping is about 10^{18}/cm^3, at 1 sun AMO, $s_0 = 1000$ cm/sec.

Ex.1103-Chin, 113 (Fig. 9). This publication further discloses:

> The total recombination and the surface recombination initially decreased with increased front doping concentrations up to 10^{18}/cm^3 at 1 sun AMO[.] … [T]he total recombination rises again at concentrations above 10^{18}/cm^3 because of the increased Auger recombination in the front doped region.

Ex.1103-Chin, 113-114. A POSITA would have understood based on the prior art that the claimed front "dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3}" was a suitable option.

1. Choi in View of Marvin Renders Obvious the Claimed Front Dopant Concentration

84. In order to evaluate the interdigitated back-contact ("IBC") cell design, Marvin presents data for solar cell performance at two states, beginning-of-life ("BOL") and end-of-life ("EOL"), and at two illumination intensities, 1 sun and 100 suns. *E.g.*, Ex.1008-Marvin, 5, 9, 11, 14, 16; Ex.2037-Holman-Tr., 33:4-16. BOL refers to the state of a solar cell when it is first made, while EOL corresponds to the state of a solar cell after it has been damaged by solar radiation after a mission in space. Ex.2037-Holman-Tr., 33:4-16; Ex.1090-Schubert-Tr., 165:10-14. One sun means regular sunlight and non-concentrator conditions, while 100 suns means concentrator conditions. Ex.2037-Holman-Tr., 42:3-17; Ex.1090-Schubert-Tr., 167:3-5. BOL and 1 sun conditions are representative of terrestrial solar cells in normal use, and, therefore, I rely on Marvin's disclosures for those conditions in my First Declaration. Ex.2037-Holman-Tr., 36:13-21, 41:10-19.

a. Marvin Discloses the Claimed Front Dopant Concentration for 1 Sun and BOL Conditions

85. As my First Declaration explains, Marvin clearly teaches on page 15 that a front surface field ("FSF") doping concentration of 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3} reduces surface recombination while also avoiding Auger recombination occurring at higher concentrations. Ex.1008-Marvin, 15; *e.g.*, Ex.1003-Decl., ¶¶159-160, 188,

245-246, 389-390. Marvin's teaching on page 15 of an FSF doping concentration of 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3} is for BOL and 1 sun (non-concentrator) solar cell conditions. Ex.1008-Marvin, 15. Dr. Schubert agrees. Ex.1090-Schubert-Tr., 169:5-11. Specifically, Marvin on page 15 states:

> The effects of FSF thickness and doping level were studied for the baseline cell geometry at ***BOL***. For thicknesses of 0.25, 0.5, and 1.0 μm at 1E18 doping, no significant effect was observed at ***1 sun***. The FSF effectiveness is relatively constant over a rather broad range around ***1E17 to 1E18 cm^{-3}***, decreasing below this level due to the weakness of the electric field and decreasing above this level due to increased Auger recombination.

Ex.1008-Marvin, 15.

86. Dr. Schubert's assertion that abrupt (also known as step) FSFs, which Marvin's "page 15 relates to," "have limited practical value" is incorrect. Ex.2028-Schubert-Decl., ¶75. Abrupt FSF and graded FSF are two types of doping profiles described by Marvin: the abrupt FSF is "uniformly doped," while Marvin's graded FSF has "a Gaussian doping profile." Ex.1008-Marvin, 15 ("This doping may be a step function …, or a graded region."), 17. Abrupt FSFs were routinely modeled in 2014 to represent experimental results, and Marvin identifies them as a "conventional" doping profile. Ex.1008-Marvin, 21; *e.g.*, Ex.1128-Lan-2015, 348 ("abrupt n^+–n junction" for "FSF silicon cells"); Ex.1104-Dai, 364 ("abrupt n^+–n high-low junction"). I note that the FSF doping concentration of 5×10^{18} cm^{-3} that Patent Owner and Dr. Schubert rely on was also for an abrupt/step FSF. Ex.1008-

Marvin, 25 ("The FSF should be an approximately 0.5 μm ***step*** with doping concentration of 5E18 cm^{-3}."); POR, 29; Ex.2028-Schubert-Decl., ¶¶72-73.

87. I disagree with Dr. Schubert's assertion that Marvin's disclosure of FSF doping concentration of 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3} pertains only "to a high radiation environment." Ex.2028-Schubert-Decl., ¶74. Marvin clearly states on page 15 that this disclosure is "at BOL," which means the solar cell has not experienced any radiation. Ex.1008-Marvin, 15. Dr. Schubert relies on a different FSF design from page 25 of Marvin, which has a graded doping profile and is for EOL and high radiation conditions. Ex.2028-Schubert-Decl., ¶74; Ex.1008-Marvin, 25. Specifically, Marvin on page 25 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, 25. I do not rely on Marvin's disclosures for EOL and high radiation conditions (*see* above ¶¶84-85).

88. Dr. Schubert acknowledges the FSF designs on Marvin's pages 15 and 25 are different (Ex.1090-Schubert-Tr., 169:5-170:15, 182:2-17; Ex.2028-Schubert-Decl., ¶74)—even though both have an FSF doping concentration of 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3}. Ex.1008-Marvin, 15, 25. Dr. Schubert agrees that Marvin's teaching on page 15 of an FSF doping concentration of 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3} is for BOL

and 1 sun (non-concentrator) solar cell conditions and for an "abrupt doping profile[]." Ex.1090-Schubert-Tr., 169:5-170:15; Ex.2028-Schubert-Decl., ¶75; Ex.1008-Marvin, 15. As for Marvin's teaching on page 25 of an FSF doping concentration of 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3}, he testified that teaching "pertain[s] to a high radiation environment," "for example, an unshielded space application" and is for a "graded" FSF design "to maximize EOL performance." Ex.2028-Schubert-Decl., ¶74; Ex.1008-Marvin, 25.

b. Marvin Discloses a Higher Dopant Concentration for Other Conditions

89. I disagree with Dr. Schubert's assertion that "Marvin's Conclusion section" on page 25 "instructs that 5×10^{18} cm^{-3} should be used for the terrestrial environment." Ex.2028-Schubert-Decl., ¶75; Ex.1008-Marvin, 25.[9] That disclosure

[9] Maxeon mischaracterizes my testimony by asserting that I did "not know of" Marvin's disclosure on page 25 of the FSF doping concentration of 5×10^{18} cm^{-3} for space applications and was unable "to explain away [that] key ***conclusion*** of Marvin." POR, 30. Contrary to Maxeon's mischaracterizations, I testified that I had read and considered "all of Marvin" and that Marvin's disclosure of 5×10^{18} cm^{-3} was for "different" "conditions" than those "relied on in [my obviousness] combination"

from Marvin of an FSF doping concentration of 5×10^{18} cm^{-3} is for space applications: it discusses "near optimal designs" "for space use" and "for missions" and that such "parameter[] [is] much more critical for 100 sun operation." Ex.1008-Marvin, 25. Specifically, Marvin's Conclusion on page 25 states:

> IV. CONCLUSION
> The design of IBC solar cells ***for space use*** has been investigated using 2-dimensional computer simulations. ***Near-optimal designs have been presented for missions*** using either planar or 100 sun concentration for arrays, under high or negligible radiation fluences. 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}***. These parameters are much more critical for ***100 sun operation***. The 1 sun efficiency of IBC cells exceeds 15%, which makes them competitive with conventional design silicon cells. The 100 sun efficiency is nearly 19%, which greatly exceeds the conventional silicon cell capability.

Ex.1008-Marvin, 25.

90. Dr. Schubert incorrectly argues that Marvin's reference to "the low radiation environment" in Marvin's Conclusion means that Marvin was discussing terrestrial conditions. Ex.2028-Schubert-Decl., ¶73; Ex.1008-Marvin, 25. But as

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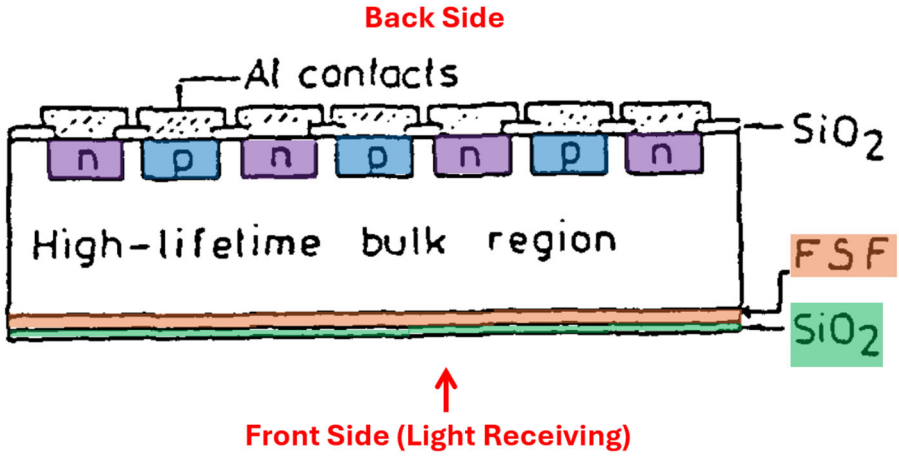
because my First "Declaration relie[d] on the one sun illumination intensity and beginning of life conditions, as those are representative of terrestrial solar cells." Ex.2037-Holman-Tr., 39:11-42:2; *id.*, 32:10-34:2.

even Dr. Schubert acknowledges, "low radiation does not necessarily mean terrestrial." Ex.2028-Schubert-Decl., ¶73.

91. Patent Owner raises the argument—which is absent from and not supported by Dr. Schubert's declaration (*see* Ex.2028-Schubert-Decl., ¶¶72-78)—that a POSITA would rely on the FSF design with a doping concentration of 5×10^{18} cm^{-3} from Marvin's Conclusion on page 25 because "that passage is specific to … [the] geometry that Marvin found 'near-optimal' for terrestrial applications." POR, 30-31; Ex.1008-Marvin, 25. According to Patent Owner, the "geometry that Marvin found 'near-optimal' for terrestrial applications" "had minority and majority carrier collection thicknesses of 0.9 μm and 3.0 μm, respectively (three times as great as in the baseline cell geometry)." POR, 30-31; Ex.1008-Marvin, 25. As explained above in paragraph 89, the FSF design with a doping concentration of 5×10^{18} cm^{-3} from Patent Owner's Conclusion on page 25—which, as Patent Owner points out, has minority and majority carrier collection thicknesses of 0.9 μm and 3.0 μm (POR 31)—is optimal for 100 suns applications. I do not rely on the embodiments Marvin teaches for 100 suns applications or EOL applications (*see* above ¶¶84-85).

92. I also disagree with Patent Owner's suggestion that Marvin's disclosure of the FSF doping concentration of 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3} is not relevant because Marvin separately optimizes the minority (n^+) and majority (p^+) carrier

collection thicknesses of its solar cell. *See* POR 30-31. I note that this argument is also absent from and not supported by Dr. Schubert's declaration. *See* Ex.2028-Schubert-Decl., ¶¶72-78. The minority (n^+) and majority (p^+) carrier collection regions (shown in Marvin's Figure 1 below) are on the rear side of Marvin's solar cell, opposite from the FSF. Ex.1090-Schubert-Tr., 156:22-158:1.



Ex.1008-Marvin, 4 (Fig.1). The minority (n^+) and majority (p^+) carrier collection regions in Marvin's solar cell are separate and independent from the FSF. Varying the thicknesses of the carrier collections regions would not affect the FSF. The purpose of the FSF is to reduce recombination at the front surface, as stated by Marvin, and the optimum doping density to do so is independent of how the carrier collection regions on the opposite side are designed. It was known that in "IBC Solar Cells" such as Marvin's, "the design of the front side (optical side) and the

back side (electrical side) can easily be optimized separately." Ex.1124-Verlinden-2012, 332.

93. Outside of its Conclusion section, Marvin elsewhere teaches the FSF doping concentration of 5×10^{18} cm^{-3} for space applications, which reinforces that 5×10^{18} cm^{-3} is intended for space applications. In the "Design Refinements" section, Marvin states:

> F. DESIGN REFINEMENTS
>
> Using the baseline cell as a starting point, the IBC cell design has been investigated to show how the parameters should be varied to produce an optimum design for various applications. …
>
> ***For space use***, where radiation is present, EOL performance must be considered. ***The baseline cell parameters are near optimum for EOL*** efficiency.

Ex.1008-Marvin, 16. The referenced "baseline cell parameters" that Marvin teaches "are near optimum for EOL" conditions and "[f]or space use" are provided in Marvin's Table 2 (shown below). Ex.1008-Marvin, 10, 16; Ex.1090-Schubert-Tr., 159:7-21.

Table 2. Basline Cell Design

p^+ width	35 μm
n^+ width	145 μm
p^+ thickness	1.0 μm
n^+ thickness	0.3 μm
p thickness	50 μm
τ_n in base	136 μs 1.10 μs[a] 0.32 μs[b]
τ_n in p^+ contact	0.128 μs 78 ns[a] 78 ns[b]
τ_p in n^+ contact	32.6 ns 12 ns[a] 12 ns[b]
FSF doping	5E18 p type
FSF thickness	0.5 μm

Ex.1008-Marvin, 10 (Table 2). As Dr. Schubert acknowledges, the baseline cell parameters include the FSF doping concentration of 5×10^{18} cm^{-3}. Ex.1090-Schubert-Tr., 159:7-21.

94. Thus, because I rely on Marvin's teachings pertaining to BOL and 1 sun conditions that are representative of terrestrial use (*see* above ¶¶84-85), Dr. Schubert is incorrect that Marvin "teaches that the preferred dopant concentration for an implementation similar to [my] proposed combination is 5×10^{18} cm^{-3}." Ex.2028-Schubert-Decl., ¶72.

c. Dr. Schubert's Remaining Arguments About Marvin Are Inapposite

95. I further disagree with Dr. Schubert's assertion that "Marvin's simulations have limited meaningfulness" because they are not "experimental results" and "especially [] since [they] are two-dimensional, which is less realistic

than a three-dimensional simulation." Ex.2028-Schubert-Decl., ¶76. POSITAs routinely rely on lower-dimensional simulations to provide useful guidance when exploring design parameters, and they are not necessarily less reliable than three-dimensional simulations. In fact, the Desa and Procel publications that Dr. Schubert and Patent Owner rely on involve two-dimensional simulations and no experimental results. Ex.2003-Desa, 69, 71; Ex.2005-Procel, 128; Ex.1090-Schubert-Tr., 218:18-21, 226:17-227:7.

96. Marvin is a reputable study, having been "reviewed and approved for The Aerospace Corporation."[10] Ex.1008-Marvin, i. The researchers of Marvin used a modeling program with an "extensive" "range of processes" and validated the accuracy of the program by, among other things, reproducing "several simulations of IBC cells reported in the literature" and "ensuring accurate absolute efficiencies." Ex.1008-Marvin, 7. Further, Marvin's teaching that an FSF doping concentration of around 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3} balances surface and Auger recombination

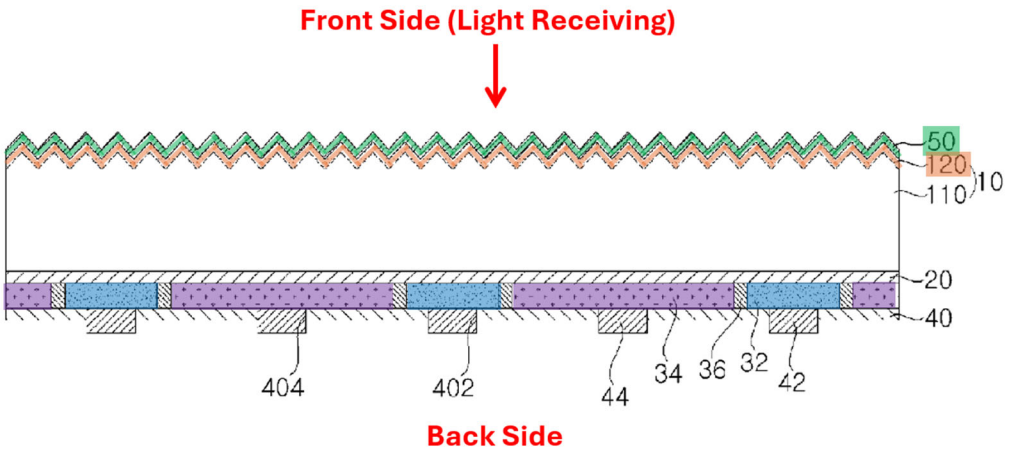
[10] "The Aerospace Corporation has provided independent technical and scientific research, development, and advisory services to national security space programs since 1960," and as of 2014, had "more than 50 years of experience with space systems." Ex.1132-Aerospace-About-Us.

(Ex.1008-Marvin, 15) is confirmed by numerous other publications disclosing that the desired dopant concentration was around 1×10^{18} cm^{-3} for the same reason (*see* above ¶83).

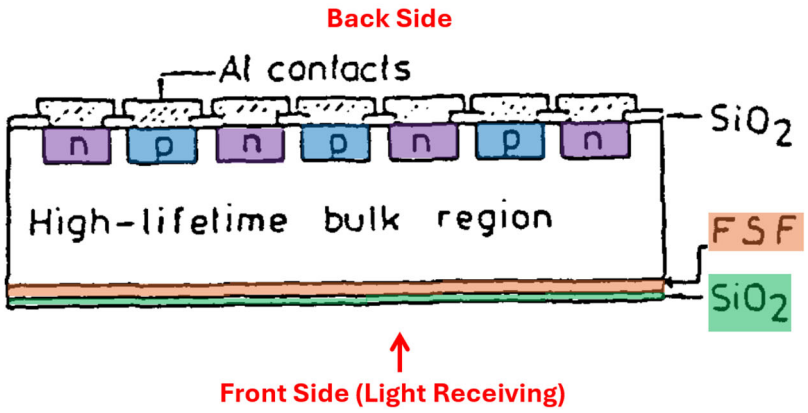
97. Finally, Dr. Schubert argues "that Marvin's teachings are not equally applicable to TOPCon solar cell configurations" like Choi's because Marvin uses a "conventional solar cell configuration." Ex.2028-Schubert-Decl., ¶78. I note that Patent Owner's POR omits this argument. *See* POR, 28-32. Choi's tunneling layer 20 and polysilicon layers make it a TOPCon solar cell. Both the tunneling layer 20 and the polysilicon layers are on the rear side of the solar cell. Thus, the tunneling layer 20 and the polysilicon layers would not have discouraged a POSITA from implementing Marvin's FSF doping concentration in Choi's FSF layer at the front side of the solar cell. As explained above in paragraph 92, the front and rear regions of a solar cell are independent of each other and "can easily be optimized separately." Ex.1124-Verlinden-2012, 332

98. A POSITA could have readily implemented Marvin's FSF dopant concentration of 1×10^{17} cm^{-3} to 1×10^{18} cm^{-3} in Choi's solar cell. As shown below, Choi and Marvin are both back-contact solar cells with similar front side configurations comprising an FSF layer to reduce recombination and a silicon oxide passivation layer. Ex.1006-Choi, Fig.1, [0029]-[0030], [0032]; Ex.1008-Marvin, 4

(Fig.1), 15. Dr. Schubert agrees. Ex.1090-Schubert-Tr., 107:8-110:12, 156:16-157:13.



Ex.1006-Choi, Fig.1.



Ex.1008-Marvin, 4 (Fig.1).

2. Choi in View of Granek Render Obvious the Claimed Front Dopant Concentration

99. I understand that neither Patent Owner nor Dr. Schubert disputes that Granek discloses the required dopant concentration of "approximately less than or

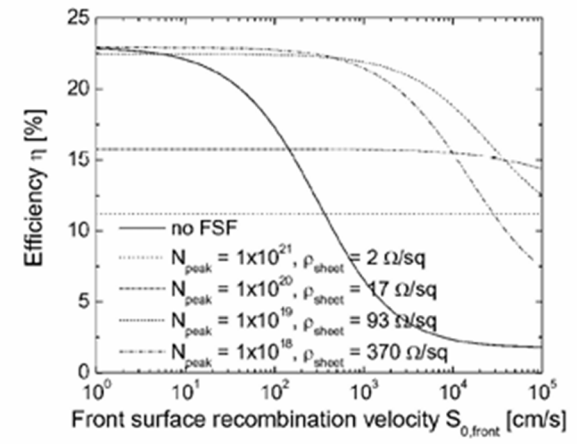
equal to 2×10^{18} cm^{-3}." Instead, Patent Owner and Dr. Schubert only argue that Granek does not teach that this dopant concentration is "preferred." As an initial matter, I have been informed that, for obviousness, the law does not require that a particular combination must be the preferred, or the most desirable, combination described in the prior art. Consequently, the combination of Choi and Granek (or Cousins and Granek) renders obvious the challenged limitations. Nevertheless, as I explain below, Patent Owner's and Dr. Schubert's assertions that "Granek does not teach that a dopant concentration of less than 2×10^{18} cm^{-3} is preferred" are incorrect.

100. Specifically, (a) Dr. Schubert is mistaken that Granek's experimental results report a preference for an FSF dopant concentration greater than 2×10^{18} cm^{-3}, (b) his reliance on front surface recombination velocities greater than 500 cm/s is flawed, (c) he is incorrect that Granek's simulation results for solar cells without an FSF contradict "well-accepted experimental results," (d) he is wrong that achieving low surface recombination velocity would have been difficult, (e) contrary to Dr. Schubert's assertion, a POSITA would not have considered the top graph of Figure 7-3 of Granek because it is not relevant to solar cells with well-passivated front surfaces, and (f) he is incorrect that "Granek's simulations have limited relevance." I address each point in more detail below.

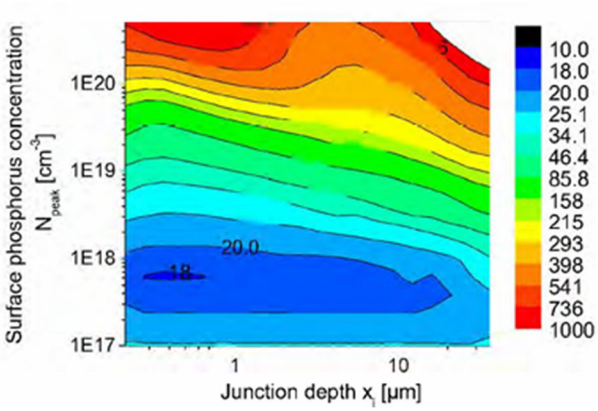
a. Granek Does Not Report a Preference for an FSF Dopant Concentration Greater Than 2×10^{18} cm^{-3}

101. Patent Owner and Dr. Schubert are incorrect that "Granek's experimental results indicate that a dopant concentration greater than 2×10^{18} cm^{-3} is preferable." POR 32-33; Ex.2028-Schubert-Decl., ¶¶80, 89-90. Patent Owner and Dr. Schubert overlook that Granek's simulation results and experimental results both indicate that further lowering the FSF dopant concentration below 3.8×10^{18} cm^{-3} would further increase solar cell efficiency. *See* Ex.1010-Granek, 121 (Fig.7-1), 122 (Fig.7-3), 132 (Table 7-5). While Granek does not show experimental results for FSF dopant concentrations lower than 3.8×10^{18} cm^{-3}, a POSITA reading Granek would have expected that lowering the dopant concentrations below 3.8×10^{18} cm^{-3} would have resulted in higher efficiency.

102. For example, Figure 7-1 of Granek and the bottom graph of Figure 7-3 of Granek (which corresponds to well-passivated surfaces) show simulations that indicate a solar cell with an FSF dopant concentration of around 1×10^{18} cm^{-3} yields a higher efficiency than solar cells with greater FSF dopant concentrations. Ex.1010-Granek, 121 (Fig. 7-1), 122 (Fig. 7-3).



Ex.1010-Granek, 121 (Fig. 7-1)

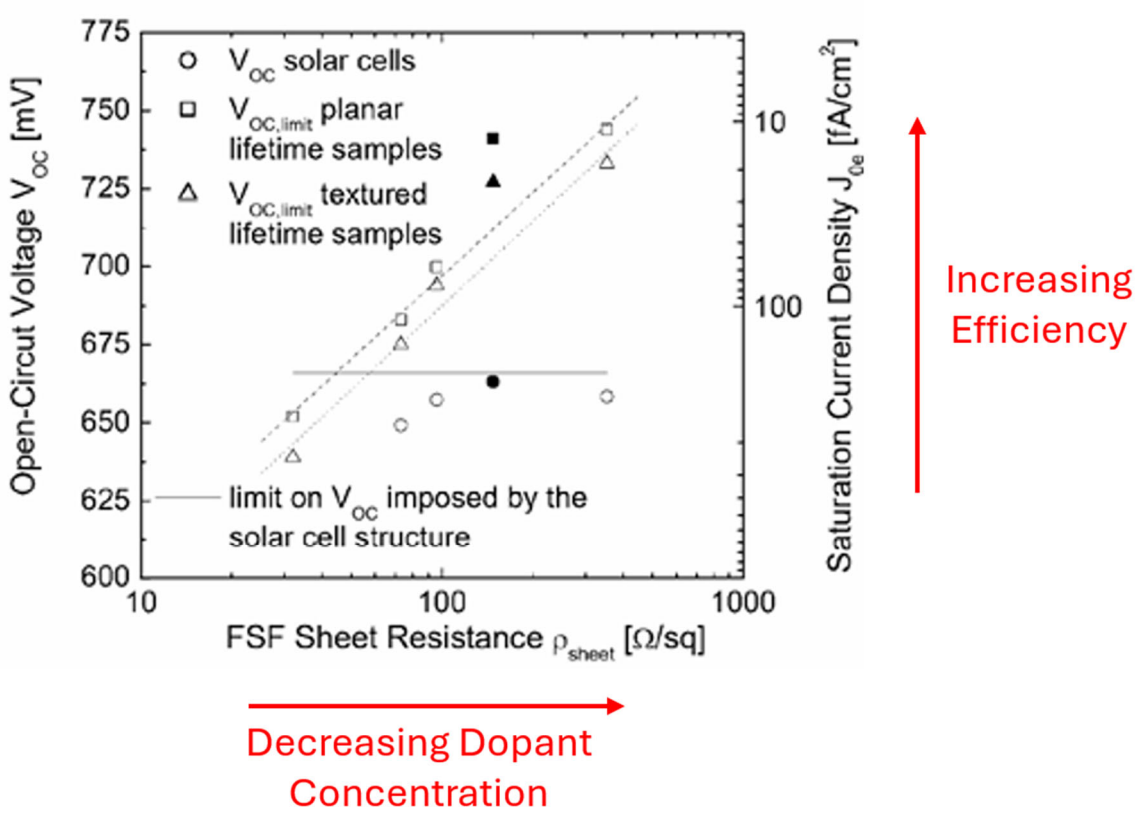


Ex.1010-Granek, 122 (Fig. 7-3)

103. Indeed, the bottom graph of Figure 7-3 of Granek shows that, for a junction depth of 1 µm, the saturation current density of a solar cell with an FSF dopant concentration of 1×10^{18} cm^{-3} is less than half the saturation current density of a solar cell with an FSF dopant concentration of 1×10^{19} cm^{-3}. All things being equal, a relatively lower saturation current density yields a relatively more efficient solar cell.

104. Similarly, Table 7-5 and Figure 7-10 show that experimental results also indicate that increasing the FSF sheet resistance (by lowering its dopant concentration) results in an increase in solar cell efficiency. Ex.1010-Granek, 132 (Table 7-5), 133 (Fig. 7-10). For example, Figure 7-10 of Granek shows that FSF sheet resistance has an inverse relationship with saturation current density (as shown

by the right axis of the graph which decreases from bottom to top). Reducing the saturation current density, in turn, increases the efficiency of the solar cell.



Ex.1010-Granek, 133 (Fig. 7-10)

105. Although the lowest value with which Granek experimented was an FSF surface dopant concentration of 3.8×10^{18} cm^{-3} (and a peak doping concentration of 5×10^{18} cm^{-3}), based on the combined simulation and experimental results of Granek, a POSITA would have reasonably anticipated that further lowering the FSF dopant concentration to around 1×10^{18} cm^{-3} would have resulted in improved solar cell efficiency. Ex.1010-Granek, 121-122, 132-133.

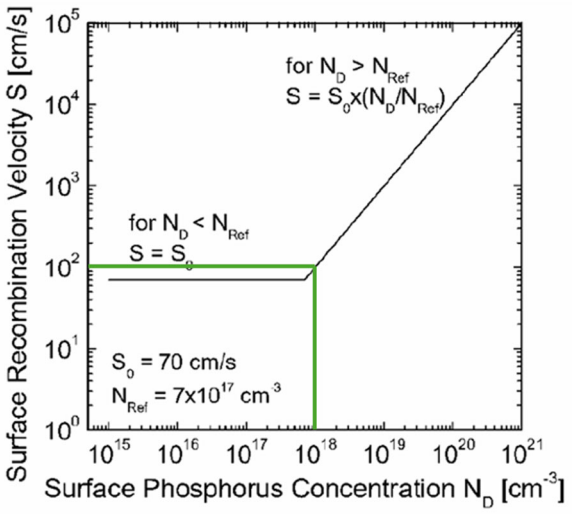
b. Dr. Schubert's Reliance on Front Surface Recombination Velocities Greater Than 500 cm/s Is Flawed

106. Patent Owner and Dr. Schubert mischaracterize Figure 7-1 of Granek. POR 34-37; Ex.2028-Schubert-Decl., ¶¶82-84. Specifically, Patent Owner's and Dr. Schubert's focus on the right side of Figure 7-1 of Granek, where front surface recombination velocities are greater than 500 cm/s, is flawed, as Choi (and Cousins) has a well-passivated front surface, which results in a low front surface recombination velocity. Ex.1090-Schubert-Tr., 188:14-189:6. For instance, Choi explains that the "anti-reflective film 50 decreases reflectivity of light incident upon the front surface of the semiconductor substrate 10 and ***passivates defects present on the surface or in the bulk of the front surface field layer 120***." Ex.1006-Choi, [0030]. Similarly, Cousins discloses forming a "passivating oxide" on the front side surface of the solar cell. Ex.1007-Cousins, 3:7-11. Front surface recombination velocities for well-passivated front surfaces were lower than 500 cm/s in 2014. Ex.2037-Holman-Tr., 52:10-53:8; *see also*, *e.g.*, Ex.1118-Aberle-2000, 447; Ex.1041-Hermle, 1; Ex.1008-Marvin, 16-17.

107. Patent Owner asserts that a "typical front surface recombination velocity" would have been 1,000 cm/s (POR, 35), but that is higher than what a POSITA would have expected at the time. For example, by 2012, many authors had

reported a front surface recombination velocity of 10 cm/s. Ex.1118-Aberle-2000, 474 (showing a surface recombination velocity of 10 cm/s in 2000); Ex.1041-Hermle, 1 (showing a surface recombination velocity below 10 cm/s was achievable in 2008). Indeed, even Marvin reported in 1989 that a surface recombination velocity lower than 10 cm/s can be achieved with "excellent passivation." Ex.1008-Marvin, 16-17.

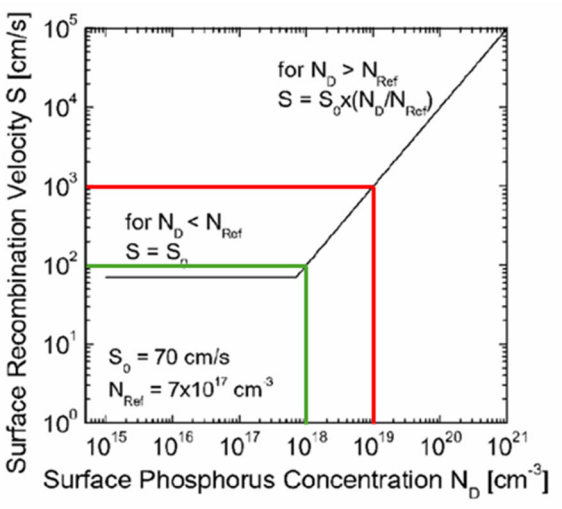
108. In Figure 3-6, Granek presents an empirical model from a paper authored by Andrés Cuevas based on experimental results for silicon dioxide passivation layers. Figure 3-6 of Granek shows that front surface recombination velocity for an FSF with a phosphorus dopant concentration of 1×10^{18} cm^{-3} would be 100 cm/s. Ex.1010-Granek, 42 (Fig. 3-6).



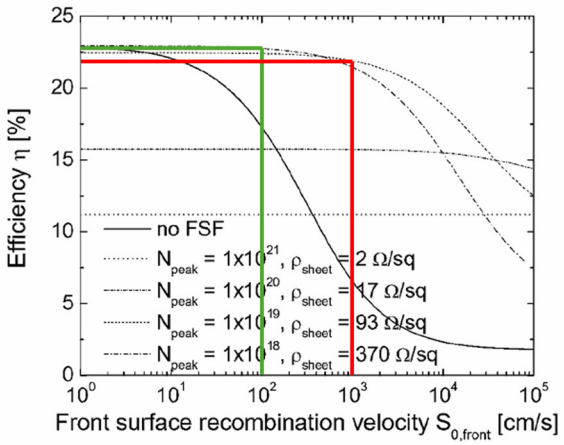
Ex.1010-Granek, 42 (Fig.3-6)

109. In addition, surface recombination velocity depends (in part) on the dopant concentration of the silicon surface being passivated. For example, as shown in Figure 3-6 of Granek, as dopant concentration increases above 7×10^{17} cm^{-3} (N_{Ref}), surface recombination velocity also increases, reaching a value of 1,000 cm/s only for a surface dopant concentration of 1×10^{19} cm^{-3}.

110. Applying the surface recombination velocities shown in Figure 3-6 in Figure 7-1 of Granek, a POSITA would have concluded that the solar cell with an FSF dopant concentration of 1×10^{18} cm^{-3} (green) has higher efficiency than the solar cell with an FSF dopant concentration of 1×10^{19} cm^{-3} (red). This is also consistent with the results of the bottom graph of Figure 7-3, for which Granek similarly used the surface recombination velocities of Cuevas in Figure 3-6 (note that the y-axis of Figure 7-3 says $S_{0,front} = S_{Cuevas}$). The bottom graph of Figure 7-3 shows that the lowest saturation current density (indicating higher efficiency) is obtained when the FSF dopant concentration is around 7×10^{17} cm^{-3}.



Ex.1010-Granek, 42 (Fig. 3-6)



Ex.1010-Granek, 121 (Fig. 7-1)

111. Similarly, for any other front surface recombination velocity value that a POSITA would have expected in 2014 for a well-passivated surface, Figure 7-1 of Granek shows that the solar cell with an FSF dopant concentration of 1×10^{18} cm^{-3} has higher efficiency than the solar cell with an FSF dopant concentration of 1×10^{19} cm^{-3}. Patent Owner admits that this holds true for any front surface recombination velocity lower than "approximately 500 cm/s," (POR, 34-35), which represents the surface recombination velocity range for well-passivated surfaces, as explained above in paragraph 107.

c. Dr. Schubert Is Incorrect That Granek's Simulation Results Contradict "Well-Accepted Experimental Results"

112. Patent Owner's and Dr. Schubert's analyses of Figure 7-1 of Granek for "solar cell[s] without a front surface field" are flawed. POR, 37-38; Ex.2028-

Schubert-Decl., ¶¶85, 88. In particular, Patent Owner is incorrect that Figure 7-1 of Granek contradicts "well-accepted experimental results that have firmly established the usefulness of an FSF layer." FSFs in solar cells are added to aid in reducing surface recombination—that is their purpose. As a result, a POSITA would have understood that adding an FSF would not increase the efficiency of a solar cell if the solar cell already has an extremely low surface recombination velocity (indicating no, or nearly no, surface recombination). Consistent with this notion, Figure 7-1 shows that, at an extremely low front surface recombination velocity of 1 cm/s, solar cells without an FSF and solar cells with an FSF have comparable efficiencies. This is expected. No evidence supports Patent Owner's and Dr. Schubert's purported "usefulness" of an FSF at such an unusually low front surface recombination velocity. Instead, for typical front surface recombination velocities, Figure 7-1 of Granek confirms that solar cells with an FSF are more efficient than solar cells without an FSF.

d. Dr. Schubert Is Wrong That Achieving Low Surface Recombination Velocity Would Have Been Difficult

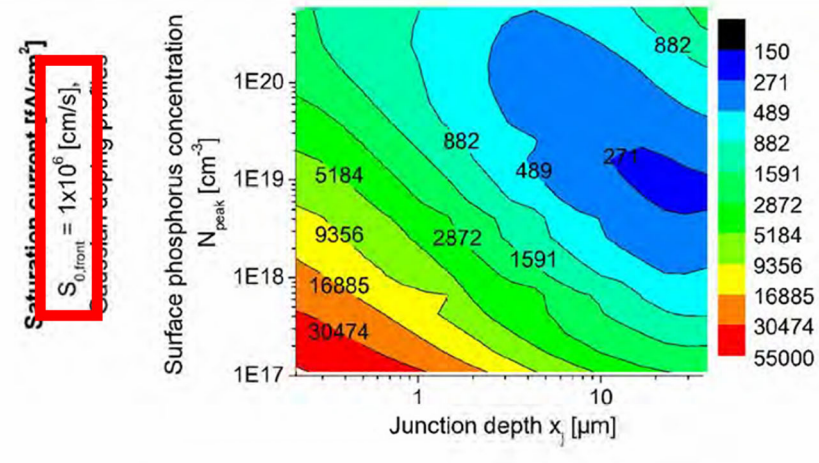
113. Patent Owner and Dr. Schubert are incorrect that it would have been difficult to achieve a low surface recombination velocity in 2014. POR, 38-39; Ex.2028-Schubert-Decl., ¶87. Patent Owner and Dr. Schubert only cite King, a research paper from 1990, to support this assertion. However, the design and

manufacturing of solar cells had significantly improved by the time the '315 patent was filed nearly 25 years later in December 2014. By 2014, it was well understood how to achieve a low surface recombination velocity, including surface recombination velocities much below 500 cm/s. *See, e.g.*, Ex. 1111-King-1990, 229 (Fig. 3); *see also* Ex.1118-Aberle-2000, 474 (showing a surface recombination velocity of 10 cm/s in 2000); Ex.1041-Hermle, 1 (showing a surface recombination velocity below 10 cm/s was achievable in 2008).

114. By 2014 it was well understood that low surface recombination velocities could be achieved by passivating the surface of a solar cell, e.g., by using a thermally grown silicon dioxide layer ("thermal oxide"). Ex.1111-King-1990, 229 (Fig. 3) (reporting a surface recombination velocity below 200 cm/s for a phosphorus doping concentration of 1×10^{18} cm^{-3} at the silicon wafer surface); Ex.1041-Hermle, 1 ("There are several methods for the passivation of silicon surfaces, e.g., using a thermal oxide, with which surface recombination velocities of below 10 cm/s can be achieved on lowly doped n-type surfaces."); Ex.2037-Holman-Tr., 53:9-54:12. As explained above in paragraph 106, both Choi and Cousins teach solar cell structures with well-passivated FSFs, which would result in low front surface recombination velocities. Ex.1006-Choi, [0031], [0079]; Ex.1007-Cousins, 3:7-11.

e. A POSITA Would Not Have Considered the Top Graph of Figure 7-3 of Granek

115. Patent Owner's and Dr. Schubert's analyses of the top graph of Figure 7-3 of Granek are misguided because a POSITA would not have expected the solar cell of Choi (or Cousins) to have a surface recombination velocity of 1,000,000 cm/s, which is what that graph corresponds to. POR, 39-41; Ex.2028-Schubert-Decl., ¶87. Specifically, a surface recombination velocity of 1,000,000 cm/s does not apply to well-passivated surfaces like the solar cells of Choi or Cousins. Instead, a POSITA would have understood that a surface recombination velocity of 1,000,000 cm/s would apply to non-passivated front surfaces or metalized surfaces. Ex.1090-Schubert-Tr., 206:3-6 ("Q. A surface recombination velocity of a million would correspond to non-passivated front surfaces, right? A. It could, yes. Or to metallized surfaces."). Moreover, the caption for the top graph of Figure 7-3 indicates that it corresponds to "the case of the ***metalized diffusion profiles***." Ex.1010-Granek, 122. A POSITA would not have considered a graph corresponding to "metalized diffusion profiles" given that, as I explained above in paragraph 106, the FSFs of Choi and Cousins have well-passivated surfaces. Ex.1006-Choi, [0031], [0079]; Ex.1007-Cousins, 3:7-11.



Ex.1010-Granek, 122 (Top graph of Fig.7-3)

116. The bottom graph of Figure 7-3 of Granek, instead, corresponds to "the case of passivated diffusion profiles." Ex.1090-Schubert-Tr., 206:7-10 ("Q. The bottom graph of Figure 7-3 of Granek is for solar cells with passivated front surfaces, right? A. Yes."). In particular, the bottom graph of Figure 7-3 corresponds to solar cells with a surface recombination velocity modeled on experimental data in a paper published by Cuevas. As Granek explains, the Cuevas model applies to "surfaces [that were] passivated with thermally grown silicon oxide." Ex.1010-Granek, 42; Ex.1118-Aberle-2000, 477, 485 (referencing the Cuevas model ([16]) for "oxide-passivated phosphorus-diffused Si surfaces"). As I explained above in paragraph 106, both Choi and Cousins teach structures with well-passivated FSFs. Ex.1006-Choi, [0031], [0079]; Ex.1007-Cousins, 3:7-11.

117. Furthermore, even if Cuevas's parameterization does not apply to Choi or Cousins, as Patent Owner suggests, a POSITA would have understood that the bottom graph of Figure 7-3 of Granek provides a better approximation to the efficiencies expected in the solar cells of Choi and Cousins given that the bottom graph of Figure 7-3 of Granek corresponds to a well-passivated front surface, whereas the top graph corresponds to a metalized front surface. As I explained above in paragraph 106, both Choi and Cousins teach structures with well-passivated FSFs. Ex.1006-Choi, [0031], [0079]; Ex.1007-Cousins, 3:7-11.

f. Dr. Schubert Is Incorrect That "Granek's Simulations Have Limited Relevance"

118. Finally, Patent Owner and Dr. Schubert are incorrect that "Granek's simulations have limited relevance." POR, 40-41; Ex.2028-Schubert-Decl., ¶¶79, 81. In 2014, a POSITA would have been familiar with the benefits of simulation tools. Simulations are widely accepted and recognized to be valuable in the field of solar cells. A POSITA would have understood that simulations can be used to show general trends as different parameters (such as doping concentration) are varied. *See also* Ex.1090-Schubert-Tr., 40:5-20; Ex.1136-Ruby-Tr., 65:20-66:7, 73:16-74:7, 75:5-9. Analyzing both the simulation results and experimental results of Granek together, a POSITA would have expected that lowering the dopant concentration of the FSF below 3.8×10^{18} cm^{-3} would have resulted in improved efficiency.

119. Granek reports experimental results for a set of five solar cell structures, and the lowest FSF dopant concentration he tested was 3.8×10^{18} cm^{-3}. Ex.1010-Granek, 126. In contrast, Granek's simulations explored a broader range of values for FSF doping concentration: 1×10^{17} to 1×10^{21} cm^{-3}. Ex.1010-Granek, 121. Both Granek's simulation results and experimental results confirm that lowering the doping concentration results in increased efficiency. As such, a POSITA would have been motivated to use a lower doping concentration than 3.8×10^{18} cm^{-3}, and would have been motivated to use a doping concentration that was simulated to be optimal (but that Granek did not fabricate). In other words, a POSITA would have expected that a doping concentration of about 1×10^{18} cm^{-3} would have resulted in higher solar cell efficiency than the FSF5 structure explored by Granek, which used a doping concentration of 3.8×10^{18} cm^{-3}.

120. Furthermore, Patent Owner and Dr. Schubert argue that "Granek employs one-dimensional simulations, which are even less reliable than two-dimensional or three-dimensional simulations." POR, 41; Ex.2028-Schubert-Decl., ¶81. One-dimensional simulations are commonly used by skilled artisans during the design of solar cells. A POSITA would have been familiar with the usefulness of one-dimensional simulations, and in particular, their ability to compare between multiple values of design parameters (such as FSF doping concentration).

Moreover, Granek's simulations were performed using PC1D (Granek, 120), which was at the time (and currently still is) the most commonly used software for simulating solar cells. *See e.g.*, Ex.1135-PVLighthouse; Ex.1129-Clugston, 207 ("PC1D is the simulation program in most widespread use among the photovoltaic community" "for modeling crystalline solar cells"); Ex.1136-Ruby-Tr., 72:13-22 ("Q. And the computer program that you're referring to, was that something that you've designed or is that an off-the-shelf product? A. It is actually free software. Q. What is it called? A. PC1D, written by one of my collaborators, Paul Basore. Q. So is that software that people like you can just download for free? A. Yes.").

3. A POSITA Would Not Have Chosen a Higher Front Dopant Concentration Based on Lamers, Desa, Or Procel

121. I disagree with Dr. Schubert's assertion that a POSITA would have chosen a "dopant[] concentration greater than 2×10^{18} cm^{-3}" to implement in Choi's solar cell based on Lamers, Desa, and/or Procel. Ex.2028-Schubert-Decl., ¶¶96-100. Lamers, Desa, and Procel are not applicable to Choi's solar cell for the reasons I explain below.

a. Lamers

122. Dr. Schubert relies on Lamers' disclosure of an FSF doping level of 3×10^{18} cm^{-3}. Ex.2028-Schubert-Decl., ¶98. Specifically, Lamers discloses:

> The function of the front surface is to reduce the recombination at the front side and improve lateral transport. Recombination in the FSF should be minimal and the optimal doping level was found to be 3.10^{18} atoms/cm^2 *[sic]*. [] Improved lateral tran[s]port by the FSF becomes increasingly important for larger pitches and higher base resistivity. For this, the optimal resistance was found to be 150 Ω/sq for the FSF. These specifications indicate that the FSF profile should be deep, close to 1μm. In order to fabricate this by diffusion in an industrial process, a long process time is required which is undesired.

Ex.2002-Lamers, 2. Lamers states that the FSF with "optimal doping level" of 3×10^{18} cm^{-3} has dual functions of "reduc[ing] recombination … and improv[ing] lateral transport" and has a "deep" "FSF profile" "close to 1μm." Ex.2002-Lamers, 2. Lamers also teaches that this FSF design with the deep FSF profile requires longer fabrication steps and added complexity—which Lamers states is "undesired" in an "industrial process." Ex.2002-Lamers, 2.

123. Lateral transport means moving charge carriers sideways in the solar cell. Ex.2037-Holman-Tr., 145:8-147:4. The lateral transport function is needed when pitches between contacts are large and the base substrate has high resistance because, under such circumstances, charge carriers need to travel sideways over long distances (in addition to vertically) to reach the contacts. *See* Ex.2002-Lamers, 2 ("lateral transport is of less importance" "[f]or moderate to low bulk resistances and small pitches").

124. Unlike in Lamers' solar cell, lateral transport is not a required function of Choi's front surface field. Ex.2037-Holman-Tr., 145:5-147:4. Choi's solar cell

is built such that "the front surface field layer 120 prevents electrons and holes separated by incident light from being recombined and then decay on the front surface of the semiconductor substrate." Ex.1006-Choi, [0029]. That is, Choi's front surface field has one function (not two): reducing surface recombination.

125. For the conditions applicable to Choi's solar cell, Lamers proposes a different FSF design. Specifically, Lamers discloses:

> For moderate to low bulk resistances and small pitches the additional value of the FSF for lateral transport is of less importance. 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]. These specifications allow a short diffusion time in an industrial process.

Ex.2002-Lamers, 2. That is, where "lateral transport is of less importance"—for example in Choi's solar cell—Lamers teaches to use "a lightly doped and shallow FSF." Ex.2002-Lamers, 2. Lamers teaches that this "lightly doped and shallow FSF" design is more desirable than the deep FSF profile with "optimal doping level" of 3×10^{18} cm^{-3} (*see* above ¶122). Unlike the deep FSF design, which requires an undesirably "long process [and diffusion] time," the "lightly doped and shallow FSF" design "allow[s] [for] a short diffusion time in an industrial process." Ex.2002-Lamers, 2.

126. Lamers' citation to "[5]" for the "lightly doped and shallow FSF" is to Granek:

> [5] Granek, F., "High Efficiency Back-Contact Back-Junction Silicon Solar Cells". Thesis, 2009

Ex.2002-Lamers, 2, 4; Ex.2037-Holman-Tr., 145:5-147:4; Ex.1090-Schubert-Tr., 111:12-15.

127. Granek teaches that such a "lowly doped and shallow" FSF corresponds to the "well passivated surface" from its "Figure 7-3 bottom." Ex.1010-Granek, 122-123. Specifically, Granek states:

> On the other hand, for the well passivated surfaces, an optimal diffusion profile is lowly doped and shallow (see Figure 7-3 bottom), with the sheet resistance of around 200 to 800 Ω/sq.

Ex.1010-Granek, 123. As I explained above in paragraphs 102-103, 110 and in my First Declaration, Figure 7-3 (bottom graph) of Granek shows the simulated solar cell's recombination level is lowest when the FSF dopant concentration is approximately 1×10^{18} cm^{-3}. Ex.1003-Decl., ¶¶149, 187.

128. Dr. Schubert is incorrect that Lamers' reference to the "lightly doped and shallow FSF" encompasses Lamers' disclosure of 3×10^{18} cm^{-3} and Granek's disclosure of "$N_{peak} = 5\times10^{18}$ cm^{-3}." Ex.2028-Schubert-Decl., ¶97 (citing Ex.2002-Lamers, 2; Ex.1010-Granek, 46). Lamers teaches that the FSF design with a doping level of 3×10^{18} cm^{-3} has a "deep" "FSF profile" that is "close to 1μm" (not a shallow FSF). Ex.2002-Lamers, 2; *see* above ¶122. The disclosure from Granek of "$N_{peak} = 5\times10^{18}$ cm^{-3}" is for a "deeply diffused" FSF profile of "1.4 μm" (Ex.1010-Granek,

46), not a "shallow" FSF. Ex.2002-Lamers, 2. The disclosure from Granek on which Dr. Schubert relies states:

> The front side is textured with random pyramids and passivated with a lightly doped (N_{peak} = 5×10^{18} cm^{-3}) and deeply diffused (1.4 μm) phosphorus front surface field (FSF).

Ex.2028-Schubert-Decl., ¶97 (citing Ex.1010-Granek, 46). In fact, at "1.4 μm," this FSF from Granek is even more deeply diffused than Lamers' "deep" "FSF profile" of ~ "1μm." *Compare* Ex.1010-Granek, 46 *with* Ex.2002-Lamers, 2.

129. Furthermore, the disclosure from Granek of an FSF doping level of 5×10^{18} cm^{-3} is from Granek's chapter describing experimental procedures and methods (chapter 4, "Design and technology"). Ex.1010-Granek, 45. The disclosures from Granek teaching an FSF dopant concentration of around 1×10^{18} cm^{-3} (*see* above ¶¶102-103) are from Granek's chapter describing optimization of the FSF (chapter 7, "Front surface passivation using a front surface field"). Ex.1010-Granek, 117, 121 (Fig. 7-1), 122 (Fig. 7-3). Indeed, in the same paragraph disclosing the FSF doping level of 5×10^{18} cm^{-3} relied on by Patent Owner, Granek states that it will later, in chapter 7, "comprehensive[ly] analy[z]e" the FSF design. Ex.1010-Granek, 45.

130. Finally, Dr. Schubert points to Lamers' statement that: "J_{sc} is optimal for dopants at 3.10^{18} atoms/cm^3". Ex.2002-Lamers, 2. J_{sc} is not a metric that is particularly sensitive to recombination.

b. Desa

131. Choi and Desa have different solar cell designs with respect to the regions near their wafers' front surfaces. Ex.2037-Holman-Tr., 149:6-12. Desa's solar cell has a floating (p-n) junction, *i.e.*, its front surface has the opposite doping polarity of the rest of its wafer. Ex.2003-Desa, 70, 80 (Table 1); Ex.2037-Holman-Tr., 147:8-150:6. Desa's Table 1, which lists the "[s]olar cell parameters used for simulation," shows that the dopants in the front region of the wafer are "Phosphorus" (n-type) while the wafer is "p-type." Ex.2003-Desa, 70, 80 (Table 1).

TABLE I
SOLAR CELL PARAMETERS USED FOR SIMULATION OF SCREEN PRINTED IBC SOLAR CELL

Serial No.	Parameters		Value
1.	Wafer	Thickness	200µm
		Type	p-type
		Resistivity	2Ω.cm
		Width	3000µm
2.	Front Surface Field (Floating Junction)	Dopants	Phosphorous
		Concentration	Varied
3.	Emitter	Dopants	Phosphorous
		Concentration	Varied
		Width	1000µm
4.	Back Surface Field (BSF)	Dopants	Aluminum
		Concentration	Varied
		Width	1000µm
5.	Back Surface Recombination Velocity (BSRV)	Value	1000cm/s
6.	Front Surface Recombination Velocity(SRV)	Value	500cm/s

Ex.2003-Desa, 80 (Table 1).

132. Choi's solar cell has a front surface field (Ex.1006-Choi, [0024]-[0025], [0029]; Ex.1003-Decl., ¶¶131-132, 228-237), which is a high-low (n+/n or p+/p) junction where the front region has the same doping polarity as the substrate. Ex.1124-Verlinden-2012, 333, 335; Ex.2037-Holman-Tr., 147:5-150:6. As Dr. Schubert confirmed, a floating junction is different from and "not directly related to a front surface field." Ex.1090-Schubert-Tr., 221:19-222:20.

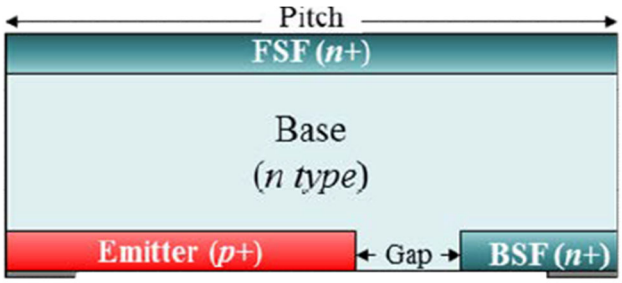
c. Procel

133. Dr. Schubert refers to Procel (Ex.2005) and "the pertinent results of Ex. 2005" without stating what "pertinent results" he is referring to. Ex.2028-Schubert-Decl., ¶100. I will assume he means Procel's (Ex.2005) disclosure of an FSF doping of "3.47×10^{18} cm^{-3}," which was cited by Patent Owner's POR. POR, 44 (citing Ex.2005-Procel, 131-132).

134. The same research group later identified 1×10^{18} cm^{-3} as a desirable FSF doping concentration in a publication cited in my First Declaration. Ex.1003, ¶82 (quoting Ex.1040-Procel, 15); Ex.2037-Holman-Tr., 151:14-153:22. The later Procel publication (Ex.1040) cites to Ex.2005-Procel for its selection of an FSF doping concentration of 1×10^{18} cm^{-3}. Ex.1040-Procel, 15, 18 (citation [5] is Ex.2005-Procel). Given the teachings of Procel (Ex.1040), a POSITA would not have preferred the FSF doping of "3.47×10^{18} cm^{-3}" specified in Procel (Ex.2005).

135. Dr. Schubert suggests that Procel's (Ex.2005) FSF doping level of "3.47×10^{18} cm^{-3}" is more pertinent than Procel's (Ex.1040) disclosure of FSF doping concentration of 1×10^{18} cm^{-3}. Ex.2028-Schubert-Decl., ¶100. According to Dr. Schubert, Procel (Ex.1040) is not as pertinent because its "aim … was 'to improve the physical understanding of the impact of different rear geometries on the performance of the [Back-Contact Back-Junction] solar cells.'" Ex.2028-Schubert-Decl., ¶100 (quoting Ex.1040-Procel, 15). I disagree.

136. Procel (Ex.1040) varies the widths of the elements on the rear side of the solar cell (shown below from Procel's Fig. 1).



Ex.1040-Procel, Fig. 1. Specifically, Procel (Ex.1040) varies the widths of the emitter, gap, BSF, and pitch to "calculate the impact of [their] variations on the performance" of the solar cell. Ex.1040-Procel, 16. Those features, which are on the rear side of Procel's solar cell, are independent from the FSF on the front side. "[T]he design of the front side (optical side) and the back side (electrical side) can easily be optimized separately." Ex.1124-Verlinden-2012, 332. Therefore, varying the rear geometries would not affect the design of the FSF.

D. Claims 13-14

137. Dr. Schubert does not dispute that it would have been obvious to implement an FSF using a p-type dopant, or boron specifically, with respect to the combination of Choi with Marvin or the combination of Choi with Marvin and Istratov.

138. With respect to the combination of Choi with Granek, I disagree with Dr. Schubert that it would not have been obvious to implement the dopant concentration as disclosed by Granek with a p-type dopant. Choi itself discloses the use of both n- and p-type dopants for its substrate and FSF, Ex.1006-Choi, [0025], [0029], and there are several reasons why a person of ordinary skill in the art would have elected to implement Choi's solar cell using a p-type wafer and FSF.

139. As I explained in my First Declaration, p-type silicon wafers were more common and less expensive than n-type silicon wafers as of the earliest possible priority date of the '315 patent. Ex.1003-Decl., ¶427; Ex.2037-Holman-Tr., 156:9-12, 158:10-14. Dr. Schubert asserts that "Granek states otherwise," Ex.2028-Schubert-Decl., ¶118, but that is not correct. Granek refers to a "shortage of the p-type silicon feedstock," Ex.1010, 48, but that is not inconsistent with the fact that p-type silicon wafers were more commonly used and less expensive than n-type silicon. As I explained during my deposition, in 2008 (when Granek was writing),

the solar industry was growing faster than the wafer industry could supply wafers. Ex.2037-Holman-Tr., 155:15-156:12; 157:2-22; 158:9-22. That is, a shortage existed of p-type wafers due to a shortage of all silicon solar wafers in 2008. Despite the shortage, it was still the case that p-type solar cells were far more common than n-type solar cells, which continued through the earliest possible priority date for the '315 patent. For example, a 2014 industry report showed that p-type silicon accounted for approximately 95% of the market in 2013:

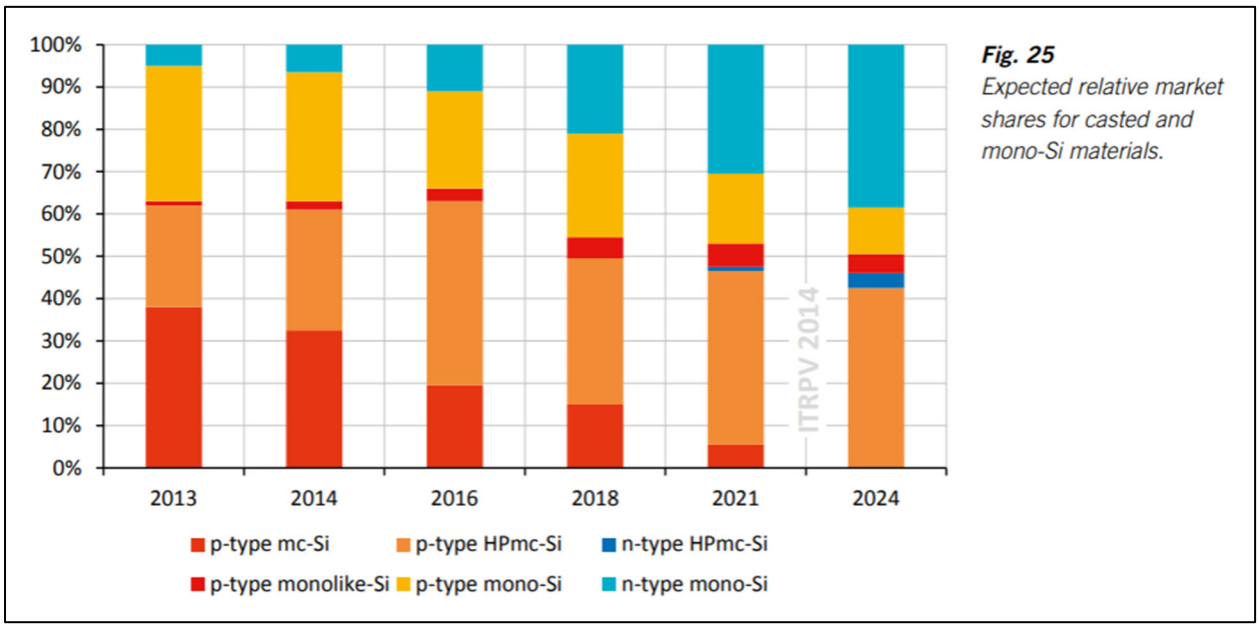
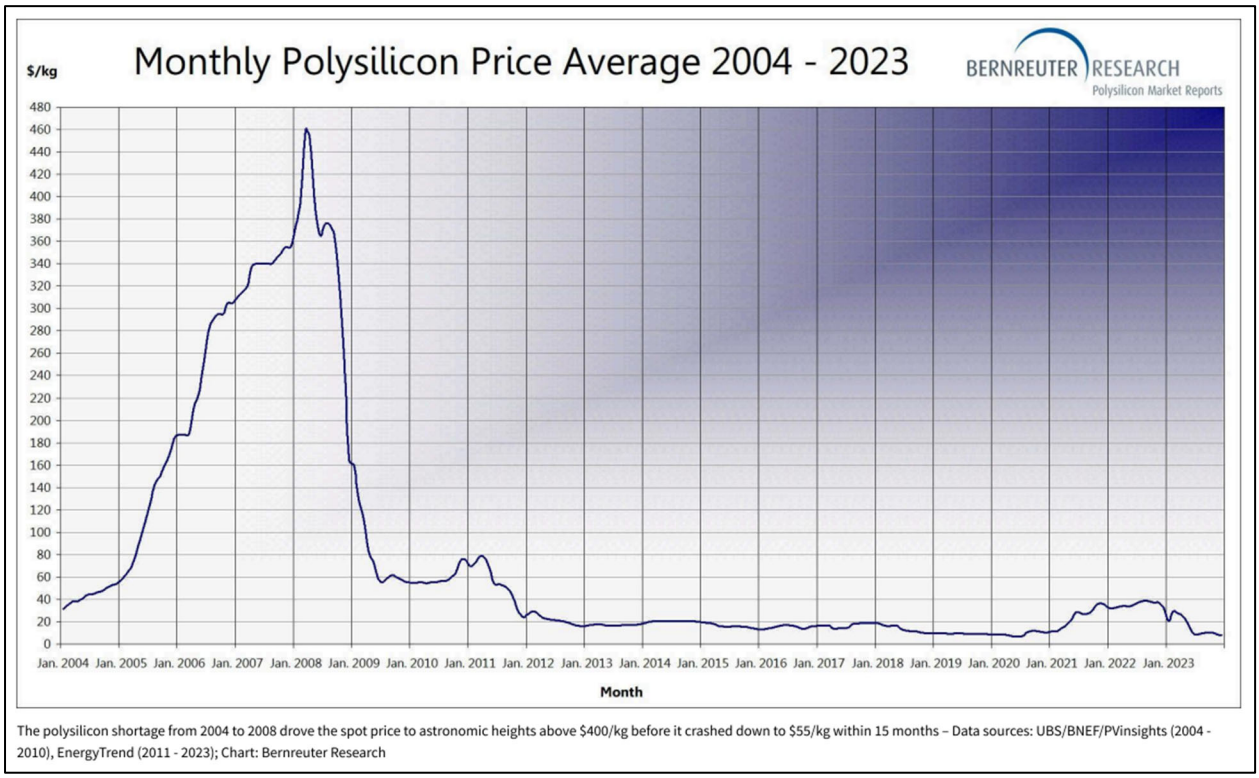


Fig. 25
Expected relative market shares for casted and mono-Si materials.

Ex.1115-ITRPV, 28 Fig. 25; *see also* Ex.1114-Hoex-2007, 112107 ("Presently, most Si solar cells are fabricated from p-type c-Si base material"). The same report stated that "n-type wafers are expected to be more expensive than p-type wafers, at least until 2018." Ex.1115-ITRPV, 27.

140. Dr. Schubert also asserts that "there was a shortage of p-type silicon in 2014," Ex.2028, ¶118, but that too is incorrect, and Dr. Schubert cites no support. In fact, there was a shortage of wafers from 2006 through 2008, and prices rose significantly. Ex.1130-SiS-2008. By 2009, however, supply had increased to meet demand, and prices dropped sharply:



Ex.1116-Bernreuter. There was no shortage of wafers by 2014.

141. It would also have been within the ability of a POSITA to implement the n-type dopant concentration taught by Granek in the p-type FSF taught by Choi. Ex.2037-Holman-Tr., 133:4-7; Ex.1003-Decl., ¶427. The '315 patent presumes that it would have been within the ability of a POSITA to design for both n- and p-type

FSFs. The '315 patent claims both n- and p-type FSFs, but it discloses only a single dopant concentration, and it does not disclose any adjustments to account for the use of any particular dopant or dopant polarity. Dr. Schubert also stated that "one skilled in the art would be able to practice the invention as it is described." Ex.1090-Schubert-Tr., 230:6-16.

142. Further, I disagree with Dr. Schubert's assertion that "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." Ex.2028-Schubert-Decl., ¶102. Dr. Schubert specifically points to the different surface recombination velocities for phosphorus and boron in Granek's Figure 3-6 as an example of a purported difference between n- and p-type dopants. Ex.2028-Schubert-Decl., ¶103. However, the relationship between dopant concentration, surface recombination velocity, and emitter saturation current density for both boron and phosphorus was well understood long before the earliest possible priority date of the '315 patent. For example, a 1990 publication ("King-1990") depicted for both boron (p-type) and phosphorus (n-type) the same contour plot of emitter saturation current density that Granek simulated for phosphorus in Figure 7-3:

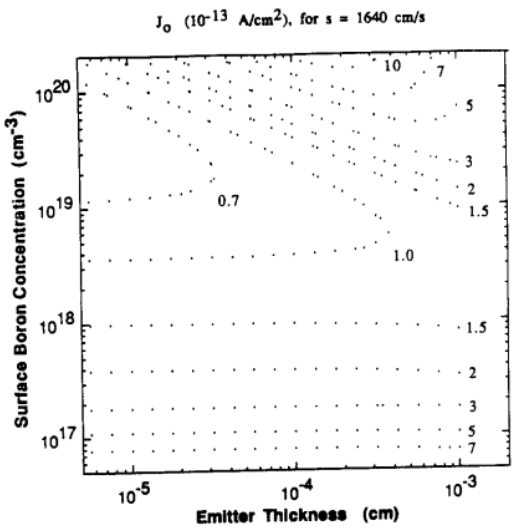


Figure 4. Contours of constant J_o for untextured, oxide-passivated emitters with a gaussian boron profile, using experimental values of surface recombination velocity after FGA.

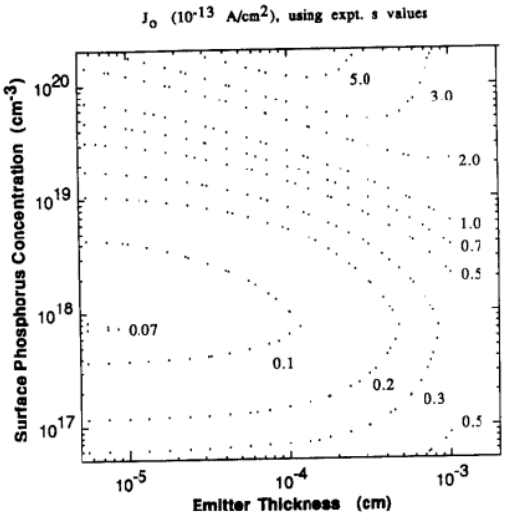
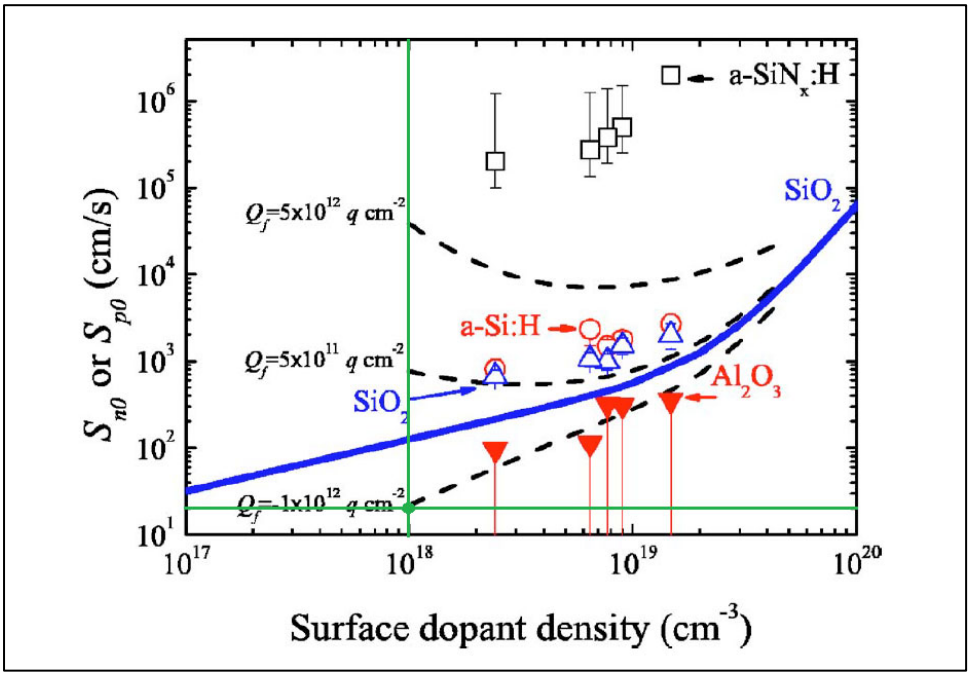


Figure 5. Contours of constant J_o for untextured, oxide-passivated emitters with a gaussian phosphorus profile, using experimental values of surface recombination velocity after FGA.

Ex.1111-King-1990, 230 Figs. 4, 5.

143. While King-1990 suggests an optimal dopant concentration of approximately 1×10^{18} cm^{-3} for phosphorus (Figure 5, the same as Granek) and 2×10^{19} cm^{-3} for boron (Figure 4), the latter is due to a high surface recombination velocity for passivated boron-doped silicon surfaces at that time. Ex.1111-King-1990, 229, Figs. 2, 3. Similarly, the parametrization of Cuevas (from 1997) that is graphed in Granek Figure 3-6 (in 2008) assumed a high surface recombination velocity for boron-doped surfaces passivated with silicon dioxide. Around the time that Granek was writing, however, there were important new developments relating to the passivation of p-type silicon surfaces in solar cells, and, by the earliest possible priority date of the '315 patent, it was known that significantly lower surface recombination velocities could be achieved for p-type silicon using aluminum oxide

(Al_2O_3) passivation layers. Ex.1113-Hoex-2006 (demonstrating surface recombination velocity of 13 cm/s on p-type silicon); Ex.1112-Schmidt (demonstrating surface recombination velocity of 70 cm/s on p-type silicon); Ex.1136-Ruby-Tr., 58:7:59:2 (acknowledging the development of "atomic layer deposition of aluminum oxide, which, for the first time allowed the passivation of p-type surfaces on solar cells" as an improvement to fabrication processes before 2008). In fact, a 2007 paper demonstrates that "highly doped p-type surfaces can as effectively be passivated as highly-doped n-type [surfaces]." Ex.1114-Hoex-2007, 112107-3. As shown in Figure 4, Hoex-2007 extrapolates a surface recombination velocity of approximately 20 cm/s for a boron-doped surface (*e.g.*, an FSF) with a surface dopants density of 1×10^{18} cm^{-3} (intersection of annotated green lines):



Ex.1114-Hoex-2007, Fig. 4 (annotated). The blue line depicts the empirical relation for silicon dioxide (SiO_2) passivated n-type silicon, similar to and approximately consistent with the left-hand graph of Granek's Figure 3-6 for phosphorus. The lower dashed line is a model fit to empirical measurements for Al_2O_3 passivated p-type silicon, and is similar to, but slightly lower than, SiO_2 passivated n-type silicon.

144. A POSITA in 2014 would have known that similar surface recombination velocities could be achieved for n- and p-type silicon, and therefore would have understood that Granek's findings for n-type FSFs provide reliable guidance for p-type FSFs.

X. CLAIM 18 IS INVALID AS OBVIOUS OVER CHOI, GRANEK OR MARVIN, OPTIONALLY ISTRATOV, AND SMITH (GROUND II)

145. Dr. Schubert does not challenge that the combination of Choi, Granek or Marvin, optionally Istratov, and Smith renders claim 18 obvious (Ground II) beyond arguing that the combination of Choi, Granek or Marvin, and optionally Istratov, does not render claims 10 and 16 obvious (Ground I).

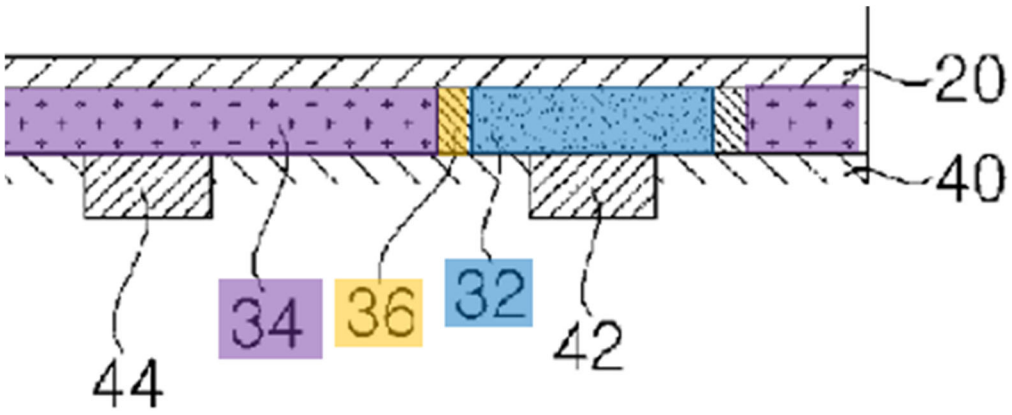
146. I will respond to the Board's questions about why modifying Choi's solar cell with Smith's trench "would be an improvement on what Choi already provides, or why Choi's barrier area 36 is deficient in any respect, such that a POSITA would have looked to a reference like Smith." Paper 17 (ID), 25.

147. As an initial matter, I note that Smith and Choi share similar objectives. Choi's objective is to improve solar cell efficiency by using surface passivation techniques and preventing recombination. Ex.1006-Choi, [0006]-[0007], [0011], [0029]-[0031]. Smith's objective is to "improve surface passivation" and "increase[] [solar cell] efficiency by providing isolation between adjacent p-type and n-type doped regions, thereby preventing recombination." Ex.1011-Smith, Abstract, [0022], [0025].

148. Choi allows for the integration of Smith's trench by teaching the barrier area 36 may be thinner than the surrounding layers. Specifically, Choi teaches:

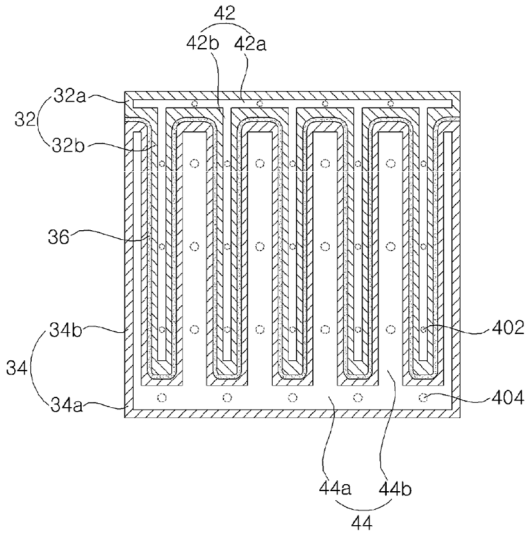
> [W]hen the barrier area 36 is separately formed with the first and second conductive type areas 32 and 34, that is, the barrier area 36 is formed by patterning or the like, the barrier area 36 may not have the same thickness as the first and second conductive type areas 32 and 34. … [I]n order ***to reduce raw materials for forming the barrier area 36***, ***the thickness of the barrier area 36 may be smaller than that of the first and second conductive type areas 32 and 34***.

Ex.1006-Choi, Fig. 1, [0040]. Choi's barrier area 36 and the adjacent first conductive type area 32 and the second conductive type area 34 are shown below from Choi's Figure 1.



Ex.1006-Choi, Fig. 1. Choi teaches that an advantageous embodiment for "reduc[ing] raw materials" is to form the barrier area 36 such that it is thinner than the first and second conductive type areas 32 and 34. Ex.1006-Choi, Fig. 1, [0040].

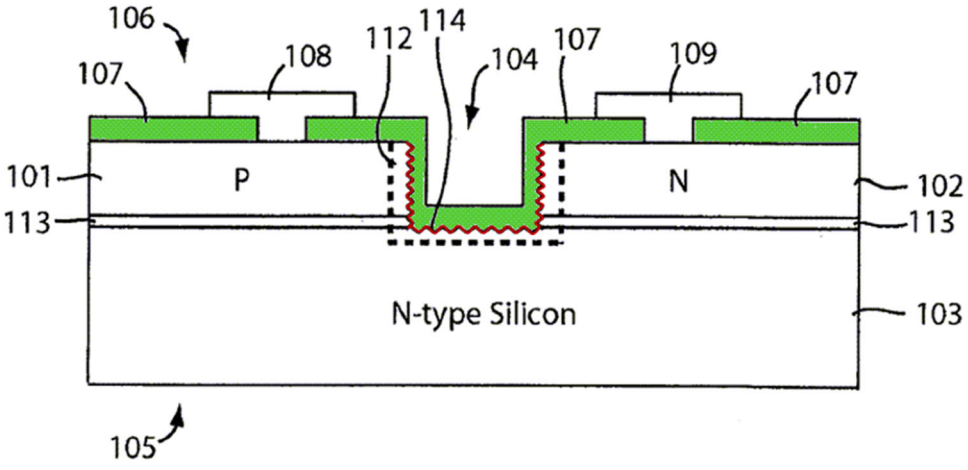
149. A barrier area with a thickness less than the adjacent conductive type areas that it separates (*i.e.*, first and second conductive type areas 32 and 34) is effectively a trench because it would form a linear hole. Choi's Figure 4 shows the barrier area 36 following a linear (snaking) path.



Ex.1006-Choi, Fig. 4.

150. Choi further teaches "[t]he barrier area 36 may be an undoped insulating material (for example, … nitride) or the like." Ex.1006-Choi, [0039].

151. Smith's trench 104 similarly "separates the doped regions 101 and 102 so they are not physically in contact." Ex.1011-Smith, [0025]; Ex.1003-Decl., ¶338. Like Choi's barrier area 36, Smith's trench may also be made of a nitride. Ex.1011-Smith, [0022] ("a silicon nitride 107 is deposited in the trench 104"). As shown below, Smith's trench is a thinner layer than the surrounding doped regions 101 and 102, similar to the embodiment of Choi's barrier area 36 described above in paragraphs 148-149.



Ex.1011-Smith, Fig.2.

152. Smith's trench would improve the performance of Choi's solar cell in at least two ways through two features. First, as shown in Smith's Figure 2 above,

Smith's trench includes a "textured surface 114" that "improves solar radiation collection of light incident on the back of the solar cell." Ex.1011-Smith, [0021], [0025]; Ex.1003-Decl., ¶¶344-345. A POSITA would have recognized that the additional solar radiation that the solar cell is able to collect when a trench is used—as taught by Smith—would provide an additional improvement to solar cell efficiency compared to using the untextured barrier area taught by Choi. Ex.1003-Decl., ¶344.

153. Second, Smith's trench is covered by a dielectric silicon nitride layer 107, which acts as an "accumulation layer [that] repels minority carriers" to improve surface passivation. Ex.1011-Smith, Fig.2, [0022], [0025]; Ex.1003-Decl., ¶¶344-345. While Choi teaches the barrier area 36 is electrically insulating, Choi does not teach that it could provide passivation of the silicon wafer surface. Ex.1006-Choi, [0039]. A POSITA would have recognized that the ability to improve surface passivation by repelling minority carriers would provide an enhancement to the barrier area taught by Choi. Ex.1003-Decl., ¶344.

XI. CLAIMS 10-15 ARE INVALID AS OBVIOUS OVER COUSINS, GRANEK OR MARVIN, AND ISTRATOV (GROUND III)

A. Cousins in View of Istratov Renders Obvious "a First Emitter Region" and "a Second Emitter Region Having Metal Impurities"

154. Dr. Schubert relies on the same arguments to dispute the obviousness of the "metal impurities" limitation of claims 10-15 in view of Cousins and Istratov as he does for the Choi-Istratov combination. Ex.2028-Schubert-Decl., ¶111. As I explained above (*see* ¶¶44-82), Dr. Schubert's arguments are incorrect.

155. Dr. Schubert incorrectly asserts that Cousins' substrate 101 does not contain metal impurities. Ex.2028-Schubert-Decl., ¶111. Cousins anticipates the presence of metal impurities in its substrate 101 and describes a solar cell processing step for "cleaning [] the substrate 101 to remove metal contamination." Ex.1007-Cousins, 4:23-35. Specifically, Cousins states:

> [A]n N-type silicon substrate 101 is prepared for processing into a solar cell by undergoing a damage etch step. The substrate 101 is in wafer form in this example, and is thus typically received with damaged surfaces due to the ***sawing process*** used by the wafer vendor to slice the substrate 101 from its ingot. The substrate 101 may be about 100 to 250 microns thick as received from the wafer vendor. In one embodiment, the damage etch step involves removal of about 10 to 20 μm from each side of the substrate 101 using a wet etch process comprising potassium hydroxide. The damage etch step may also include ***cleaning of the substrate 101 to remove metal contamination***.

Ex.1007-Cousins, 4:23-35. As I explained above (*see* ¶¶44-62), typical solar-grade silicon wafers as of 2014 contained high levels of metal impurities, and metal

impurities could be additionally introduced during silicon solar cell manufacturing. It was known that both sawing processes and etching processes could introduce metal impurities into silicon solar cell devices. Ex.1047-Istratov-2000, 491; *see* above ¶¶59-60. Cousins describes the "remov[al of] metal contamination" from "the substrate 101," which a POSITA would have understood were present in silicon wafers and introduced through solar cell processing through steps such as sawing and etching.

156. Dr. Schubert suggests that Cousins might have "employ[ed] high-quality silicon wafers" because "Cousins is assigned to SunPower Corporation." Ex.2028-Schubert-Decl., ¶111. In addition to being the assignee of Cousins, SunPower is also the assignee of U.S. 2014/0087496 A1 ("Wong-496"), which relates to solar cell fabrication, more specifically, a "plasma-enhanced chemical vapor deposition (PECVD) [process] for forming an anti-reflective coating (ARC) including silicon nitride on a solar cell" substrate. Ex.1101-Wong-496, [0001]. Wong-496 discloses the following measurements of iron, nickel and chromium "levels at the center and along the edges of the solar cell" "subsequent to" the PECVD process: "≤2e16," "≤3e16," and ~"6.4e15" cm^{-3}, respectively. Ex.1101-Wong-496, Fig. 4, [0021]. Thus, a POSITA would not have assumed Cousins

employed silicon wafers lacking metal impurities or employed solar cell fabrication processes that did not introduce metal impurities.

157. Dr. Schubert also vaguely suggests that gettering might "adversely impact[] the solar cell of Cousins," Ex.2028-Schubert-Decl., ¶111, without any explanation about ***how*** gettering could adversely impact Cousins. As I explained above (*see* ¶¶79-82), a POSITA would have adapted Istratov's gettering process for Cousins' solar cell by lowering the temperature and/or processing time to avoid any detrimental impacts.

B. Cousins in View of Marvin or Granek Renders Obvious the Claimed Front Dopant Concentration

158. Dr. Schubert relies on the same arguments to dispute the obviousness of the front dopant concentration limitation of claims 10-15 in view of Cousins and Marvin or Granek as he does for the Choi-Marvin and Choi-Granek combinations. Ex.2028-Schubert-Decl., ¶112. As I explained above (*see* ¶¶83-136), Dr. Schubert's arguments are incorrect.

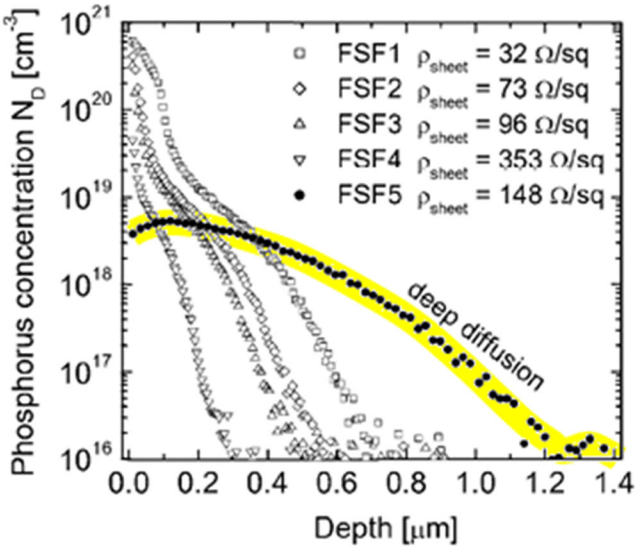
159. Patent Owner raises an additional argument regarding Cousins, asserting that "Granek itself reveals the imprecision of the simulations of Figure 7-4." POR, 51-54. Patent Owner is incorrect. Figure 7-4 plots "[s]heet resistance of the phosphorous doped Gaussian diffusion profiles in a wide range of surface phosphorous concentration and junction depth." Ex.1010-Granek, 123. Patent

Owner, however, compares values extracted from Table 7-1 of Granek to Figure 7-4. Table 7-1 appears as follows:

Profile	Type	ρ_{sheet} [Ω/sq]	N_S [cm^{-3}]	x_j [μm]
FSF1	erfc	32	6.0×10^{20}	0.78
FSF2	erfc	73	4.0×10^{20}	0.66
FSF3	erfc	96	3.2×10^{20}	0.56
FSF4	erfc	353	4.5×10^{19}	0.38
FSF5	Gauss	148	3.8×10^{18}	1.44

160. As explained in Table 7-1 of Granek, FSF1 through FSF4 correspond to doping profiles following an "error function" distribution ("erfc"). An error function distribution is fundamentally different than a Gaussian distribution. Since Figure 7-4 of Granek only applies to Gaussian distributions, a POSITA would not have compared the sheet resistance values for FSF1 through FSF4 reported in Table 7-1 to the values shown in Figure 7-4.

161. Moreover, although FSF5 may be approximated by a Gaussian distribution, FSF5 does not follow a true Gaussian distribution. The shape of the FSF5 distribution is shown in Figure 7-6 of Granek:



162. As shown in Figure 7-6, FSF5 has a surface dopant concentration of 3.8×10^{18} cm^{-3} and a peak dopant concentration of about 5×10^{18} cm^{-3}. In other words, the dopant profile of FSF5 first increases from its surface dopant concentration to a peak value at a depth of approximately 0.1 μm, after which it decreases. As a result, FSF5 does not follow a true Gaussian distribution, which has a peak dopant concentration at the surface. A POSITA therefore would have anticipated that the values presented in Figure 7-4 of Granek for FSF5 would differ from the experimental results reported in Table 7-1.

C. Claims 13-14

163. Dr. Schubert makes the same argument for claims 13 and 14 with respect to the combination of Cousins with Granek as with Choi and Granek. For the same reasons I explained in my First Declaration, Ex.1003-Decl., ¶¶424-427,

and as further explained above in paragraphs 138-144 with respect to Choi, a POSITA would have been motivated to implement Cousins with Granek or Marvin using a p-type wafer and FSF, and it would have been within the ability of a POSITA to do so.

XII. AVAILABILITY FOR CROSS-EXAMINATION

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

XIII. RIGHT TO SUPPLEMENT

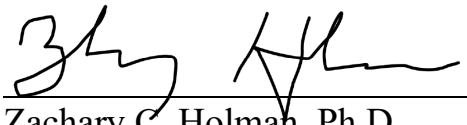
165. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner raises and to take into account new information as it becomes available to me.

XIV. JURAT

166. I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false

statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Dated: August 14, 2025



Zachary C. Holman, Ph.D.

APPENDIX D

Appendix D: Materials Considered

No.	Description
1001	U.S. Patent No. 11,251,315 B2 ("USP315")
1002	File History for U.S. Patent No. 11,251,315 B2 (App. No. 16/877,255) ("USP315FH")
1003	Declaration of Dr. Zachary Holman Regarding U.S. Patent No. 11,251,315 ("Decl.")
1004	Declaration of June Munford ("Munford-Decl.")
1005	Complaint for Patent Infringement, *Maxeon Solar Pte. Ltd. v. Hanwha Solutions Corp., et al.*, Civil Action No. 2:24-cv-262 (E.D. Tex. Apr. 19, 2024), ECF No. 1 ("Complaint")
1006	U.S. Patent App. Pub. No. 2014/0311567 ("Choi")
1007	U.S. Patent No. 8,207,444 ("Cousins")
1008	D.C. Marvin, S.L. Froedege, "Interdigitated Back Contact Solar Cell Analysis and Design Recommendations for Space Use," Space Systems Division Air Force Systems Command, Report 88D-TR-90-04 ("Marvin")
1010	F. Granek, High-Efficiency Back Contact Back-Junction Silicon Solar Cells (2009) (Ph.D. Dissertation, Fraunhofer Institute for Solar Energy Systems ISE) ("Granek")
1011	U.S. Patent App. Pub. No. 2013/0240029 ("Smith")
1012	A.A. Istratov, H. Väinölä, W. Huber, E. R. Weber, "Gettering in silicon-on-insulator wafers: experimental studies and modelling," Semicond. Sci. Technol. 20: 568–575 (April 2005) ("Istratov")
1013	EP1732142A1 ("Froitzheim")
1014	JP07-106611 ("Okayasu") Translation
1015	Translation Declaration for Okayasu
1016	N. G. Tarr, "A polysilicon emitter solar cell," IEEE Electron Device Letters, vol. 6, no. 12, pp. 655-658, Dec. 1985 ("Tarr")
1017	U.S. Patent No. 6,262,359 ("Meier")

No.	Description
1018	Zachary C. Holman, Electron Transport in Amorphous Silicon (May 2005) (Thesis Presented to The Division of Mathematics and Natural Sciences, Reed College) ("Holman-Thesis")
1019	P.J. Verlinden, R.A. Sinton, K. Wickham, R.A. Crane, and R.M. Swanson, "Backside-contact silicon solar cells with improved efficiency for the `96 world solar challenge," in Proceedings of the 14th European Photovoltaic Solar Energy Conference, Barcelona, Spain, 96-9 (1997) ("Verlinden")
1020	R.A. Sinton and R.M. Swanson, "Simplified backside-contact solar cells," IEEE Transactions on Electron Devices, 37 (2), 348-52, (1990) ("Sinton")
1021	R.R. King, R.A. Sinton, R.M. 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")
1022	W.P. Mulligan, D.H. Rose, M.J. Cudzinovic, D.M. De Ceuster, K.R. McIntosh, D.D. Smith, and R.M. Swanson, Manufacture of solar cells with 21% efficiency, in Proceedings of the 19th European Photovoltaic Solar Energy Conference, Paris, France, 387-90 (2004) ("Mulligan")
1023	J. Nelson, The Physics of Solar Cells, Imperial College Press, Chapters 1, 3, 4, 7, 9, 10 (2003) ("Nelson")
1024	R. F. Pierret, Semiconductor Device Fundamentals, Addison-Wesley Publishing Company, Inc., Excerpts from Chapters 1-4 (1996) ("Pierret")
1025	S.J. Fonash, Solar Cell Device Physics, Elsevier, Excerpts from Chapter 2 (2d Ed. 2010) ("Fonash")
1026	C. Hu, R.M. White, Solar Cells: From Basics to Advanced Systems, McGraw-Hill (1983) ("Hu")
1027	O. von Roos, B. Anspaugh, "The Front Surface Field Solar Cell, A New Concept," Proceedings of the 13th IEEE PVSEC, pp. 1119-1120 (1978) ("von Roos")

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1028	E. van Kerschaver, G. Beaucarne, "Back-contact Solar Cells: A Review," Prog. Photovolt: Res. Appl. 14:107-123 (2005) ("van Kerschaver")
1029	U.S. Patent No. 8,222,516 B2 ("USP516")
1030	U.S. Patent No. 4,234,352 ("Swanson-352")
1031	J. Bultman, I. Cesar, B. Geerligs, Y. Komatsu, W. Sinke, "Methods of emitter formation for crystalline silicon solar cells," Photovoltaics International 6, pp. 69-80 (2012) ("Bultman")
1032	U.S. Patent No. 5,444,001 ("Tokuyama")
1033	I. Perichaud, "Gettering of impurities in solar silicon," Solar Energy Materials & Solar Cells 72:315–326 (2002) ("Perichaud")
1034	Mark John Kerr, Surface, Emitter and Bulk Recombination in Silicon and Development of Silicon Nitride Passivated Solar Cells (2002) (Ph.D. Thesis, The Australian National University) ("Kerr")
1035	U.S. Patent App. Pub. No. 2012/0006392 ("Gupta")
1036	File History for U.S. Patent No. 9,520,507 B2 (App. No. 14/579,935) ("USPA935FH")
1037	File History for U.S. Patent No. 9,899,542 B2 (App. No. 15/213,273) ("USPA273FH")
1038	File History for U.S. Patent No. 10,170,642 B2 (App. No. 15/876,927) ("USPA927FH")
1039	File History for U.S. Patent No. 10,658,525 B2 (App. No. 16/228,165) ("USPA165FH")
1040	P. Procel, V. Maccaronio, F. Crupi, G. Cocorullo, M. Zanuccoli, "Analysis of the Impact of Rear Side Geometry on Performance of Back-Contact Back-Junction Solar Cells," 2014 Fotonica AEIT Italian Conference on Photonics Technologies, Naples, Italy, 2014, pp. 1-4, IEEE (2014) ("Procel")
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1043	S.W. Glunz, R. Preu, D. Biro, "Chapter 1.16: Crystalline Silicon Solar Cells – State-of-the-Art and Future Developments," Comprehensive Renewable Energy, Elsevier (2012) ("Glunz")
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1045	U.S. Patent No. 4,665,277 ("Sah")
1046	M. Green, "Silicon solar cells: evolution, high-efficiency design and efficiency enhancements," Semiconductor Science & Technology 8 (1993) ("Green")
1047	A.A. Istratov, H. Hieslmair, E.R.Weber, "Iron contamination in silicon technology," Appl. Phys. A 70, 489–534 (2000) ("Istratov-2000")
1048	A. Metz, R. Meyer, B. Kuhlmann, M. Grauvogl, R. Hezel, 18.5% Efficient First-Generation MIS Inversion-Layer Silicon Solar Cells, 26th PVSC (1997) ("Metz")
1049	D. De Ceuster, P. Cousins, D. Rose, D. Vicente, P. Tipones, W. Mulligan, "Low Cost, High Volume Production of >22% efficiency silicon solar cells," 22nd European Photovoltaic Solar Energy Conference, 3-7 September 2007, Milan, Italy, pp. 816-819 ("De Ceuster")
1051	M.D. Lammert and R.J. Schwartz, "The interdigitated back contact solar cell: a silicon solar cell for use in concentrated sunlight," IEEE Transactions on Electron Devices, ED-24 (4), 337-42, (1977) ("Lammert")

No.	Description
1052	D. Lysáček, M. Lorenc, L. Válek, "Structure and gettering properties of polycrystalline silicon layers," Proceedings of the 16th Joint Seminar Development of Materials Science in Research and Education, Czechoslovak Association for Crystal Growth, published by Czech and Slovak Crystallographic Association, Praha 2006 (ISBN 80-901748-7-6) p. 40-41 ("Lysacek")
1053	K. Ishisaka, H. Tanaka, T. Nakashizu, "Gettering Properties of Silicon Wafer Covered by Polysilicon," NIPPON STEEL TECHNICAL REPORT No. 59 (Oct. 1993) ("Nippon")
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1063	Petition for Inter Partes Review of U.S. Patent No. 11,251,315, Canadian Solar Inc. v. Maxeon Solar Pte. Ltd., Case No. IPR2024-01038, Paper 1 (June 25, 2024) ("CSI-1038-Petition")
1064	A. A. Istratov, W. Huber, E. R. Weber, "Experimental evidence for the presence of segregation and relaxation gettering of iron in polycrystalline silicon layers on silicon," Appl. Phys. Lett. 85, 4472–4474 (2004) ("Istratov-2004")
1065	KR1020130044982 ("Choi-982") (Translation)
1066	Translation Declaration for Choi-982
1068	U.S. Patent No. 6,998,288 ("Smith-288")
1069	CN 1949545A to Li ("Li")-Translation
1070	Translation Declaration for Li
1072	R. J. Komp, Practical Photovoltaics Electricity From Solar Cells, 3rd Ed., Chapters 1-3, 6 (2002) ("Komp")
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1074	J. Benick, J. Rentsch, Ch. Schetter, C. Voyer, D. Biro, R. Preu, PECVD PSG as a Dopant Source for Industrial Solar Cells, Presented at the 21st European Photovoltaic Solar Energy Conference, September 4-8, 2006, Dresden (2CV.4.26) ("Benick")
1075	M. Green, Silicon Solar Cells Advanced Principles & Practice, Centre for Photovoltaic Devices and Systems, Chapters 2, 10 (1995) ("Green-1995")

No.	Description
1076	Petition for Inter Partes Review of U.S. Patent No. 11,251,315, Canadian Solar Inc. v. Maxeon Solar Pte. Ltd., Case No. IPR2024-01194, Paper 1 (July 19, 2024) ("CSI-1194-Petition")
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1078	S. Pizzini, M. Acciarri, S. Binetti, "From electronic grade to solar grade silicon: chances and challenges in photovoltaics," phys. stat. sol. (a) 202, No. 15, 2928–2942 (2005) ("Pizzini")
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1089	Reply Declaration of Dr. Zachary Holman Regarding U.S. Patent No. 11,251,315 ("Reply-Decl.")
1090	Deposition Transcript of E. Fred Schubert, July 15, 2025, in *Hanwha Solutions Corp. v. Maxeon Solar Pte, Ltd.*, IPR2024-01198 ("Schubert-Tr.")
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