

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

HANWHA SOLUTIONS CORPORATION,
Petitioner

v.

MAXEON SOLAR PTE. LTD.,
Patent Owner

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

PATENT OWNER'S RESPONSE

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<i>Vicor Corp. v. Delta Elecs., Inc.</i> , IPR2024-00704, Paper 11 (Oct. 2, 2024)	21
<i>Winner Int'l Royalty Corp. v. Wang</i> , 202 F.3d 1340 (Fed. Cir. 2000)	47

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PATENT OWNER'S EXHIBIT LIST

Exhibit	Description
2001	Declaration of David Carroll, Ph.D. in Support of Patent Owner Preliminary Response
2002	Lamers et al., "Towards 21% Efficient N-CZ IBC based on Screen Printing," <i>26th European Photovoltaic Solar Energy Conference and Exhibition</i> , (2011)
2003	Desa et al., "Optimization of p-type Screen Printed Interdigitated Back Contact Silicon Solar Cell with Aluminum Back Surface Field," <i>International Journal of Engineering & Technology IJET-IJENS</i> , 14(2) (2014)
2004	Pham et al., "Dopant-grading proposal for polysilicon passivating contact in crystalline silicon solar cells," <i>Journal of Power Sources</i> , 522, 2022
2005	Procel et al., "Analysis of the Impact of Doping Levels on Performance of Back Contact – Back Junction Solar Cells," 4th International Conference on Silicon Photovoltaics, SiliconPV 2014, Italy, 2014, pp 128-132, ScienceDirect
2006	Federal Court Management Statistics (September 30, 2024)
2007	<i>Intentionally Left Blank</i>
2008	<i>Intentionally Left Blank</i>
2009	Invalidity Contentions, <i>Maxeon Solar Pte. Ltd. v. Canadian Solar Inc.</i> , Case No. 2:24-cv-00210-JRG (E.D. Tex. Sept. 6, 2024)
2010	<i>Intentionally Left Blank</i>
2011	<i>Intentionally Left Blank</i>
2012	<i>Intentionally Left Blank</i>
2013	<i>Intentionally Left Blank</i>
2014	<i>Intentionally Left Blank</i>
2015	<i>Intentionally Left Blank</i>
2016	"Nanotechnology improves solar cell efficiency," <i>EarthSky</i> , August 28, 2007 (accessible at https://earthsky.org/humanworld/nanotechnology-improves-solar-cell-efficiency ; last accessed October 14, 2024)
2017	"New Plastic Solar Cell Breaks Efficiency Record," <i>ScienceDaily</i> , April 20, 2007 (accessible at https://www.sciencedaily.com/releases/2007/04/070419140902.htm), last accessed October 14, 2024)

Exhibit	Description
2018	Capshaw-Mack, C., "Power Games: Project seeks to improve methods of harnessing solar energy," <i>Winston-Salem Journal</i> , August 4, 2013 (accessible at https://journalnow.com/news/local/article_1d243ff0-fc9e-11e2-b607-001a4bcf6878.html ; last accessed October 15, 2024)
2019	<i>Intentionally Left Blank</i>
2020	<i>Intentionally Left Blank</i>
2021	Docket Sheet, <i>Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.</i> , Case No. 2:24-cv-00210-JRG (E.D. Tex.)
2022	Docket Sheet, <i>Maxeon Solar Pte. Ltd. v. Hanwha Solutions Corp.</i> , Case No. 2:24-cv-00262-JRG (E.D. Tex.)
2023	Docket Sheet, <i>Maxeon Solar Pte. Ltd. v. REC Solar Holdings AS</i> , Case No. 2:24-cv-00260-JRG (E.D. Tex.)
2024	Counterclaims, <i>Maxeon Solar Pte. Ltd. v. Hanwha Solutions Corp.</i> , Case No. 2:24-cv-00262-JRG (E.D. Tex. Nov. 15, 2024)
2025	Petition for <i>Inter Partes</i> Review, Paper 1, <i>Canadian Solar, Inc. v. Maxeon Solar Pte. Ltd.</i> , Case No. IPR2024-01038 (PTAB June 25, 2024)
2026	Petition for <i>Inter Partes</i> Review, Paper 1, <i>Canadian Solar, Inc. v. Maxeon Solar Pte. Ltd.</i> , Case No. IPR2024-01194 (PTAB July 19, 2024)
2027	Declaration of Dr. Mary K. Bolin <i>Served and Not Filed</i>
2028 New	Declaration of Fred Schubert, Ph.D. in Support of Patent Owner's Response
2029 New	<i>Curriculum Vitae</i> of Fred Schubert, Ph.D.
2030 New	McGraw-Hill Dictionary of Scientific and Technical Terms, 6th ed. (2003) (excerpts)
2031 New	Merriam-Webster's Collegiate Dictionary, 11th ed. (2006) (excerpts)
2032	<i>Intentionally Left Blank</i>
2033 New	Coletti, G., "Sensitivity of State-of-the-Art and High Efficiency Crystalline Silicon Solar Cells to Metal Impurities," <i>Prog. Photovolt: Res. Appl.</i> 2013; 21, pp. 1163-1170

Exhibit	Description
2034 <i>New</i>	Vossier, A., et al., “Is Auger Recombination the Ultimate Performance Limiter In Connector Solar Cells?” Applied Physics Letters 97, 193509 (2010)
2035 <i>New</i>	Korte, L., et al., “Surface Photovoltage Investigation of Recombination at the a-Si/c-Si Heterojunction,” Thin Solid Films 517, pp. 6396-6400 (2009)
2036 <i>New</i>	Cuevas, A., et al., “Extraction of the Surface Recombination Velocity of Passivated Phosphorous-Doped Silicon Emitters,”
2037 <i>New</i>	Transcript of deposition of Zachary Holman, Ph.D. taken May 1, 2025
2038 <i>New</i>	https://www.ioffe.ru/SVA/NSM/Semicond/Si/electric.html (accessed May 20, 2025)
2039 <i>New</i>	Declaration of Dr. Mary K. Bolin

I. INTRODUCTION

Solar cell design requires careful consideration of various design parameters. Petitioner's theories fail to recognize that, and instead builds a series of obviousness theories premised on the notion that a person of ordinary skill in the art would have plucked different design parameters, such as dopant concentration and dopant type, from various secondary references without regard for how those choices would impact the solar cells of the primary references. For example, Petitioner proposes adding a heat treatment step found in a non-analogous reference but fails to appreciate how the elevated temperatures and prolonged times would negatively impact the solar cell device of the primary references. Similarly, Petitioner proposes doping concentrations that appear in certain references but fail to consider whether those concentrations would have been appropriate under the design constraints of the primary references.

Petitioner compounds its error by misreading the relevant references. For example, Petitioner argues that the Marvin reference teaches a dopant concentration of less than $2 \times 10^{18} \text{ cm}^{-3}$, when in fact that reference teaches a dopant concentration of $5 \times 10^{18} \text{ cm}^{-3}$ for a terrestrial application (the application relevant to Petitioner's theories). Petitioner also elevates imprecise numerical modelling above empirical data. For example, Petitioner argues that the Granek reference would steer a person of ordinary skill in the art toward a dopant concentration of

$1 \times 10^{18} \text{ cm}^{-3}$ based on certain simulations even though Granek found that, among the solar cells that were actually made and tested, dopant concentrations above $2 \times 10^{18} \text{ cm}^{-3}$ yielded the best results.

Technical facts cited in this Response are supported by the declaration testimony of Patent Owner's expert Dr. Fred Schubert. *See generally* Ex. 2028.

II. THE '315 PATENT

A. Solar Cell Background

The '315 patent is directed to a solar cell. Simply, a solar cell converts energy from sunlight, i.e., electromagnetic energy, into electricity. This conversion takes place when a photon strikes a solar cell—often made of silicon—and dislodges an electron (also thereby creating a “hole” or electron vacancy). Ex. 2028, ¶ 36. Ideally, the dislodged electrons do not recombine with holes before migrating to an emitter, which is connected to an electric circuit. *Id.* Such electrons would then flow through the circuit and rejoin with the holes, but only after travelling through the circuit and thereby providing electrical power. *Id.* Solar cells often reside in a solar panel. This allows the electricity of multiple solar cells to be joined into a single device.

A solar cell designer is often concerned with numerous attributes, for example, mechanical reliability, cost, and efficiency. “Efficiency” in the solar field refers to the ratio of energy that is output by a solar cell relative to the amount of

energy in the sunlight that it receives. In 2014—the time of the invention of the '315 patent—solar cells often had efficiencies of around 20%. Two factors that heavily influence efficiency are “lifetime” and “passivation.” The term “lifetime” refers to the time during which a dislodged electron lasts before “recombining” with a hole. If an electron recombines before it is collected at the emitter and travels through the circuit, no electric power is harnessed from that electron. A “lifetime” is often much less than one second. A longer lifetime translates into a greater chance for an electron to be harnessed as useful electricity before prematurely recombining with holes. This increases efficiency.

Two techniques to reduce recombination and thereby increase lifetime (and thus efficiency) are “passivation” and “doping.” Ex. 2028, ¶ 37.

Passivation is the process of covering a surface of a substrate with a material (often an oxide) to reduce recombination at the surface. Electrons and holes tend to recombine at such surfaces due to “dangling bonds” at a material’s surface. Simply, a “dangling bond” refers to a valence band of electrons that is not fully satisfied (or “filled”). This has the tendency to attract electrons or holes. The idea behind passivation is to satisfy or fill the valence bands thereby reducing or eliminating their tendency to attract electrons or holes.

Doping is the introduction of a charged impurity into the substrate. This charge will repel one of either an electron or hole, but not the other. This repulsion

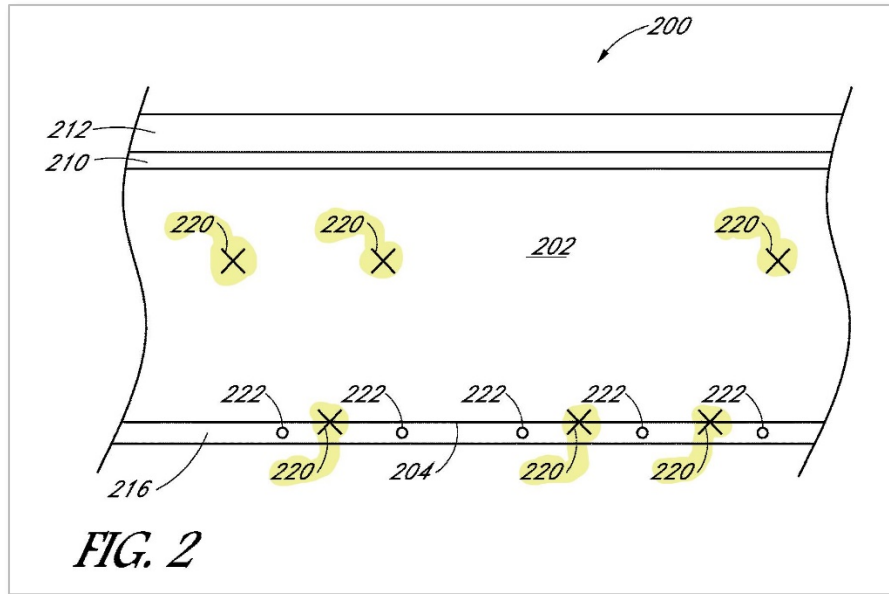
helps maintain separation of electrons and holes, i.e., it prevents recombination, thereby increasing lifetime and efficiency.

Another impediment to solar efficiency is the presence of impurities (e.g., metals) within the silicon substrate. Two common ways of reducing such impurities were to (1) begin with pure or near pure (“impurity free”) substrates or (2) remove the impurities through a process called “gettering.”

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

The '315 patent is directed at improving solar cell lifetime, passivation, and/or efficiency in tunnel oxide passivated contact (“TOPCon”) solar cell configurations. '315 patent, 3:17-21.

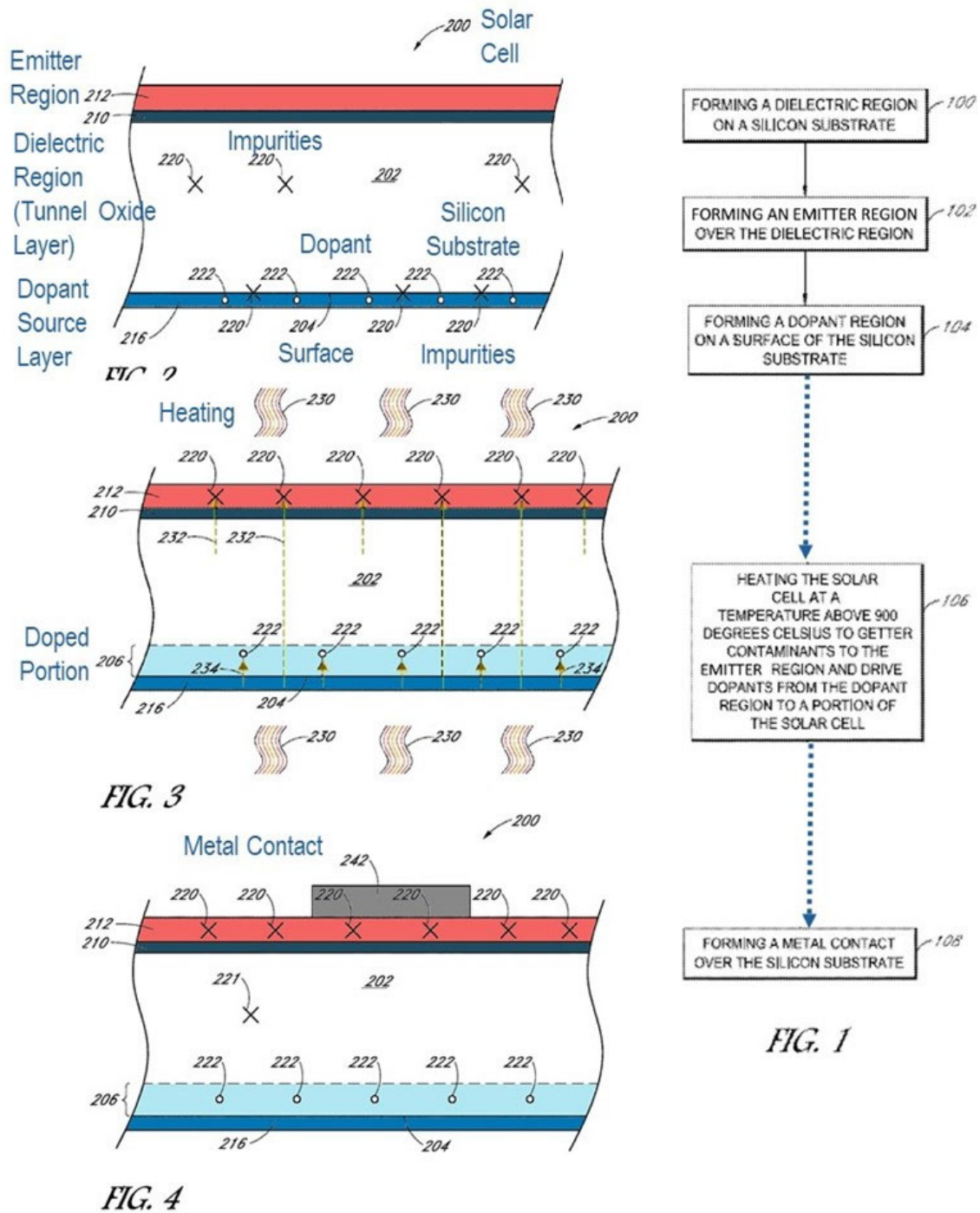
One aspect of the '315 patent is the solution to the problem that an oxide layer may prevent the gettering of metal contaminants that are originally present in a silicon substrate to emitter regions above the oxide layer. The '315 patent discusses that “[m]etal impurities can be detrimental to the electrical conduction of the solar cell as these impurities can be sources of recombination, resulting in poor lifetime.” '315 patent, 5:1-4. According to the '315 patent, “the impurities 220 can be located at or near a surface 204 of the silicon substrate.” *Id.*, 5:5-6. Also, “the impurities 220 can be located within the silicon substrate 202.” *Id.*, 5:7-8. The metal contaminants 220 are shown in Figure 2:



'315 patent, Fig. 2 (annotated).

The '315 patent also recognizes that “[t]he emitter regions 212, e.g., polysilicon regions, can be a good sink and/or trap for the metal impurities 220 discussed above.” *Id.*, 5:10-12. Thus, according to the '315 patent, “[a] gettering process can be used to trap the metal impurities 220 in the emitter regions 212, reducing recombination within the silicon substrate 202 and improving overall solar cell lifetime.” *Id.*, 5:12-15. However, as the '315 patent recognizes, “[o]xides and/or tunnel oxides, such as the dielectric region 210 of FIG. 2, can be barriers to gettering of the metal impurities 220 to emitter regions 212.” *Id.*, 5:15-18. Thus, the '315 patent sets out the problem of not being able to getter metal contaminants 220 from the substrate 202 through oxide region 210 to emitter regions 212.

The '315 patent discloses a solution to this problem. Specifically, the '315 patent discloses the fabrication of a solar cell by the following steps: (1) forming a dielectric region (e.g., a tunnel oxide layer) over a silicon substrate, (2) forming an emitter region over the dielectric region, (3) forming a dopant region (e.g., a dopant source layer) on a surface of the silicon substrate, and (4) heating the solar cell above 900°C such that (i) the surface of the solar cell is doped to a concentration of less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and (ii) the emitter region contains contaminants gettered from the silicon substrate through the dielectric region. These fabrication steps are illustrated as follows:



'315 patent, Figs. 1-4 (annotated).

The '315 patent explains that this particular combination of steps increased efficiency in a unique and unexpected way. The inventors of the '315 patent

examined four processes under which the heating temperature and surface dopant concentrations were altered. The gettering location, surface passivation, lifetime, and efficiency results were measured. The results are reflected in Figure 11 of the '315 patent.¹

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

Table 1. Example Processes for Solar Cell Fabrication

'315 patent, Fig. 11 (annotated).

In Example Process A, the solar cell was heated at a relatively low temperature (i.e., $\leq 900^\circ\text{C}$) and the substrate was doped at a relatively low concentration (i.e., $2 \times 10^{18} \text{ cm}^{-3}$). The '315 patent explains that “[o]xides and/or tunnel oxides, such as the dielectric region . . . can be barriers to gettering of the

¹ The parties agree that Figure 11 includes a typographical error and that the temperature for Example Processes C and D should show that the temperature was greater than 900°C . See Petition at 21 n.3.

metal impurities 220 to emitter regions” and that “heating at temperature at 900 degrees Celsius or below can be insufficient to diffuse metal impurities through a tunnel oxide and into a polysilicon region.” ’315 patent, 5:15-20. Accordingly, the “Gettering Location” for Example Process A is the “non-poly” silicon substrate, rather than the “poly” emitter region. The combination of variables in Example Process A yielded good surface passivation but poor lifetime.

Example Process B also used low temperature heating, but a relatively high surface dopant concentration (i.e., $4 \times 10^{18} \text{ cm}^{-3}$). Like Example Process A, the gettering location remains in the “non-poly” silicon substrate. The variables of low temperature and relatively high surface dopant concentration results in a good lifetime, but poor surface passivation. Example Processes A and B demonstrate the kind of trade-offs that are made when designing solar cells. Having a low surface dopant concentration may result in good surface passivation but poor lifetime; whereas a high surface dopant concentration may result in good lifetime but poor surface passivation. For both Example Processes A and B, the efficiency of the solar cell remained at the same baseline level.

The unexpected result came from Example Process C, where high-temperature (i.e., $> 900^\circ\text{C}$) heating and low surface dopant concentration are used. In this process, contaminants from the silicon substrate gettered through the dielectric region and into the “poly” emitter region. At the time of the invention, it

was not known whether high-temperature heating would getter impurities through the dielectric region, while leaving this region intact and functional. In this way, the '315 patent discovered a solution to the gettering issue noted above. In particular, "heating at temperatures above 900 degrees Celsius can include gettering metal impurities 220 through the dielectric region 210, e.g., tunnel oxide, to into the emitter region 212, e.g., polysilicon regions." '315 patent, 5:21-24. Further, a person of ordinary skill in the art would not have expected lifetime to improve by high-temperature heating because the silicon substrate also contains oxygen defects, which would be enlarged at higher temperatures and increase the likelihood of Ingot Ring Defects, which would reduce lifetime. Notably, as the results of Example Process C show, surface passivation and lifetime both improved, resulting in a 0.5% increase in efficiency over the other example processes.

In Example Process D, a high-temperature (i.e., $> 900^{\circ}\text{C}$) was used, but this did not further improve the lifetime beyond what a high surface dopant concentration already produced in a TOPCon solar cell configuration (e.g., Example Process B). Thus, Example Process D demonstrates that high-temperature heating alone does not yield improved efficiency, but instead that such heating should be performed with a relatively low dopant concentration. Thus, the

'315 patent requires a specific combination of fabrication steps and dopant concentration to improve the performance of the TOPCon solar cell structure.

C. Prosecution of the '315 Patent

The '315 patent issued from an application that was the fifth in a chain of applications. '315 patent, Field (60). That chain of applications underwent thorough examination. Certain aspects of the claims of the '315 patent were the subject of rejections and argument during the prosecution of the preceding four applications. All applications in the chain were deemed allowable.

The application from which the '315 patent issued was filed on May 18, 2020, and claims priority through the chain to an application filed on December 22, 2014. '315 patent, Fields (22), (60). Petitioner does not dispute that the disclosure in the first application fully supports the challenged claims of the '315 patent. Accordingly, the date of invention for this proceeding is December 22, 2014.

III. THE LEVEL OF ORDINARY SKILL

For purposes of this IPR, Patent Owner accepts the level of ordinary skill in the art that is proposed in the Petition. *See* Paper 1 ("Petition") at 23.

IV. CLAIM CONSTRUCTION

Patent Owner proposes construction of one term: "metal impurities." That term appears in claims 10 and 16, which recite, "a first emitter region having *metal impurities* formed over the dielectric region" and "a second emitter region having

metal impurities formed over the dielectric region,” respectively. Patent Owner proposes that the term “metal impurities” be construed as “undesired foreign metals.”

A. The Board Should Construe “metal impurities”

For the reasons set forth in section V.A.1 below, the Board should affirm the patentability of all claims because Petitioner presents only two arguments with respect the “metal impurities” limitations, each based on a condition precedent that is not satisfied. Thus, none of Petitioner’s contingent arguments have been triggered.

If the Board nevertheless considers the patentability of the challenged claims in view of Petitioner’s arguments, construction is appropriate to resolve the parties’ dispute regarding the meaning of “metal impurities.” Claim terms should be construed “when a term has more than one ‘ordinary’ meaning or when reliance on a term’s ‘ordinary’ meaning does not resolve the parties’ dispute.” *O2 Micro Int’l, Ltd. v. Beyond Innovation Tech. Co.*, 521 F.3d 1351, 1361 (Fed. Cir. 2008).

Petitioner appears to recognize that “metal impurities” may carry different meanings when it presents alternative arguments under different possible meanings of “metal impurities.” Specifically, Petitioner first presents an argument that Choi alone discloses the “metal impurities” limitations. Petition at 54 (“To the extent Patent Owner argues that the claimed invention includes any metal or any source

of metal . . .”); *see also id.* at 59. Petitioner alternatively argues that Istratov teaches or renders obvious the limitation under a more limited understanding. Petition at 55 (“To the extent Patent Owner contends that the claimed ‘metal impurities’ must be elements other than Group III or V elements . . .”); *see also id.* at 59. Petitioner does not state which of those two understandings it believes is correct. Regardless of which position Petitioner may later take in this proceeding, both constructions are incorrect. Rather, the proper construction is “undesired foreign metals.” As each of these three potential constructions (the two in the Petition and Patent Owner’s proposal) results in different claim scope and impacts the patentability analysis under Petitioner’s grounds, the Board should construe the term.

B. Patent Owner’s Proposed Construction of “metal impurities” Is Correct

The Board should construe “metal impurities” as “undesired foreign metals.” This is the plain and ordinary meaning of the term that the inventors clearly adopted.

Patent claims are construed in IPR proceedings by applying the same standard as that applied in district court. 37 C.F.R. § 42.100(b). Under that standard, generally claim terms are construed in accordance with the ordinary and customary meaning of the terms as understood by a person of ordinary skill in the art at the time of the invention and in the context of the entire patent disclosure.

Phillips v. AWH Corp., 415 F.3d 1303, 1312-14 (Fed. Cir. 2005) (en banc). Two exceptions are when (1) the patentee acts as lexicographer and (2) the patentee disavows the full scope of the claim. *Luminara Worldwide, LLC v. Liown Elecs. Co.*, 814 F.3d 1343, 1353 (Fed. Cir. 2016).

The term “impurities” has more than one plain and ordinary meaning, and the ’315 patent clearly indicates which applies. Specifically, “impurities” can mean either (1) an undesired material within another material or (2) any material within another material. Ex. 2028, ¶ 43. For example, a relevant technical dictionary defines “impurity” as “[a]n undesirable foreign material in a pure substance.” Ex. 2030 at 4. To be sure, the term has in some instances been used more broadly to cover even desired materials, such as dopants. Ex. 1006 at ¶ [0025] (“[T]he first conductive-type dopant may be an n-type impurity such as . . .”). However, for the following reasons, it is clear that the ’315 patent uses “impurities” under the first meaning.

The ’315 patent equates “impurities” and “contaminants.” The ’315 patent states that “[a]s referred throughout, contaminants and/or impurities can be used interchangeably.” ’315 patent, 5:8-9. The term “throughout” means not only the specification, but the claims as well. Hanwha’s expert, Dr. Holman, agrees. Ex. 1037, 122:15-123:1.

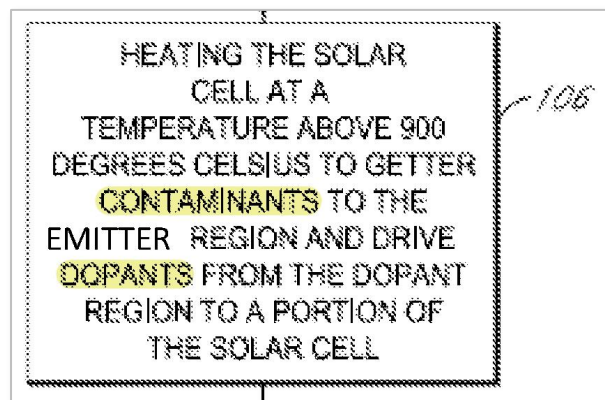
This is consistent with a key aspect of the '315 patent, which is to improve solar cell efficiency by removing contaminants from a substrate and gettering them into an emitter region. The '315 discusses the drawbacks of metal contaminants in a substrate. '315 patent, 5:1-4 (“Metal impurities can be detrimental 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.”). The '315 patent also recognized the opportunity to getter the metal contaminants to the emitter regions 212, which “can be a good sink and/or trap for the metal impurities 220.” *Id.*, 5:10-12. The '315 patent recognized that the problem of the dielectric region 210 acting as a barrier to such gettering can be overcome by heating at temperatures above 900°C. *Id.*, 5:15-25.

The '315 patent further reflects the interchangeability of “impurities” and “contaminants” in its use of reference numbers. A reference number is used to refer to the same part of an invention. 37 C.F.R. § 1.84(p)(4) (“The same part of an invention appearing in more than one view of the drawing must always be designated by the same reference character, and the same reference character must never be used to designate different parts.”). Here, the '315 patent uses reference number 220 to designate both “contaminants and/or impurities,” “impurities,” and “contaminants.” '315 patent, 4:66, 5:7, 5:11, 5:17, 5:22, 6:6, 6:9. Further, the '315 patent uses reference number 320 as follows: “In an example, impurities and/or

contaminants 320, e.g. metal impurities 320 and/or metal contaminants.” *Id.*, 6:57-

59. Similarly, the '315 patent uses reference number 520 to designate “impurities and/or contaminants” as well as “metal impurities.” *Id.*, 8:16-19.

By contrast, the '315 patent does not equate “impurities” with “dopants.” Thus, when the '315 patent discusses “dopants”, it never characterizes them as impurities. Dopants provide desired properties and are thus purposefully introduced. Figure 1 of the '315 patent illustrates the distinction between contaminants (impurities) and dopants:



'315 patent, Fig. 1 (partial, annotated). As reflected in the above, “contaminants” are gettered or removed from a substrate to an emitter region while “dopants” are purposefully driven into the substrate.

The '315 patent's use of “and/or” between “impurities” and “contaminants” does not weigh against Patent Owner's proposed construction. The '315 patent explicitly states that “contaminants *and/or* impurities can be used interchangeably.” '315 patent, 5:8-9 (emphasis added). In view of this, a person of

ordinary skill in the art would understand that the patentee uses “and/or” to show equivalence between contaminants and impurities, not to distinguish the two. Ex. 2028, ¶ 53.

A “contaminant” is an undesired material. For example, a technical dictionary defines “contaminate” as “[t]o render unfit or to soil by the introduction of foreign or unwanted material.” Ex. 2030 at 3. A general purpose dictionary is in accord. Specifically, “contaminant” is “something that contaminates,” and the following definitions are provided for “contaminate”:

- “to soil, stain, corrupt, or infect by contact or association”
- “to make inferior or impure by admixture”
- “to make unfit for use by the introduction of unwholesome or undesirable elements”

Ex. 2031 at 3. Any of those definitions align with Patent Owner's proposed construction. Consistent with these dictionaries, Dr. Holman recognizes that “contaminant” carries a negative connotation. Ex. 2037, 114:5-9.

C. Other Claim Terms

For all other terms, Patent Owner applies the plain and ordinary meaning as those terms would have been understood by a person of ordinary skill in the art at the time of the invention.

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

Grounds I and III fail to satisfy two limitations of claim 10 of the '315 patent: (1) "a first emitter region having metal impurities formed over the dielectric region" and (2) "wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$." All of challenged claims 11-20 depend directly or indirectly from claim 10. Accordingly, Petitioner fails to show that any of the challenged claims is unpatentable.

Grounds I and III also fail to establish the unpatentability of dependent claims 13 and 14 because they fail to show that it would have been obvious to use a p-type dopant such as boron with all other limitations of those claims.

Ground I also fails to establish the unpatentability of claim 16 because that ground (the only ground used for claim 16) fails to establish the limitation "a second emitter region having metal impurities formed over the dielectric region."

Ground II fails because it depends on Ground I establishing the unpatentability of claims 10 and 16, which Ground I fails to do.

A. Ground I

1. Petitioner Fails to Present a Live Argument with Respect to “a first emitter region having metal impurities” (Claim 10)

Petitioner's arguments with respect to the “metal impurities” limitations are buried under two contingencies, neither of which is satisfied. Specifically, Petitioner includes certain arguments after the contingency: “To the extent Patent Owner argues that the claimed invention includes any metal or any source of metal.” Petition at 54. Petitioner then presents an alternative argument after a different contingency: “To the extent Patent Owner contends that the claimed ‘metal impurities’ must be elements other than Group III or V elements.” Petition at 55.² Neither of the above two contingencies have been met. That is, Patent Owner has not argued, and does not argue, that “metal impurities” either (1) is satisfied by any metal or any source of metal or (2) is limited to Group III or V elements. Rather, as made clear in section IV.B above, Patent Owner argues the term means “undesired foreign metals.” Thus, the term does not encompass any metal or any source of metal. Also, the term is not tied to any particular group of elements. With neither contingency satisfied, Petitioner's arguments should be disregarded. *See Microchip Tech. Inc. v. Aptiv Techs. AG*, IPR2024-00494, Paper

² Petitioner includes similar alternatives with respect to the limitation “a second emitter region having metal impurities” of claim 16. Petition at 59.

12 at 12 (Oct. 7, 2024) (“The contingency upon which the claim construction in the Petition is based and has not been met and, according to its own terms, the Petition should be denied.”).

If Petitioner contends that in its Petition it was *sub silentio* advocating for either of the constructions in the Petition, the Board should reject such a belated proposal. The Petition does not include any argument or evidence supporting either construction. It is too late for Petitioner to introduce argument and evidence now. *Intelligent Bio-Systems, Inc. v. Illumina Cambridge Ltd.*, 821 F.3d 1359, 1369 (Fed. Cir. 2016) (“It is of the utmost importance that petitioners in the IPR proceedings adhere to the requirement that the initial petition identify ‘with particularity’ the ‘evidence that supports the grounds for the challenge to each claim.’”) (*quoting* 35 U.S.C. § 312(a)(3)). Petitioner was aware that “metal impurities” was subject to multiple interpretations when it filed its Petition. It should have stated the interpretation it believed was correct and the evidence supporting that contention. In similar circumstances, the Board has refused to adopt a construction that a Petitioner did not advocate for in its Petition. *See Microchip Tech.* at 12 (declining to adopt a proposed construction that “is not persuasively argued or adequately supported by either party.”). The Board likewise should reject Petitioner’s two proposed constructions (if that is what they are) here.

Petitioner fails to identify which of the possible constructions it prefers much less provide any support for either construction.

If Petitioner contends that neither construction in its Petition is correct, the Board should reject Petitioner's challenges. A petitioner cannot carry its burden by making arguments under a claim interpretation that it recognizes is incorrect. This is because the Petitioner necessarily is unable to establish the propriety of such an interpretation. For example, in *Vicor Corp. v. Delta Elecs., Inc.*, IPR2024-00704, Paper 11 (Oct. 2, 2024), the petitioner advanced a claim construction that it acknowledged was not proper. *Id.* at 8-9. The Board found that the petitioner's failure to establish the appropriateness of that construction was "fatal" to the ground. *Id.* at 8. For the same reasons, the Board should reject Petitioner's grounds based on all claim constructions that it acknowledges are incorrect.

If the Board nevertheless addresses Petitioner's contingent arguments on their merits, it should find that Petitioner has failed to carry its burden.

2. *Petitioner Fails to Show That Choi Discloses "a first emitter region having metal impurities" (Claim 10)*

Under the proper construction of "metal impurities," Choi fails to disclose a first emitter region having metal impurities. Petitioner contends that Choi's second conductive area 34 corresponds to the "first emitter region" of claim 10. Petition at 54. To support the argument that Choi's second conductive area 34 has metal impurities, Petitioner relies on Choi's disclosure that certain dopants may be added

to second conductive area 34. Petition at 54 (citing Ex. 1006, ¶¶ [0026], [0036]-[0037]). However, those dopants are not undesired foreign metals. Instead, they are purposefully added because they improve the performance of Choi's device. Notably, the key aspect of gettering impurities from the silicon substrate to the polysilicon emitter layer (*see* '315 patent, 5:1-25) would not be achieved if dopants in the emitter layer qualify as "metal impurities." Petitioner does not attempt to show that Choi discloses "metal impurities" under the proper construction.

3. *It Would Not Have Been Obvious to Achieve a "first emitter region having metal impurities" by Employing Istratov's Gettering in Choi (Claim 10)*

Petitioner's alternative argument for the "first emitter region having metal impurities," which is based on a Choi-Istratov combination, is likewise unavailing.

a. Choi Does Not Have Contaminants That Need to Be Gettered

As an initial matter, Petitioner fails to explain why a person of ordinary skill in the art would have been prompted to modify Choi to include gettering, much less that disclosed by Istratov. Petitioner argues that "[u]pon identifying detrimental levels of metal impurities in a solar cell substrate, a POSITA would have been motivated to add Istratov's gettering process . . ." Petition at 43. However, Petitioner fails to explain why a person of ordinary skill in the art would have made such an identification. Choi does not disclose that its substrate has

metal impurities, and Petitioner did not argue that the substrate of Choi inherently would have metal impurities.

Dr. Holman's declaration testimony does not help Petitioner. Dr. Holman declared that metal impurities "could" be present in silicon wafers. Ex. 1003, ¶ 83. However, Dr. Holman admitted that he never argued metal impurities necessarily would have been present. Ex. 2037, 91:21-92:3. Further, Dr. Holman admits in his declaration that "[g]ettering was only required in solar cells with significant metal impurity levels in the wafer." Ex. 1003, ¶ 83. Petitioner fails to show that Choi's substrate includes any contaminants much less significant levels that would require gettering.

During his deposition, Dr. Holman suggested that dopants in Choi's substrate are impurities. Ex. 2037, 88:16-89:20. However, Dr. Holman conceded that those impurities are not gettered to another location. *Id.*, 102:6-103:6. Thus, those dopants could not qualify as the "metal impurities" recited in claim 10.

In the absence of a problem of metal contaminants in Choi's substrate, a person of ordinary skill in the art would not have searched for a potential solution to that problem, such as gettering.

b. Istratov Is Not Analogous

Further, Petitioner's reliance on a Choi-Istratov combination is unavailing because Istratov is not analogous art. A reference must be analogous to the

claimed invention in order to qualify as prior art for an obviousness determination.

Airbus S.A.S. v. Firepass Corp., 941 F.3d 1374, 1379 (Fed. Cir. 2019). Two tests are employed to define the scope of analogous prior art: “(1) whether the art is from the same field of endeavor, regardless of the problem addressed and, (2) if the reference is not within the field of the inventor’s endeavor, whether the reference still is reasonably pertinent to the particular problem with which the inventor is involved.” *Id.* (quoting *In re Bigio*, 381 F.3d 1320, 1324 (Fed. Cir. 2004)).

Istratov fails both tests.

With regard to the first test, Istratov is not in the same field as the ’315 patent. The ’315 patent is in the field of solar cell devices, a point on which Petitioner agrees. Petition at 36 (“Choi, Granek, and Marvin are analogous art to the Challenged Claims because they are in the same field as the Challenged Claims (solar cell devices).”). Istratov, by contrast, relates to silicon-on-insulator (SOI) and separation by implanted oxygen (SIMOX) technology in connection with silicon integrated circuits. Ex. 1028, ¶ 61. Istratov does not mention “solar” or “sun.” *See Airbus*, 941 F.3d at 1380 (upholding the Board’s finding that reference was not analogous where “the term ‘fire’ does not appear at all in [reference]”). In fact, integrated circuits are purposefully shielded from sunlight as it damages them. Ex. 1028, ¶ 61. Petitioner attempts to define the field too broadly when it argues that Istratov “is in the field of silicon semiconductor devices, which encompasses

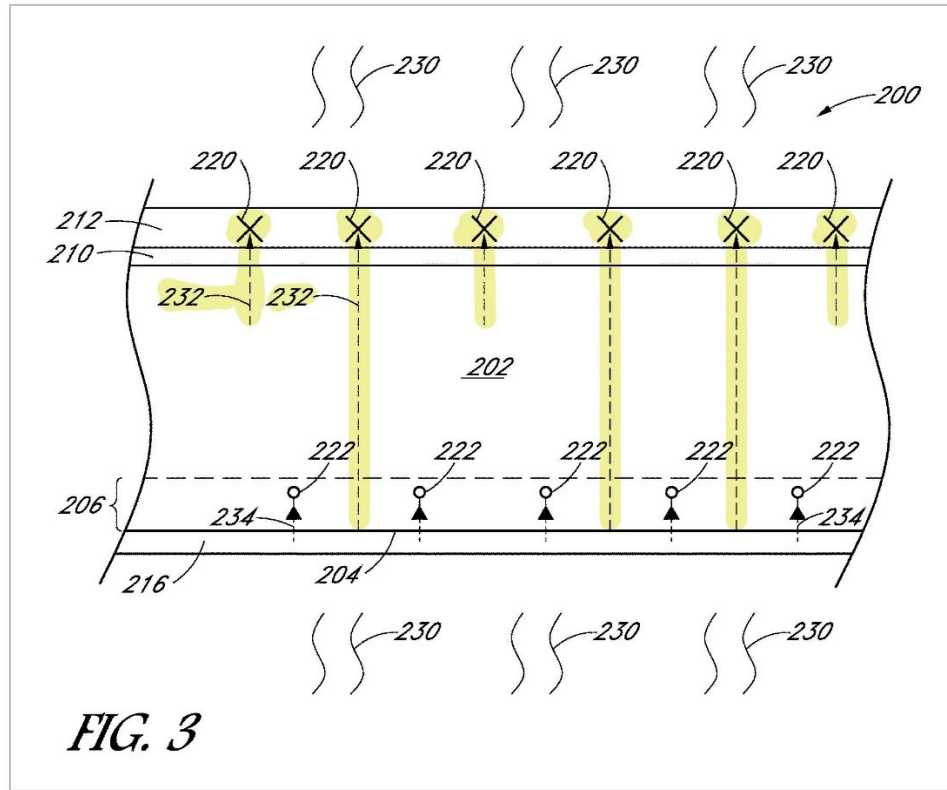
solar cells.” Petition at 42. *See Airbus*, 941 F.3d at 1380 (upholding finding of non-analogousness where patent claims addressed a breathable fire-preventive and fire suppressive atmosphere and prior art was directed to equipment for providing hypoxic air in an enclosed area for athletic training or therapy). Indeed, Petitioner appears to inadvertently concede that Istratov is of a different field than the ’315 patent when it states, “Istratov is in the field of silicon semiconductor devices, from which POSITAs frequently adopted processing technologies.” Petition at 42. One “adopts” something only if it did not have it originally.

With regard to the second test, Istratov is not reasonably pertinent to the particular problem with which the inventors of the ’315 patent were involved. The ’315 patent aims to move contaminants from a substrate to a polysilicon emitter layer. Istratov is directed at the opposite process. In particular, Istratov seeks to move impurities from a polysilicon device layer to gettering sites within a substrate. Ex. 1012, p. 568; Ex. 1028, ¶ 64. In this regard, Dr. Holman appears to have overlooked Istratov’s purpose. When asked whether “Istratov is interested in gettering impurities from a device layer to a substrate,” he replied in the negative. Ex. 2037, 81:5-8; *see also id.*, 81:17-21. Dr. Holman had to be directed to Istratov’s introduction, which clearly states its focus. *Id.*, 82:5-84:1.

c. Istratov's BOX Layer Is Unlike Choi's Oxide Layer or the '315 Patent's Oxide Layer

The oxide layer in Istratov (the BOX layer) is fundamentally different than oxide layer in the '315 patent (i.e., dielectric layer 210) as well as tunnel oxide layer 20 of Choi. Istratov teaches BOX oxide thickness values of at least 200 nm. Ex. 1012 at Figs. 2, 3 (disclosing BOX oxide thicknesses of 200 nm and 1300 nm, respectively). Choi teaches tunnel oxide thickness values of “0.5 nm to 5 nm (for example, 1.0 nm to 4 nm).” Ex. 1006 at ¶ [0034]. Thus, Istratov's BOX layer is 40 to 2,600 times thicker than Choi's tunnel oxide. Relatedly, Istratov's BOX layer is beneficial “since it prevents degradation of the device yield in the event of contamination of the back surface of the wafer.” Ex. 1012 at p. 574. Similarly, Istratov also teaches that the BOX layer “represents an almost impenetrable barrier for iron at normal processing temperatures.” *Id.* at p. 573.

By contrast, in the '315 patent, contaminants in silicon substrate 202 travel to the device layer through the dielectric layer. This is illustrated as 232 in Figure 3:



'315 patent, Fig. 3 (annotated); *see also id.*, 6:5-10.

In sum, Istratov teaches the opposite of the '315 patent. That is, Istratov teaches that the device layer (above Istratov's BOX layer) is "protected from the contaminants residing in the substrate as long as short annealing times and fast cooling rates typical for rapid thermal processing are used." Ex. 1012 at p. 574. By contrast, the purpose of the '315 patent is not to prevent migration of contaminants across the oxide layer but instead to force the contaminants originally in the substrate through the dielectric oxide layer to the emitter layer.

d. Istratov's Process Would Be Detrimental to Choi

Incorporating the heat treatment processes that Istratov used in certain experiments into Choi would not have been obvious; indeed, they would have been detrimental. Istratov teaches heat treatments of 1020°C for 8 hours, 690°C for 5 hours, and 1150°C for 2 hours. *See* Ex. 1012 at 570-571. Such severe and prolonged heat treatments would likely negatively impact the front surface field of Choi by causing the dopants to disperse throughout the silicon substrate. Additionally, Istratov's heat treatments could negatively impact the thin tunneling oxides in Choi and possibly dissolve them. Ex. 1028, ¶ 70.

Dr. Holman anticipated the foregoing criticisms but failed to adequately rebut them. Dr. Holman suggested in his deposition that the temperatures and times of Istratov could be adjusted because Choi has a thinner oxide layer than Istratov. Ex. 2037, 93:17-94:20. However, Dr. Holman does not show that there is any temperature-time combination that could be employed to both (i) achieve the requisite gettering and (ii) not negatively impact Choi's device. Ex. 2037 at 100:3-101:21.

4. *Petitioner Fails to Show That It Would Have Been Obvious to Implement Choi with the Claimed Dopant Concentration (Claim 10)*

Petitioner errs in relying on Marvin and Granek in alleging that it would have been obvious to use a dopant concentration of less than $2 \times 10^{18} \text{ cm}^{-3}$.

a. Petitioner Misreads Marvin

If a person of ordinary skill in the art would have followed the teachings of Marvin, they would have used a dopant concentration of $5 \times 10^{18} \text{ cm}^{-3}$. Marvin determined that concentration is “near-optimal” for terrestrial solar cells. The relevant passage of Marvin is in the “Conclusion” section and is as follows:

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 $0.9 \text{ }\mu\text{m}$ and $3.0 \text{ }\mu\text{m}$, respectively. The FSF should be an approximately $0.5 \text{ }\mu\text{m}$ step with *doping concentration of $5\text{E}18 \text{ cm}^{-3}$* .

Ex. 1008 at p. 25 (emphasis added). The “low radiation” environment corresponds with a terrestrial (i.e., land-based) application. For example, earlier in Marvin, it states, “In cases where radiation exposure is not present as the result of shielding or terrestrial use . . .” Ex. 1008 at p. 16. Thus, the link between the “low radiation” environment discussed in the Conclusion of Marvin and a terrestrial application is clear. Ex. 1028, ¶ 73. Notably, Dr. Holman’s obviousness opinions assume a terrestrial application, not a space application. Ex. 2037, 33:17-21, 36:15-21, 40:2-4, 41:15-19. Further, “ $5\text{E}18 \text{ cm}^{-3}$ ” is another way of expressing $5 \times 10^{18} \text{ cm}^{-3}$. Ex. 1028, ¶ 73.

Dr. Holman could not harmonize this disclosure—from Marvin's conclusion—with his obviousness opinions during his deposition. When asked to admit that Marvin teaches that at least under one set of circumstances, $5 \times 10^{18} \text{ cm}^{-3}$ is the preferred doping concentration, Dr. Holman initially alleged to not know of any such disclosure. Ex. 2037, 32:10-14. Finally, Dr. Holman said, "I'd probably like to spend a little bit more time with Marvin." Ex. 2037, 39:19-20. That is not satisfying. Marvin is a key reference in Petitioner's obviousness combination, and Dr. Holman alleges to have read Marvin in its entirety multiple times. Ex. 2037, 41:3-6. His inability to explain away a key *conclusion* of Marvin that undercuts his theory casts serious doubt on his opinions.

Petitioner latches onto an irrelevant dopant concentration in Marvin. For space applications—where a solar cell does not enjoy the protection of the Earth's atmosphere and is subjected to increased radiation—Marvin predicts that 1×10^{17} to $1 \times 10^{18} \text{ cm}^{-3}$ will maximize end-of-life performance. Ex. 1008 at p. 25. Dr. Holman relies on a passage of Marvin that discusses that same range. In particular, Marvin observed that under a particular set of conditions "[t]he FSF effectiveness is relative constant over a rather broad range around $1\text{E}17$ to $1\text{E}18 \text{ cm}^{-3}$." Ex. 1008 at p. 15. Putting aside the passage's silence as to whether that observation was made in a terrestrial or space environment, that passage is specific to a certain geometry that is not the same geometry that Marvin found "near-optimal" for

terrestrial applications. In particular, the passage on page 15 begins, “The effects of FSF thickness and doping level were studied for the base-line cell geometry at BOL.” Ex. 1008 at p. 15. The parameters of the “base-line cell geometry” are set forth in Table 2 (page 10). Among other things, the n^+ thickness is $0.3\text{ }\mu\text{m}$ and the p^+ thickness is $1.0\text{ }\mu\text{m}$. Ex. 1008, p. 10. Those are referred to in Marvin as the minority and majority carrier collection thicknesses, respectively. Ex. 1008 at p. 14. By contrast, the solar cell that Marvin’s various simulations indicate was “near-optimal” for terrestrial applications had minority and majority carrier collection thicknesses of $0.9\text{ }\mu\text{m}$ and $3.0\text{ }\mu\text{m}$, respectively (three times as great as in the base-line cell geometry). Ex. 1008 at p. 25. Thus, a person of ordinary skill in the art would understand that the passage of Marvin on page 15 does not erase the clear disclosure in Marvin’s conclusion that in a terrestrial environment, $5\times 10^{18}\text{ cm}^{-3}$ is near optimal.

b. Marvin’s Simulations Have Limited Relevance

Petitioner’s foregoing errors are compounded by the fact that Marvin’s observations were based on numerical simulations, not experimental results. A person of ordinary skill in the art understands that simulations are not as accurate as experimental results. Ex. 1028, ¶ 76. This is because simulations depend on parameters that must be assumed. The King reference, cited by Petitioner, notes that surface recombination velocity, an important factor in solar cell design, is

“strongly dependent on technological factors, some of which are difficult to control [such as] surface roughness, surface contamination, oxidation temperature, ambient gases during oxidation, and postoxidation annealing.” Ex. 1021 at p. 365. It follows that a device whose properties are “strongly dependent on technological factors, some of which are difficult to control” cannot be simulated with assured reliability. Ex. 1028, ¶ 76. This is especially true since Marvin’s simulations are two-dimensional, which is less realistic than a three-dimensional simulation would be (actual devices are of course three-dimensional). *Id.*

For the foregoing reasons, a person of ordinary skill in the art would understand the limitations of Marvin’s simulations and would not thoughtlessly adopt any of the dopant concentrations set forth in Marvin for other applications (e.g., Choi) without independent analysis.

c. Granek Does Not Teach That a Dopant Concentration of Less Than $2 \times 10^{18} \text{ cm}^{-3}$ Is Preferred

Granek’s experimental results indicate that a dopant concentration greater than $2 \times 10^{18} \text{ cm}^{-3}$ is preferable. For example, in discussing solar cells that Granek actually manufactured and tested, Granek states as follows:

The front side is textured with random pyramids and passivated with a lightly doped ($N_{peak} = 5 \times 10^{18} \text{ cm}^{-3}$) and deeply diffused ($1.4 \text{ }\mu\text{m}$) phosphorous front surface field (FSF). The sheet resistance of the FSF (ρ_{FSF}) equals $148 \text{ }\Omega/\text{sq}$. The *diffusion profile of the FSF was optimized* to achieve an optimum front side passivation quality. The

presence of the phosphorous doped front surface field (FSF) is one of the *key features* of the developed device design.

Ex. 1010 at p. 46 (emphasis added).

Further, in a different section of the thesis, Granek measured efficiencies for various solar cells that had been manufactured. Granek found that the highest efficiency was obtained when a dopant concentration of $3.8 \times 10^{18} \text{ cm}^{-3}$ was used. Specifically, an efficiency of 20.8% was achieved in FSF5:

Table 7-5 I-V-parameters for the best solar cells with different front surface field diffusion profiles. Solar cells with base resistivity of $1 \text{ } \Omega \text{ cm}$ and pitch of $1800 \text{ } \mu\text{m}$ are presented. Results in the table are the designated cell area ($2 \times 2 \text{ cm}^2$) measurements.

Cell no.	FSF Profile	Type	ρ_{sheet} [Ω/sq]	J_{sc} [mA/cm^2]	V_{oc} [mV]	FF [%]	η [%]
BC47-2b	FSF2	erfc	73	34.1	647	81.7	18.0
BC47-6b	FSF3	erfc	96	36.1	657	81.9	19.5
BC47-11b	FSF4	erfc	353	37.8	651	81.1	20.0
BC47-16b	FSF5	Gauss	148	38.1	663	82.3	20.8
BC47-22b	no FSF	-	-	36.4	659	82.0	19.7

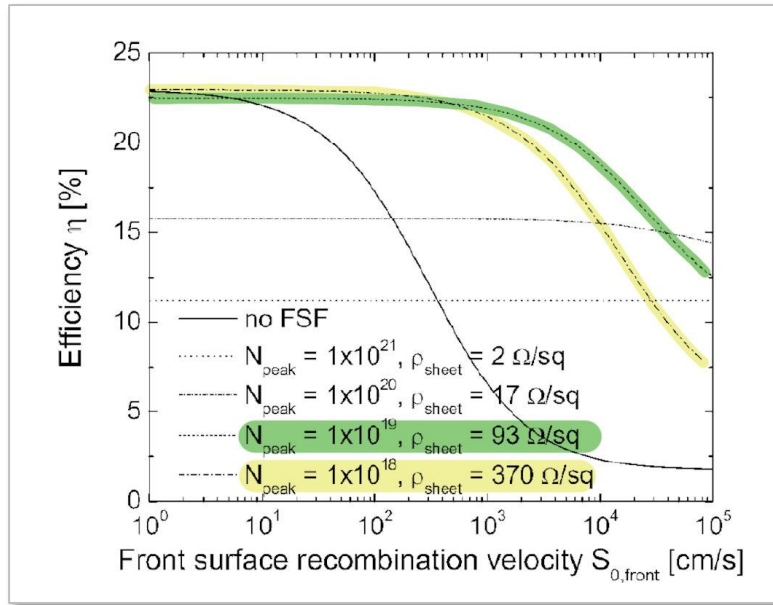
Ex. 1010, Table 7-5 (p. 132) (highlighting added). FSF5 corresponds to a doping concentration of $3.8 \times 10^{18} \text{ cm}^{-3}$, as shown in Table 7-1:

Table 7-1 Parameters of the analyzed phosphorus doped front surface field diffusion profiles.

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

Ex. 1010, Table 7-1 (p. 126) (highlighting added).

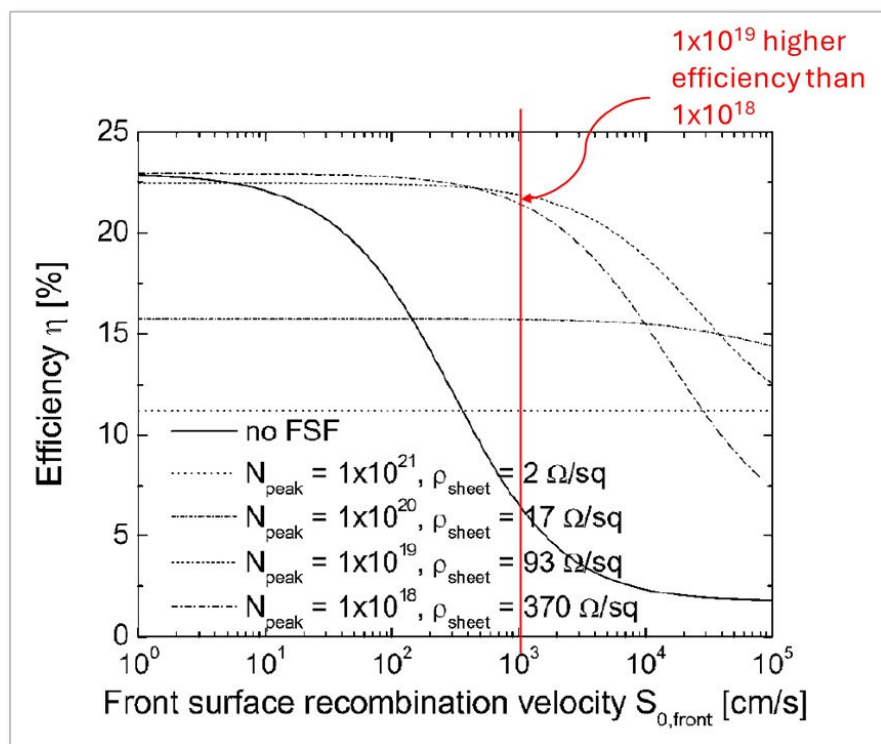
Petitioner errs in placing more emphasis on its misinterpretation of certain simulation results over the foregoing experimental results. *First*, Petitioner misinterprets Figure 7-1 of Granek as showing that a dopant concentration of $1 \times 10^{18} \text{ cm}^{-3}$ yields a higher efficiency than, for example, $1 \times 10^{19} \text{ cm}^{-3}$. Petition at 29, 50. However, that same figure (reproduced below) shows that Granek's simulations indicate that a higher efficiency is expected for a dopant concentration of $1 \times 10^{19} \text{ cm}^{-3}$ (green) than for a dopant concentration of $1 \times 10^{18} \text{ cm}^{-3}$ (yellow) for front surface recombination velocities greater than approximately 500 cm/s.



Ex. 1010, Fig. 7-1 (p. 121) (highlighting added); *see also* Ex. 2028, ¶ 82; Ex. 2037, 52:10-53:8.

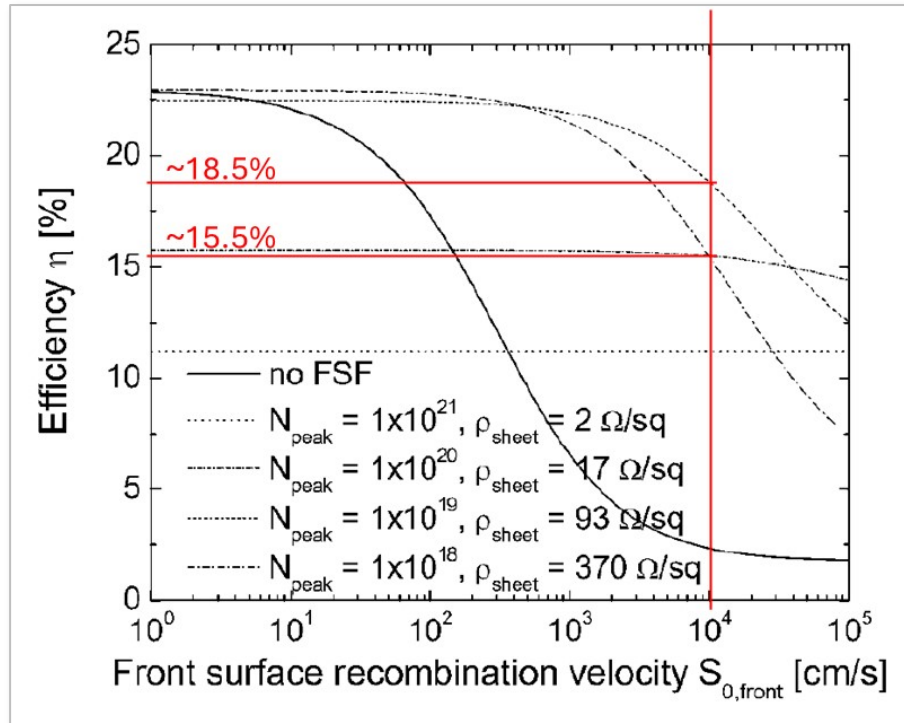
Notably, the point at which the curves for $1 \times 10^{19} \text{ cm}^{-3}$ and $1 \times 10^{18} \text{ cm}^{-3}$ cross (at approximately 500 cm/s) is lower than a typical front surface recombination velocity in solar cells. In investigating high-efficiency solar cells, Korte (Ex. 2035) used a recombination velocity of 1,000 cm/s in its simulations because that value is “a typical value for an oxide-covered c-Si surface,” i.e., a crystalline silicon substrate. Ex. 2035 at p. 6397. Marvin also assumes a front surface recombination velocity of 1,000 cm/s. Ex. 1008 at p. 10 (“Front surface recombination velocity” is “1E3 cm/s”). Granek’s Figure 7-1 simulation reveals that at a recombination velocity of 1,000 cm/s a dopant concentration of 1×10^{19}

cm^{-3} yields a higher efficiency than $1 \times 10^{18} \text{ cm}^{-3}$. This is shown in the annotated figure below.



Ex. 1010 Granek at Fig. 7-1 (p. 121) (annotated); *see also* Ex. 2028, ¶ 88.

The superiority of a dopant concentration of $1 \times 10^{19} \text{ cm}^{-3}$ over $1 \times 10^{18} \text{ cm}^{-3}$ is even more pronounced at higher front surface recombination velocities. For example, at a recombination velocity of 10^4 (10,000) cm/s, the simulated efficiencies for $1 \times 10^{19} \text{ cm}^{-3}$ and $1 \times 10^{18} \text{ cm}^{-3}$ are approximately 18.5% and approximately 15.5%, respectively.



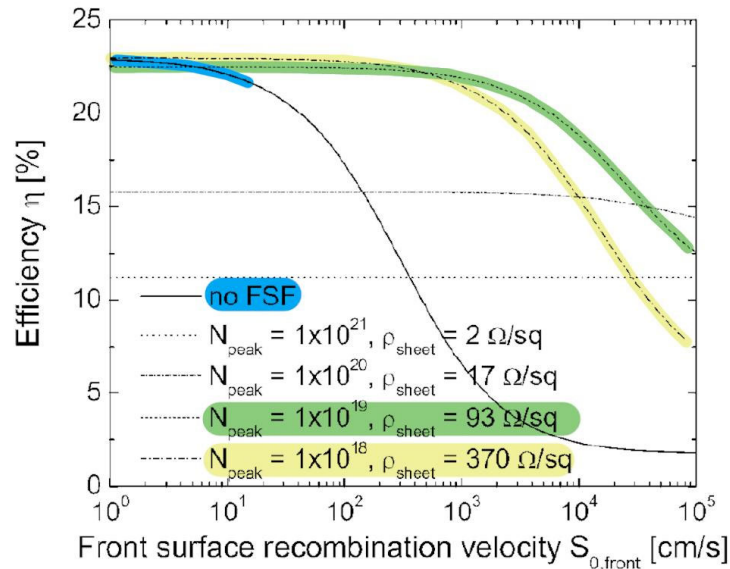
Ex. 1010 (Granek) at Fig. 7-1 (p. 121) (annotated).

This difference (approximately 3%) is roughly one-fifth of the efficiency at $1 \times 10^{18} \text{ cm}^{-3}$. A person of ordinary skill in the art would deem that as significant.

Ex. 2028, ¶ 84. By contrast, the difference in the simulated efficiencies at low front surface recombination velocities is negligible. *Id.* In fact, the separation between the two curves is likely smaller than the unavoidable uncertainties associated with Granek's simulation. *Id.*

Further, a person of ordinary skill in the art would be skeptical of Figure 7-1 of Granek, especially the portion at low front surface recombination velocities. Figure 7-1 suggests that at low front surface recombination velocities, a solar cell

without a front surface field (blue) would have an efficiency similar to those with doping concentrations of $1 \times 10^{18} \text{ cm}^{-3}$ (yellow) or $1 \times 10^{19} \text{ cm}^{-3}$ (green).



Ex. 1010, Fig. 7-1 (p. 121) (highlighting added).

However, a person of ordinary skill in the art would understand that Granek's suggestion that good results could be obtained without an FSF layer is contrary to well-accepted experimental results that have firmly established the usefulness of an FSF layer. Ex. 2028, ¶ 85. Thus, a person of ordinary skill in the art would recognize that at least the left-hand region of Figure 7-1 (with low surface recombination velocities) has limited (if any) relevance. *Id.*

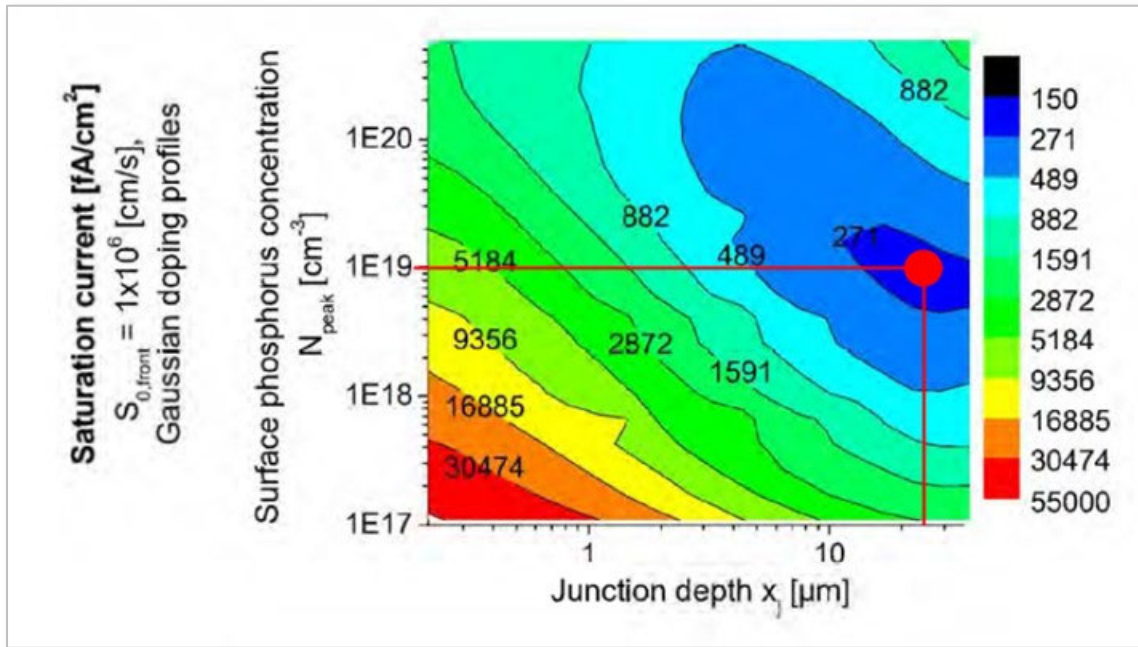
Trying to achieve the very low surface recombination velocities would be a difficult endeavor. Surface recombination velocity “is strongly dependent on technological factors, some of which are difficult to control.” Ex. 1021 (King) at

p. 365.”³ Generally, efforts to control those variables to reduce surface recombination velocity (e.g., reduce surface roughness, reduce surface contamination, etc.) involve additional cost. Ex. 2028, ¶ 87. A person of ordinary skill in the art would not expend the cost necessary to attempt to achieve very low front surface recombination velocities. They would understand that any potential increases in efficiency in doing so were likely illusory and would be marginal in any event. Ex. 2028, ¶ 87. Still further, a person of ordinary skill in the art would understand that they would not be limited to the few concentrations simulated in this figure. Ex. 2028, ¶ 80; Ex. 2037, 65:10-14.

Petitioner's reliance on Figure 7-3 of Granek is misplaced. First, Petitioner cropped the figure so as to exclude its top half. *Compare* Petition at 30 (reproducing bottom half only of Figure 7-3) *with* Ex. 1010 at Fig. 7-3 (p. 122). The half that Petitioner cropped is problematic for its theory. That portion of the figure shows that according to Granek's simulations the lowest saturation current, when surface recombination velocities are 1×10^6 cm/s, is expected with a dopant

³ Dr. Holman expressed disagreement with that quotation from King. Ex. 2037 at 53:19-54:1. However, Dr. Holman acknowledges that the factors that King mentions can impact surface recombination velocity. Ex. 2037 at 54:13-57:5.

concentration of approximately $1 \times 10^{19} \text{ cm}^{-3}$ and a junction depth of approximately 25 μm .



Ex. 1010 (Granek) Fig. 7-3 (partial, annotated); *see also* Ex. 2028, ¶ 95.

On the other hand, the lower half of Figure 7-3 assumes a front surface recombination velocity proposed by Cuevas. Ex. 1010 (Granek) at p. 122 (caption of Fig. 7-3); *see also id.* at 42 (showing recombination velocity as function of dopant concentration according to parameterization of Cuevas). However, Petitioner fails to show that Cuevas's parameterization would apply to Choi. Further, Cuevas notes that the parameterization is subject to "several sources of uncertainty." Ex. 2036 at p. 3. Cuevas identifies those sources of uncertainty as follows: "This includes not only the error in the measurements of J_s and the dopant profile but also the assumed energy bandgap narrowing and minority carrier

lifetime, especially for the deeply diffused samples.” *Id.* Choi does not suggest (much less disclose) that the conditions that would lead to Cuevas’s parametrization, e.g., that contamination is negligible, are present. *See Hynix Semiconductor Inc. v. Rambus Inc.*, 645 F.3d 1336, 1353 (Fed. Cir. 2011) (affirming non-obviousness where a combination was expected to increase cost); *see also Mianyang Boe Optoelectronics Tech. Co., Ltd. v. Samsung Display Co., Ltd.*, 2025 WL 33657, at *45 (PTAB Jan. 6, 2025) (rejecting obviousness argument where “Petitioner has not even attempted to balance the alleged benefits of [secondary reference]’s teachings with the disadvantages of reducing aperture ratio in [primary reference], which is an explicit concern of [primary reference].”).

d. Granek’s Simulations Have Limited Relevance

A person of ordinary skill in the art would understand that Granek’s simulations are subject to the same limitations as those of Marvin. In particular, due to the difficulty to control relevant parameters (e.g., surface roughness, surface contamination, etc.), simulations often do not reflect real-world behavior. Ex. 2028, ¶ 81. Further, Granek employs one-dimensional simulations, which are even less reliable than two-dimensional or three-dimensional simulations would be. *Id.* A person of ordinary skill in the art, therefore, would place greater weight on Granek’s experimental results than they would on Granek’s simulations. Ex. 2028, ¶ 79.

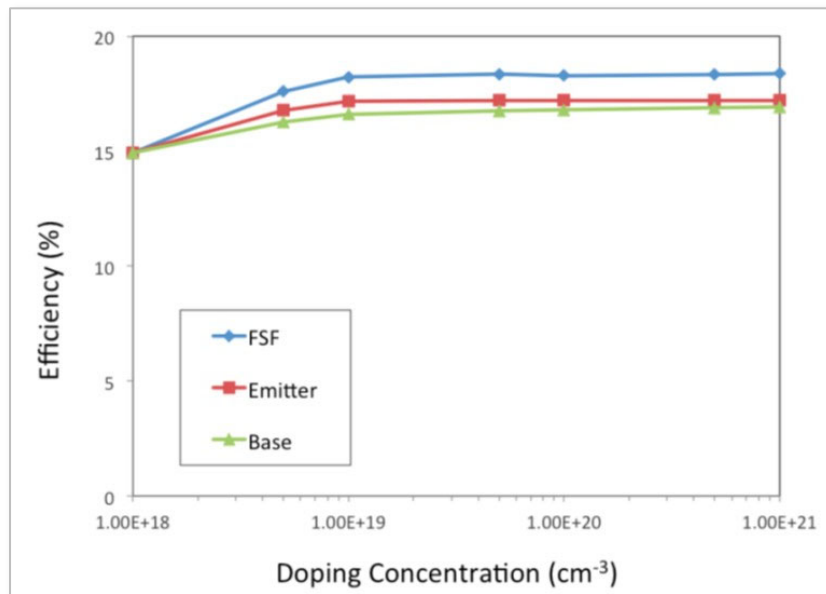
e. There Is No Optimal Doping Concentration

A salient point that emerges from the various references in this proceeding—with differing doping concentration (sometimes within the same reference)—is that there is no singular optimum doping concentration. Rather, the appropriate dopant concentration depends on design parameters. Ex. 2028, ¶ 92; Ex. 2037, 32:1-6. Thus, for example, Marvin concluded that a specific geometry and a dopant concentration of $5 \times 10^{18} \text{ cm}^{-3}$ yielded near optimal results in a terrestrial environment. Ex. 1008 at p. 25. That same reference, however, found that a different design and different dopant concentration was appropriate in a space environment. *Id.*

Indeed, other references reflect that doping concentrations above $2 \times 10^{18} \text{ cm}^{-3}$ are preferred in certain circumstances.⁴ For example, the Lamers publication reflects the efforts of researchers that sought “to increase cell efficiencies and decrease production costs.” Ex. 2002, p. 1. The researchers discovered that the optimum dopant concentration for their solution was $3 \times 10^{18} \text{ cm}^{-3}$. *Id.*, p. 2 (“[T]he

⁴ The exhibits referenced here, Exs. 2002, 2003, and 2005 were publicly available as of the date of invention as shown by the Declaration of Dr. Mary K. Bolin. *See generally* Ex. 2039.

optimal doping level was found to be 3.10^{18} atoms/cm².”)⁵ The Desa publication likewise reflects the efforts of researchers that sought to maximize solar cell efficiency soon before the invention of the '315 patent. Ex. 2003, p. 69. They found that a concentration of 1×10^{19} cm⁻³ was superior to lower concentrations, i.e., those in the claimed range:



Id., Fig. 5(c); *see also id.*, 71 (“[A]chieving good FSF doping is essential for superior performance of the IBC solar cell.”).

⁵ Lamers includes a typographical error as “cm²” should be “cm³.” Dr. Holman agrees that a person of ordinary skill in the art would have readily recognized the error. Ex. 2037, 144:16-145:4.

Still further, Procel found that, in one design, the “optimum value[] of peak doping” of a front surface field was $3.47 \times 10^{18} \text{ cm}^{-3}$, which yielded an efficiency of more than 22%. Ex. 2005, p. 132; *see also id.*, p. 131 Fig. 4(a).

Dr. Holman attempted to dismiss the above disclosures from Lamers, Desa, and Procel, but his arguments are unavailing. With respect to Lamers, Dr. Holman argued that, under the conditions of Choi, Lamers's disclosure of a “lightly doped and shallow front surface field” applies. Ex. 2037, 146:11-21. Dr. Holman appears to believe that a “lightly doped” front surface field will have a dopant concentration less than Lamers's recommendation of $3 \times 10^{18} \text{ cm}^{-3}$. That is wrong. Indeed, Granek states that $5 \times 10^{18} \text{ cm}^{-3}$ is “lightly doped.” Ex. 1010 at p. 46 (“The front side is textured with random pyramids and passivated with a *light doped* ($N_{peak} = 5 \times 10^{18} \text{ cm}^{-3}$) and deeply diffused (1.4 μm) phosphorous front surface field (FSF).”).

With respect to Desa, Dr. Holman argued that the reference does not actually disclose a front surface field because the substrate of Desa is a p-type and the dopants are n-type. Ex. 2037, 147:20-149:12. However, Desa itself considers the n-type doped region a “front surface field.” For example, on page 70, Desa states, “The solar cell parameters used for simulation have been listed in Table 1.” Ex. 2003 at p. 70. That table indicates that notwithstanding the wafer being p-type the “Front Surface Field” uses phosphorous (an n-type) dopant. Ex. 2003 at p. 80.

Desa also uses “front surface field” throughout. Ex. 2003 at pp. 70, 71. Dr.

Holman also suggests that the Figure 5(c) reflects “garbage” modelling results because he doubts the accuracy of the efficiency values at the $1 \times 10^{21} \text{ cm}^{-3}$ doping concentrations. Ex. 2037, 149:13-150:3. However, Dr. Holman did not provide any reason to doubt the efficiency value at $1 \times 10^{19} \text{ cm}^{-3}$. Ex. 2037, 150:7-14.

With respect to Procel (Ex. 2005), Dr. Holman had no direct complaints. Instead, he noted that in a near contemporaneous paper, the authors of the Procel paper published another paper in which they used a doping concentration of $1 \times 10^{18} \text{ cm}^{-3}$. Ex. 2037, 152:20-153:22. However, in the paper that Dr. Holman referenced (Ex. 1040), the authors “performed a study of rear side geometry.” Ex. 1040 at p. 15 (Abstract). The aim of their work was “to improve the physical understanding of the impact of different rear geometries on the performance of BC-BJ solar cells by a systematic simulation analysis.” *Id.* For such purposes, the authors used a doping concentration of $1 \times 10^{18} \text{ cm}^{-3}$ for the front surface field for all such simulations. *Id.* Thus, the aim of Ex. 1040 was not to find optimal front surface field doping concentrations as it was in Ex. 2005. Ex. 1040 thus does not cast doubt on the pertinent results of Ex. 2005.

Petitioner appears not to appreciate that dopant concentration is a context dependent design consideration. Instead, the grounds are premised on the notion that a person of ordinary skill in the art would thoughtlessly plug a dopant

concentration that was examined in a secondary reference (Marvin or Granek) into Choi. Petitioner does not even attempt to show, however, that the other design parameters of Choi would lead a person of ordinary skill in the art to that doping concentration. This is fatal to Petitioner's theories.

5. *It Would Not Have Been Obvious to Use a p-Type Dopant (For Example Boron) in Choi with All Other Claim Limitations (Claims 13 and 14)*

Petitioner's cursory treatment of claims 13 and 14 betrays a faulty approach. Petitioner's arguments for both of these claims extend less than a full page. Its brief argument is that because Choi discloses that its front surface field layer 120 may be boron, the limitations of claims 13 and 14 are satisfied. Petition at 57-58. However, Petitioner does not address the impact that such a design choice would have on the remaining elements of the claims, in particular the dopant concentration limitation of claim 10.

In addressing claim 10, Petitioner heavily relies on Granek's simulations in which phosphorus (an n-type dopant) was modeled. *See, e.g.*, Ex. 1010 at Fig. 7-1 (p. 121), Fig. 7-3 (p. 122), Fig. 7-4 (p. 123). Petitioner incorporated that reliance forward to claims 13 and 14. Petition at 57 ("Petitioner incorporates Section X.A.2."). That was error.

Petitioner fails to account for the fact that different dopant types will result in different behavior. A person of ordinary skill in the art would understand that

simulations or empirical results for an n-type dopant would not necessarily inform the appropriate doping levels of a p-type dopant. Ex. 2028, ¶ 103; *see also* Ex. 2037, 57:6-22, 132:10-133:7. Indeed, Granek itself reveals this. Figure 3-6 of Granek purports to depict relationships between dopant concentration and surface recombination velocity for each of phosphorous (n-type) and boron (p-type). Ex. 1010 at p. 42. Taking just two examples, the surface recombination velocity at a dopant concentration of 10^{18} cm^{-3} is approximately 70 cm/s for phosphorous and over 2,000 cm/s for boron. At a concentration of 10^{21} cm^{-3} , the surface recombination velocity for phosphorous is approximately 100,000 cm/s and for boron is approximately 22,000 cm/s. These different behaviors would have a direct impact on device performance and a proper analysis as to what the dopant concentration should be would consider what type of dopant is used. *See also* Ex. 2037 at 71:20-72:20 (Dr. Holman admitting he had not done simulations to reveal whether substituting boron for phosphorus would have yielded similar results).

An additional error in Petitioner's analysis is the failure to account for the drawbacks in moving from an n-type substrate to a p-type substrate. Granek sets forth numerous benefits of an n-type substrate. Ex. 1010 at 48-49. Dr. Holman agrees those benefits are accurate. Ex. 2037, 79:11-21. Petitioner does not explain why a person of ordinary skill in the art, after consulting Granek would choose a p-type wafer over an n-type wafer in view of the disadvantages that would attend that

change. In evaluating a proposed modification, “the benefits, ***both lost and gained***, should be weighed against one another.” *Henny Penny Corp. v. Frymaster LLC*, 938 F.3d 1324, 1332 (Fed. Cir. 2019) (emphasis in original); *see also Winner Int’l Royalty Corp. v. Wang*, 202 F.3d 1340, 1349 (Fed. Cir. 2000) (“Trade-offs often concern what is feasible, not what is, on balance, desirable. Motivation to combine requires the latter.”).

6. *Petitioner Fails to Show That Choi Discloses “a second emitter region having metal impurities” (Claim 16)*

Choi does not disclose a second emitter region having metal impurities for reasons similar to those presented above with respect to the “first emitter region” limitation of claim 10. Petitioner argues that Choi’s first conductive type area 32 corresponds with this limitation. Petition at 59. Petitioner further suggests (but stops short of embracing the argument) that certain dopants used in Choi qualify as “metal impurities.” *Id.* However, under the proper construction of “metal impurities,” that is incorrect. The dopants in Choi are purposefully added and are not undesired foreign metals.

7. *It Would Not Have Been Obvious to Achieve a “second emitter region having metal impurities” by Employing Istratov’s Gettering in Choi (Claim 16)*

Petitioner’s proposed Choi-Istratov combination for the “second emitter region having metal impurities” limitation suffers from the same shortcomings as discussed above in connection with the “first emitter region having metal

impurities” limitation of claim 10. Indeed, Petitioner incorporates the same discussion it provides for the “first emitter region” limitation in addressing the “second emitter region” limitation. Petition at 59 (citing Section X.A.2.iv of Petition).

B. Ground II

Ground II fails because it depends on Ground I establishing the unpatentability of claims 16 and 10. Ground II addresses only claim 18, which depends from claim 16, which depends from claim 10. Petitioner incorporates its Ground I arguments made with respect to claims 10 and 16 in Ground II. Petition at 66. Because those arguments are unavailing for the reasons set forth above, Ground II likewise fails.

C. Ground III

1. It Would Not Have Been Obvious to Achieve a “first emitter region having metal impurities” by Employing Istratov’s Gettering in Cousins (Claim 10)

Petitioner’s Cousins-Istratov combination fails for the same reasons its Choi-Istratov combination fails. Indeed, Petitioner incorporates its Choi-Istratov arguments in advancing its Cousins-Istratov arguments. Specifically, Petitioner states that “[a] POSITA would have also been motivated to add Istratov’s gettering process to the Cousins-Granek or Cousins-Marvin cell to trap impurities in the emitter and thus reduce recombination for the same reasons explained in

§X.A.1.ii.” Petition at 70. The section referenced pertains to Petitioner’s Ground I (Choi-Istratov) arguments. Accordingly, it would not have been obvious to arrive at the proposed Cousins-Istratov combination for the same reasons. *First*, Cousins does not disclose that its substrate has metal impurities, much less to such a level as to require gettering. Indeed, the evidence suggests that Cousins’s substrate would *not* include high levels of impurities. Neuhaus (Ex. 1084) states that “the IBC [Interdigitated Back Contact] solar cell design requires extraordinarily high lifetime silicon starting material” and “SunPower is using wafers with lifetimes greater than 1 millisecond and a thickness of 200 μm .” Ex. 1084 at 11. SunPower is identified as the assignee of Cousins. Ex. 1007 at Field (73) (Assignee: SunPower Corporation). Thus, not only is Cousins silent regarding any impurities in its substrate 101, but that substrate could have used “extraordinarily high lifetime silicon starting material.” Such material would have had relatively low impurities. Ex. 2028, ¶ 111. *Second*, Istratov is not analogous art for the same reasons presented above with respect to Choi. *Third*, Istratov’s process would be detrimental to Cousins’s device just as it would have been to Choi’s device.

2. *Petitioner Fails to Show That It Would Have Been Obvious to Implement Cousins with the Claimed Dopant Concentration (Claim 10)*

It would not have been obvious to use a dopant concentration of less than $2 \times 10^{18} \text{ cm}^{-3}$ in Cousins. Petitioner incorporates its Ground I arguments in Ground

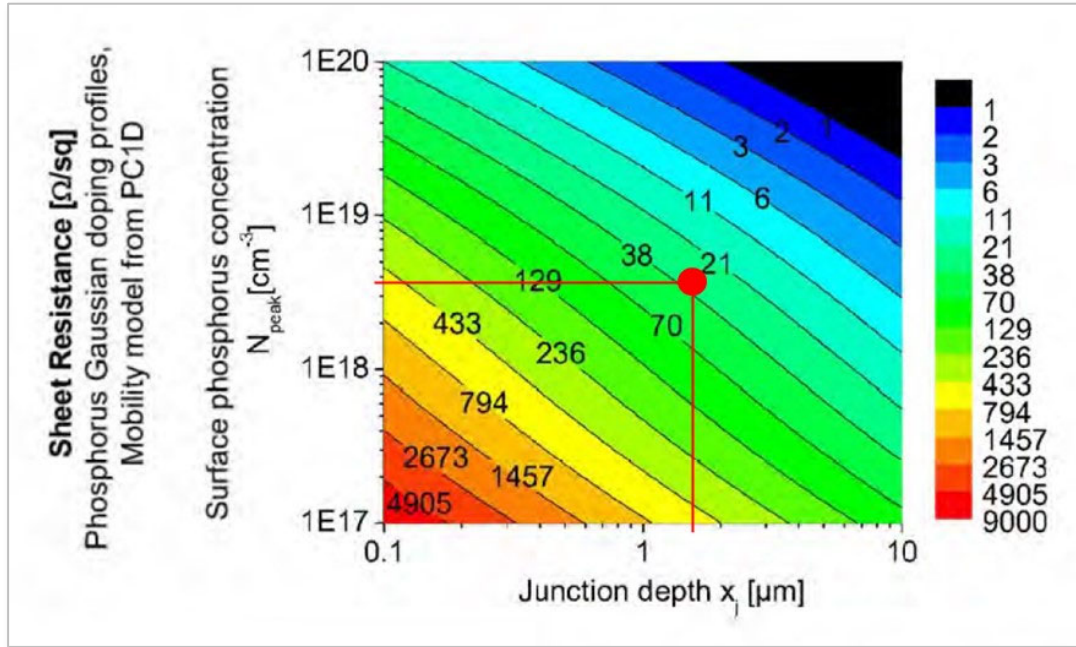
III. Petition at 68. Those arguments are faulty for the reasons set forth above.

First, Petitioner misreads Marvin, which discloses a near optimal doping concentration of $5 \times 10^{18} \text{ cm}^{-3}$ for terrestrial applications. *Second*, Granek's empirical results reveal that a dopant concentration greater than $2 \times 10^{18} \text{ cm}^{-3}$ yields the best benefits. *Third*, Granek's simulations are not to the contrary and instead show that $1 \times 10^{19} \text{ cm}^{-3}$ yields higher efficiencies than $1 \times 10^{18} \text{ cm}^{-3}$ over a broad range of surface recombination velocities. *Fourth*, the numerical simulations of Marvin and Granek are less informative than empirical results, which undercut Petitioner's arguments. *Fifth*, the optimal dopant concentration depends on design parameters and Petitioner fails to show that such parameters in Cousins would lead to a choice to use a dopant concentration less than $2 \times 10^{18} \text{ cm}^{-3}$.

Petitioner makes one unique argument with respect to Cousins and the claimed dopant concentration. Specifically, Petitioner argues that Figure 7-4 of Granek shows that Cousins's sheet resistance of 100 to 500 Ω/sq is "compatible with" or "consistent with" a dopant concentration in the claimed range. Petition at 68-69. Petitioner's arguments are flawed.

Granek itself reveals the imprecision of the simulations of Figure 7-4. For example, Table 7-1 of Granek (page 126) indicates that a sample with a Gaussian doping profile having a concentration of $3.8 \times 10^{18} \text{ cm}^{-3}$ and a junction depth of 1.44

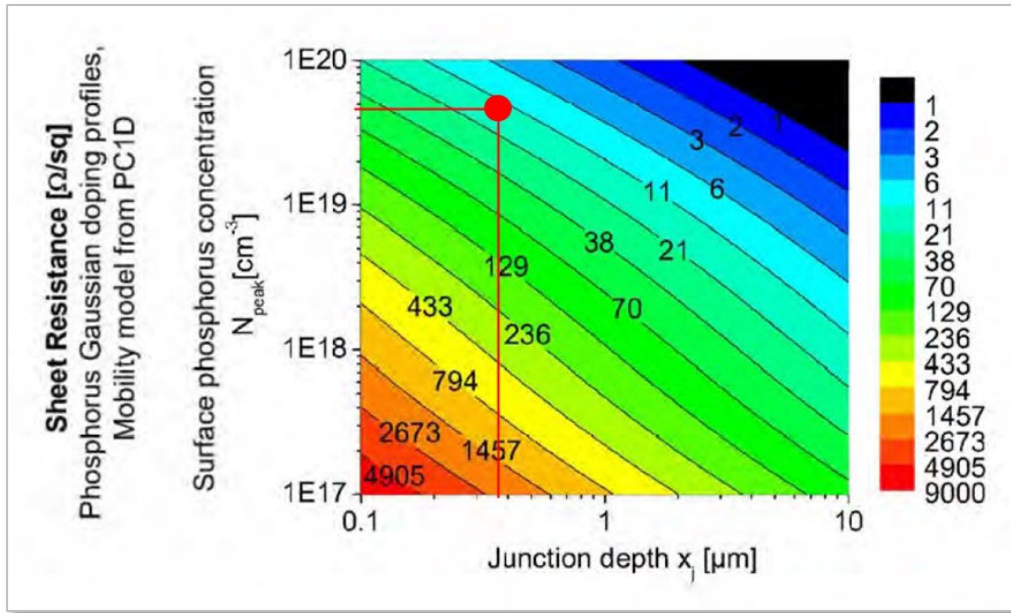
μm yielded a sheet resistance of $148 \Omega/\text{sq}$. Ex. 1010 at p. 126. However, Figure 7-4 predicts a sheet resistance under those conditions of less than $38 \Omega/\text{sq}$.



Ex. 1010 at Fig. 7-4 (annotated); *see also* Ex. 2028, ¶ 113.

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

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



Ex. 1010 (Granek) at Fig. 7-4 (annotated); *see also* Ex. 2028, ¶ 115.

However, the actual sheet resistance was measured as 353 Ω/sq. Ex. 1010 at p. 126.⁶ These discrepancies would seem to cause one to view the Figure 7-4 simulation results as—what Dr. Holman calls—“garbage.” Ex. 2037, 150:1. According to Dr. Holman, “[t]ypically when a model is wrong at some values, you don’t necessarily look to it for guidance as to other values.” *Id.*, 150:12-14. Dr. Holman does not explain why he is willing to make an exception in the case of Granek’s Figure 7-4.

⁶ In this regard, Dr. Holman is incorrect in suggesting that the teachings of Figure 7-4 of Granek (which are imprecise simulations even when a Gaussian profile is assumed) are “still relevant” when an error function profile is used. *See* Ex. 2037 at 140:12.

Indeed, the data from Granek discussed above reveal that dopant concentrations of 3.8×10^{18} and $4.5 \times 10^{19} \text{ cm}^{-3}$ are “consistent with” Cousins’s sheet resistance. Those concentrations are associated with sheet resistances of 148 and 353 Ω/sq , respectively. Ex. 1010 at Table 7-1 (p. 126). Both are within the range of 100 to 500 Ω/sq provided by Cousins. Ex. 1007 at 2:54-55.

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

Petitioner theory for claims 13 and 14 under Ground III is even more problematic than its theory under Ground I. As with Ground I, Petitioner fails to account for the differences that would attend a change from using phosphorous (an n-type dopant) as the dopant (as Granek models) to using a p-type dopant. Additionally, Petitioner fails to address how losing the benefits of an n-type substrate would be compensated.

Further, Ground III is based on the erroneous premise that “p-type wafers were more common and cheaper than n-type wafers.” Petition at 77. Granek says otherwise. Granek states that “[p]hosphorus doped n-type silicon has received increased interest in the PV [photovoltaic] research community in recent years, due to *shortage of the p-type silicon feedstock* and due to its high minority carrier lifetime.” Ex. 1010 at 48 (emphasis added). Dr. Schubert and Dr. Holman agree that is accurate. Ex. 2028, ¶ 118; Ex. 2037 at 77:21-78:1.

VI. CONCLUSION

For the foregoing reasons, the Board should confirm the patentability of the challenged claims.

Respectfully submitted,

Date: May 22, 2025

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CERTIFICATE OF WORD COUNT

Pursuant to 37 C.F.R. § 42.24(d), the undersigned certifies that this Patent Owner Response, exclusive of the table of contents, table of authorities, certificate of service, certificate of word count, and list of exhibits, includes 10,450 words.

Pursuant to 37 C.F.R. § 42.24(d), Patent Owner has relied on the word count feature of the word-processing system used to prepare this paper.

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CERTIFICATE OF SERVICE

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