



Patent Owner's Demonstratives

Hanwha Solutions Corp. v. Maxeon Solar Pte. Ltd.

IPR2024-01198

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

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Maxeon's Exhibit 2041

Petitioner Failed to Present a Live Argument



To the extent Patent Owner argues that the claimed invention includes any metal or any source of metal, Choi also teaches a first emitter region “having metal impurities.” Choi teaches a semiconductor substrate 10 “containing a first

Petition, p. 54



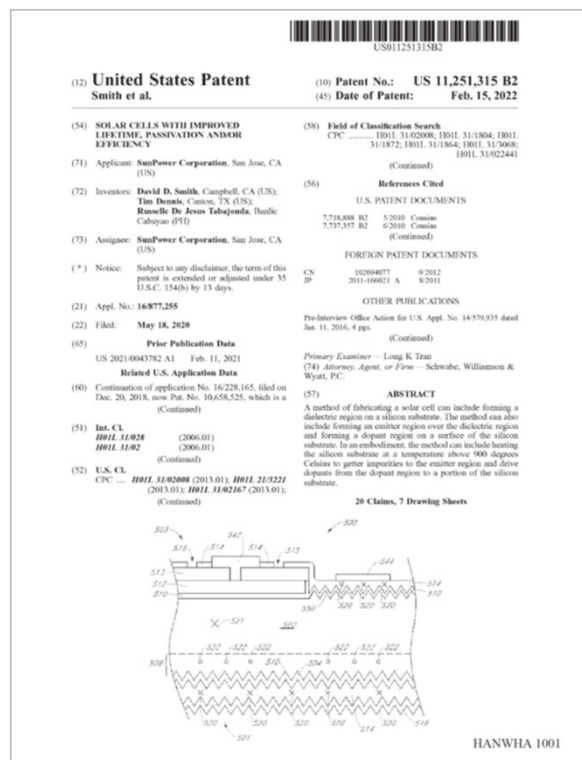
To the extent Patent Owner contends that the claimed “metal impurities” must be elements other than Group III or V elements, Choi in combination with Istratov teaches and renders obvious a first emitter having metal impurities. As discussed

Petition, p. 55

Claim Construction



“metal impurities”



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

a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and wherein the portion of the silicon substrate is formed at the front side of the solar cell;

a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar;

a first emitter region having metal impurities formed over the dielectric region; and

a first metal contact formed over the first emitter region.

16. The solar cell of claim 10, further comprising:

a second emitter region having metal impurities formed over the dielectric region; and

a second metal contact formed over the second emitter region.

'315 Patent, claims 10, 16

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

“metal impurities” – Proposed Constructions

maxeon

“metal impurities” → “undesired foreign metals”

POR, p. 12

 Hanwha Solutions

“metal impurities” → plain and ordinary meaning, i.e.,
“any element that is foreign to the element(s) of the host material, including intentionally-introduced dopants”

Pet.’s Reply, p. 2

The Board Should Construe “metal impurities”

“A determination that a claim term ‘needs no construction’ or has the ‘plain and ordinary meaning’ may be inadequate 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., Ltd., 521 F.3d 1351, 1361 (Fed. Cir. 2008)

(cited in POR, p. 12)



Construction of “metal impurities” – Legal Standard

“[A]s we have explained, the ordinary meaning of a claim term is not the meaning of the term in the abstract. Instead, the ordinary meaning of a claim term is its meaning to the ordinary artisan after reading the entire patent.”

AstraZeneca AB v. Mylan Pharms. Inc., 19 F.4th 1325, 1330 (Fed. Cir. 2021)
(internal quotations omitted)
(cited in PO’s Sur-Reply, p. 4)



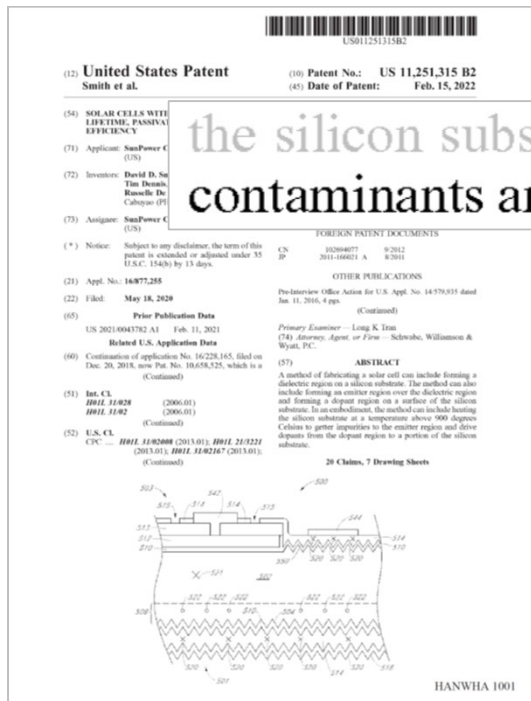
Construction of “metal impurities” – Legal Standard

“[T]he person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification.”

Phillips v. AWH Corp., 415 F.3d 1303, 1313 (Fed. Cir. 2005) (en banc)
(cited in POR, p. 14)



The Specification Support's PO's Proposed Construction



'315 Patent, 5:8-9
(cited in POR, p. 14)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

The Specification Support's PO's Proposed Construction

“We also agree with the district court that the terms ‘releasably’ and ‘detachable’ have the same meaning in the ’798 patent. . . . [T]he evidence indicates that the patentee used the two terms interchangeably.”

Baran v. Medical Device Techs., Inc., 616 F.3d 1309, 1316 (Fed. Cir. 2010)
(cited in PO’s Sur-Reply, pp. 1-2)



The Specification Support's PO's Proposed Construction

"[T]he specification and claims use the words 'emit' and 'transmit' interchangeably. This drafting choice equates the two terms for claim construction purposes."

Wasica Finance GmbH, 853 F.3d 1272, 1282 (Fed. Cir. 2017)
(cited in PO's Sur-Reply, p. 2)

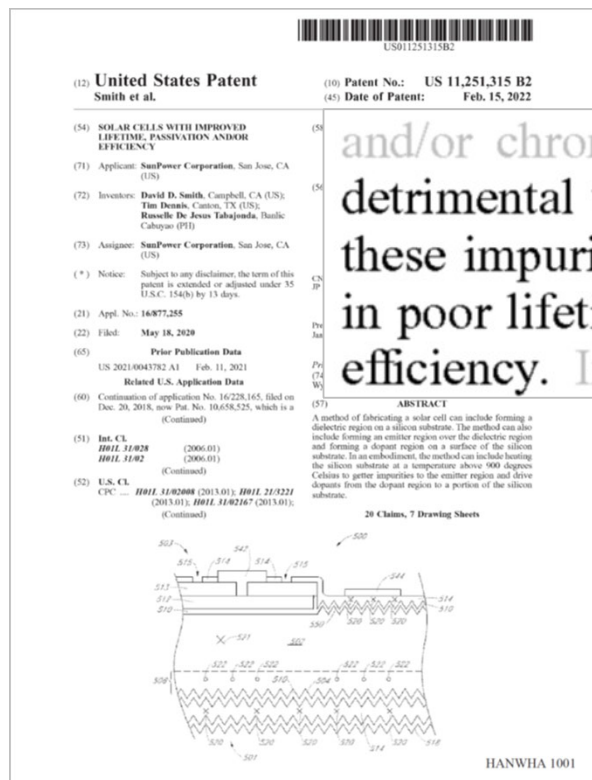


"We agree with Hamilton that the intrinsic evidence indicates that the patentee meant for those two terms to be interchangeable and to carry the same meaning within the claims."

Tehrani v. Hamilton Med., Inc., 331 F.3d 1355, 1361 (Fed. Cir. 2003)
(cited in PO's Sur-Reply, p. 2)



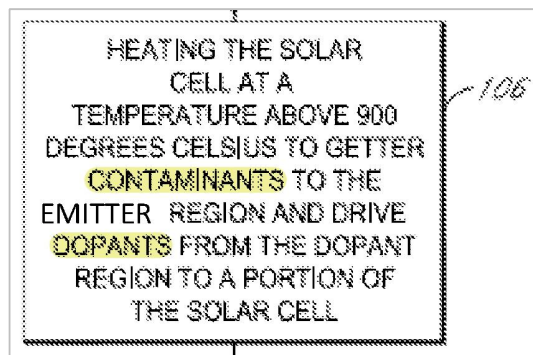
The Specification Support's PO's Proposed Construction



and/or chromium among others. 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. In an embodiment, the impurities 220 can be

'315 Patent, 5:1-5
(cited in POR, p. 15)

'315 Patent, Fig. 1
(partial, annotated)
(cited in POR, p. 16)



DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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Petitioner's "Consistent Use" Argument Is Invalid



Ex.1108-EE-Dictionary, 299; Ex.1109-Wiley-Dictionary, 363-64, and publications in the field consistently use “impurities” to include intentionally introduced dopants.

Pet.'s Reply, pp. 2-3

Petitioner's "Consistent Use" Argument Is Invalid



line. Therefore, the unintentional iron contamination level in wafers is usually higher than that of other metal impurities [2]. The major reasons why transition metals in general,

Slicing and mechanical lapping are, according to [69], very dirty operations, which may badly contaminate wafers with a variety of impurities. Fortunately, the wafers are sliced

since each measurement takes several hours. Thus, a single DLTS measurement may not be representative of the total contamination level of the wafer, if the impurity is nonuniformly distributed. In the latter case, there is a substantial

Ex. 1047, pp. 489, 492, 501
(cited in PO's Sur-Reply, pp. 2-3)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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PV Law

Petitioner's "Consistent Use" Argument Is Invalid

Q Are you aware of any instance in Exhibit 1047 where "impurity" is used to refer to a dopant?

A I'm not, because 1047 is not about dopants. The title of the paper is, Iron contamination in silicon technology, and iron creates a defect in the middle of the bandgap and is therefore not a good dopant in silicon. So the paper would not be talking about dopants; it's about iron.

Ex. 2040 (Holman Depo.), 71:9-18
(cited in PO's Sur-Reply, p. 3)



Petitioner's "Consistent Use" Argument Is Invalid

 **Solar Energy Materials & Solar Cells** 72 (2002) 315–326
www.elsevier.com/locate/solmat

Gettering of impurities in solar silicon

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Abstract

Electrical properties of crystalline silicon are degraded by metallic impurity atoms. Such a degradation requires additional processing steps needed to purify the material. Although the number of steps required to realize solar cells is low compared to integrated circuit devices, the material can be also unadvertently contaminated by metallic impurities. Moreover, during the phosphorus diffusion, as well as by Al–Si alloying are efficient, provided the temperature does not exceed 900°C. Longer treatments (2–4 h) are needed in order to increase the minority carrier diffusion length beyond the wafer thickness. So longer times are necessary to dissolve metallic atom containing precipitates. However, if the major part of the wafer is neatly improved, some regions containing dislocation tangles are poorly modified. In such regions, impurities could be involved in the formation of silicates which cannot be dissolved during the gettering treatment. Nevertheless, external gettering treatments are able to clean efficiently single crystalline and multicrystalline silicon wafers, provided the oxygen concentration and the defect density are not too high and are homogeneously distributed. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Silicon; Impurities; Gettering; Solar cells; Phosphorus; Aluminium

1. Introduction

The output power of silicon solar cells depends on several factors. If the minority carrier diffusion length (L) is in the range of 50 μm , conversion efficiencies η in the range 10–12% can be achieved provided the quality of the PN junction is good (low leakage current) and the series resistance is low. To increase the conversion efficiency

Ex. 1033, p. 316
(cited in PO's Sur-Reply, p. 3)

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PII: S0927-0248(01)00179-9

HANWHA 1033

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

The “Broadened” Definition of “Impurities” Does Not Apply

Doping in III-V Semiconductors

E. Fred Schubert
AT&T Bell Laboratories





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The deliberate doping of semiconductors with impurities required that the usage of the term ‘impurities’ was broadened. Such an extended definition was offered by Shockley (1950):

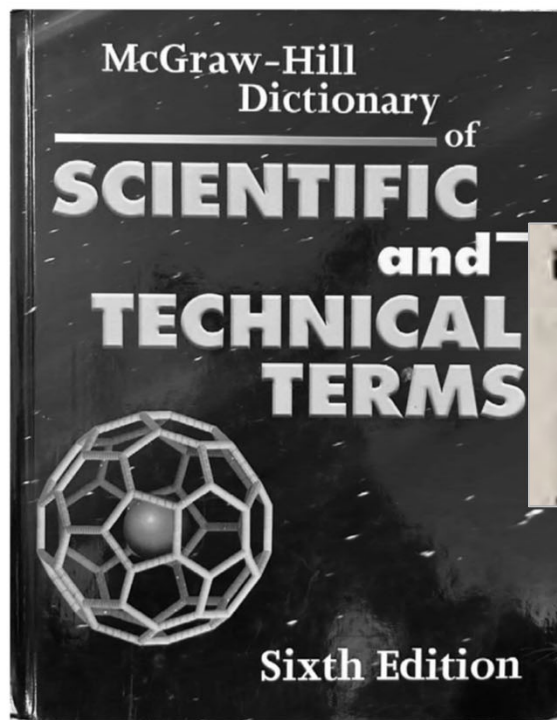
The conductivity arises from the presence of [] atoms which are termed ‘impurities’, even though added to the otherwise pure [] [semiconductor].

The term ‘dopant’ was non-existent in the English language until its introduction in 1963 by Seidman and Marshall (1963), who wrote about crystal growth from the melt:

Ex. 1105, p. 8
(cited in PO’s Sur-Reply, pp. 3-4)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Extrinsic Evidence Supports Patent Owner's Construction



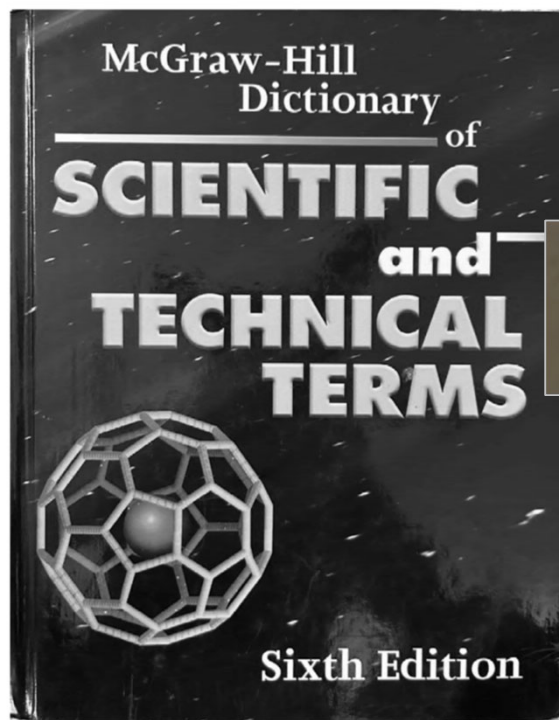
impurity [SCI TECH] An undesirable foreign material in a pure substance. [SOLID STATE] A substance that, when diffused into semiconductor metal in small amounts, either provides free electrons to the metal or accepts electrons from it. { im'pyūr·əd·ē }

Ex. 2030, p. 4
(cited in POR, p. 14)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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Extrinsic Evidence Supports Patent Owner's Construction



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Maxeon Ex. 2030

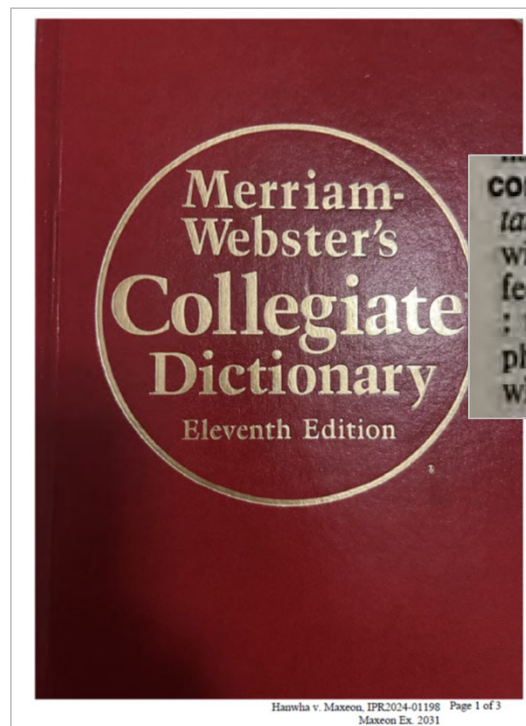
enclosure
contaminate [SCI TECH] To render unfit or to soil by the introduction of foreign or unwanted material. { kən'tam-ə,nāt }
[COMPUT SCI] Placement of data at incorrect

Ex. 2030, p. 3
(cited in POR, p. 17)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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Extrinsic Evidence Supports Patent Owner's Construction



con-tam-i-nate \kən-'ta-mə-,nāt\ *vt* -nat-ed; -nat-ing [ME, fr. L *contaminatus*, pp. of *contaminare*; akin to L *contingere* to have contact with — more at **CONTINGENT**] (15c) **1 a** : to soil, stain, corrupt, or infect by contact or association <bacteria *contaminated* the wound> **b** : to make inferior or impure by admixture <iron *contaminated* with phosphorus> **2** : to make unfit for use by the introduction of unwholesome or undesirable elements — **con-tam-i-na-tive** \-,nā-tiv\

Ex. 2031, p. 3
(cited in POR, p. 17)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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The Prosecution of the '315 Patent's Great-Great-Grandparent Does Not Aid Petitioner



Ex.1036-USPA935FH, 39, 76. The patentee did not respond that Yelundur lacks the claimed “metal impurities” but instead added a new claim limitation to avoid the prior art. Ex.1036-USPA935FH, 98; Ex.1089-Reply-Decl., ¶36.⁴

Pet.’s Reply, p. 7

Ex. 1036, p. 83
(cited in PO’s Sur-Reply, p. 5)

The Applicants have reviewed the Office Action and respectfully disagree with the Examiner’s rejections. An Applicant Initiated Interview Request Form (PTOL-413A) is attached with a proposed interview date of April 11, 2016. We look forward to discussing the rejections with the Examiner during the interview.

Choi and Cousins Do Not Disclose “metal impurities”



Grounds I-III

Choi Does Not Disclose “metal impurities”

maxeon

“metal impurities” → “undesired foreign metals”

POR, p. 12

 Hanwha Solutions

To the extent Patent Owner argues that the claimed invention includes any metal or any source of metal, Choi also teaches a first emitter region “having metal impurities.” Choi teaches a semiconductor substrate 10 “containing a first conductive-type dopant.” Ex.1006-Choi, [0025]. Choi explains that “the first

Petition, p. 54

Cousins Does Not Disclose “metal impurities”



Ex. 1007 (Cousins), 4:23-34. POR, 50. Cousins discloses a solar cell processing step for “cleaning [] the substrate 101 to remove metal contamination” (Ex.1007-Cousins, 4:23-35)—which a POSITA would have understood refers to metal impurities present in the silicon wafers and introduced during solar cell manufacturing. Ex.1089-Reply-Decl., ¶155.

Pet.’s Reply, p. 29

In FIG. 4, an 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), 4:23-34
(cited in PO’s Sur-Reply, pp. 14-15)

The Choi/Cousins-Istratov Combination Is Unavailing



Grounds I-III

Petitioner's Choi/Cousins-Istratov Combination Is Unavailing

On this record, we are not persuaded that Petitioner adequately establishes that a POSITA would have been motivated to combine Choi with Istratov as proposed. Petitioner argues that, “[u]pon identifying detrimental

Institution Decision, p. 21

emitter—thereby reducing recombination.” Pet. 43. Neither Petitioner nor Dr. Holman adequately explain, however, why a POSITA would have been concerned with the levels of metal impurities in the substrate, what level of metal impurities would be “detrimental,” or what detriment the metal impurities would cause. In that regard, Petitioner does not direct us to, nor

Institution Decision, p. 21

Choi/Cousins Did Not Have Significant Metal Impurities

gettered. *Id.* at 489, 514. Gettering was only required in solar cells with significant metal impurity levels in the wafer.

Ex. 1003 (Holman Dec.), ¶ 83
(cited in POR, p. 23)



Choi/Cousins Did Not Have Significant Metal Impurities

Q And you don't argue in your Declaration that the substrate of Choi would necessarily have had iron or copper, do you?

MR. SELWYN: Objection. Form.

A I do not argue that. I indicate that solar wafers at the time were plagued by quality issues, including metal impurities.

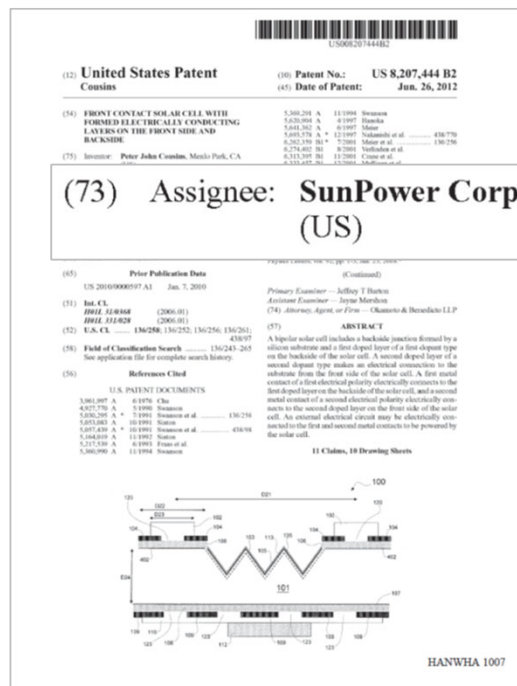
Q And you likewise do not contend in your Declaration that Cousins has a substrate that necessarily includes iron or copper, correct?

A Correct. My answer is the same as before for Choi.

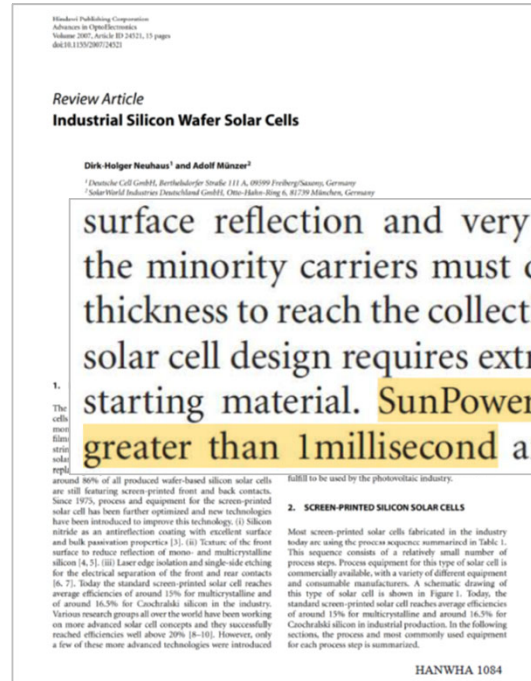


Ex. 2037 (Holman Depo.), 91:21-92:10
(cited in POR, p. 23; PO's Sur-Reply, p. 12)

Choi/Cousins Did Not Have Significant Metal Impurities



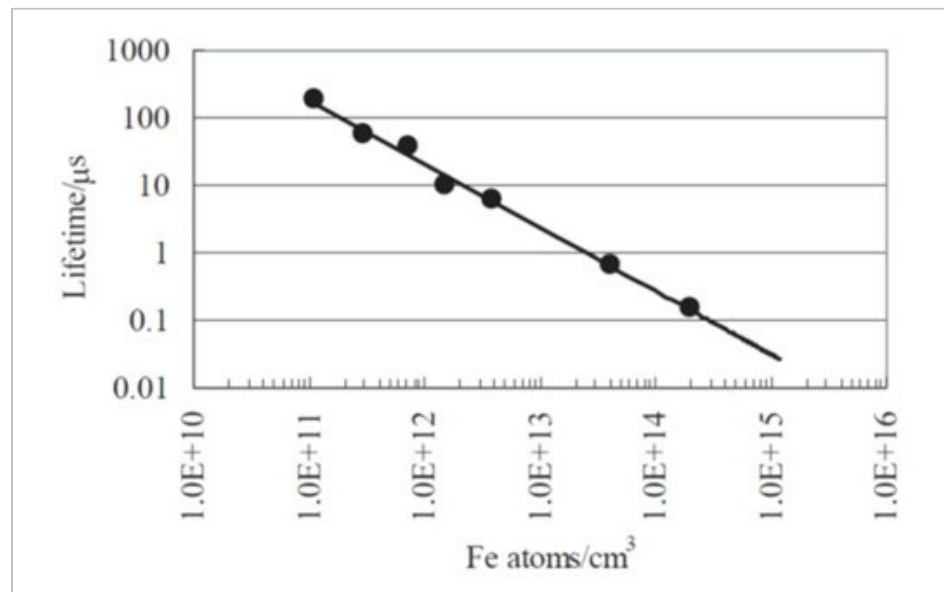
Ex. 1007 (Cousins)
(cited in POR, p. 50)



Ex. 1084, p. 11
(cited in POR, p. 50)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Choi/Cousins Did Not Have Significant Metal Impurities



Ex. 1139, p. 189 (Fig. 7)
(cited in PO's Sur-Reply, p. 11)

Dr. Carroll's Testimony Does Not Aid Petitioner

the semiconductor industry. In order to accommodate that, the silicon solar industry typically uses a lower grade of silicon, and so post processing is necessary in order to make these materials perform better.

You don't have to do that. You can use the higher-quality stuff, but it will cost you more. And



Ex. 1092 (Carroll Depo. in IPR2024-01038), 25:13-18
(cited in Pet.'s Reply, p. 12; PO's Sur-Reply, p. 14)

Dr. Carroll's Testimony Does Not Aid Petitioner

The second thing that you can do is you can interact the material, the impurity, with another impurity or dopant or what have you. What you do in that case is you raise the level -- the energy level of the impurity in the band structure of the substrate. You place it into the conduction band so that it no longer affects the carrier. That too is gettering, because it is effectively gone.



Ex. 1092 (Carroll Depo. in IPR2024-01038), 113:13-20
(cited in PO's Sur-Reply, p. 14)

Dr. Carroll's Testimony Does Not Aid Petitioner



As another example, Exhibit 1092 is cited to show the inconsistency between a past position of Maxeon's expert and Maxeon's current position, not for the substance of Dr. Carroll's testimony about silicon wafer quality. *Compare* Pet. Reply, Paper 36

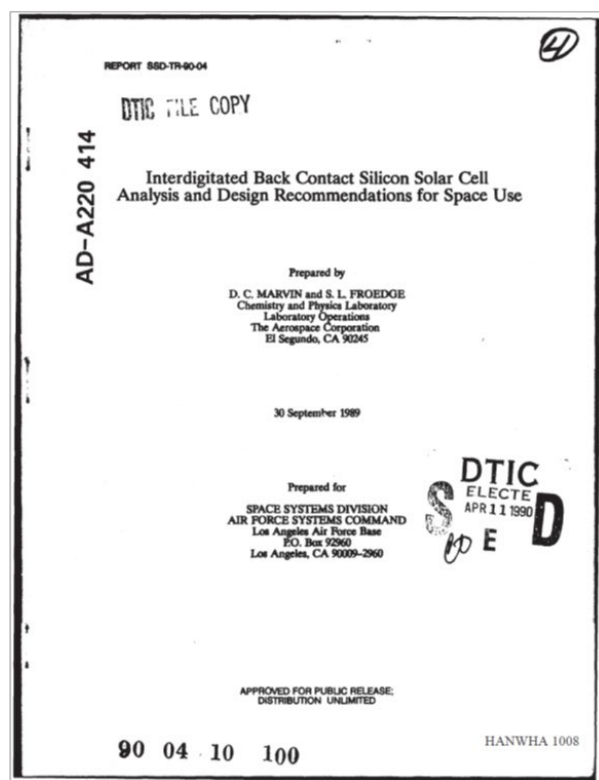
Paper 47, p. 14

It Would Not Have Been Obvious to Implement the Claimed “dopant concentration” in Choi/Cousins



Grounds I-III

Petitioner Misreads Marvin



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 $5\text{E}18 \text{ cm}^{-3}$. These

Ex. 1008, p. 25
(cited in POR, p. 29)

design for various applications. In cases where radiation exposure is not present as the result of shielding or terrestrial use, the 1 sun cell should be at least 50 μm thick, have contact doping widths approximately 90 μm for both minority and majority carriers with 20 μm spacing, and have doping thicknesses approximately 1 μm and 3 μm , respectively. The efficiency of this cell

Ex. 1008, p. 16
(cited in POR, p. 29)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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Petitioner Misreads Marvin



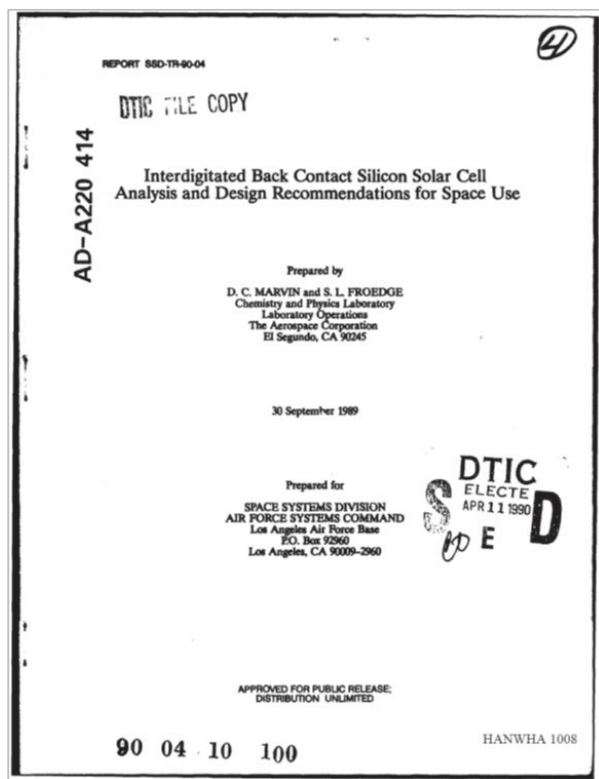
operation.” *Id.* Maxeon asserts the “low radiation environment” equates to “terrestrial application” (POR, 29), but that interpretation is proven wrong by the rest of the paragraph describing “space use” and “missions.” Ex.1008-Marvin, 25.

Pet.’s Reply, p. 19

design for various applications. In cases where radiation exposure is not present as the result of shielding or terrestrial use, the 1 sun cell should be at least 50 μm thick, have contact doping widths approximately 90 μm for both minority and majority carriers with 20 μm spacing, and have doping thicknesses approximately 1 μm and 3 μm , respectively. The efficiency of this cell

Ex. 1008, p. 16
(cited in PO’s Sur-Reply, p. 18)

Petitioner Misreads Marvin



In a high radiation environment, a different design is used to maximize the EOL performance. At 1 sun after $1\text{E}15$ 1 MeV electron fluence, the design presented here shows over 12% efficiency. The carrier collection region widths in this design are in an approximately 4 to 1 ratio, unlike the low radiation case. The FSF is graded over $15\text{ }\mu\text{m}$ with a peak doping concentration of $1\text{E}17$ to $1\text{E}18\text{ cm}^{-3}$. At 100 suns the EOL efficiency approaches 16%, which is

Ex. 1008, p. 25
(cited in POR, p. 30)

The effects of FSF thickness and doping level were studied for the base-line cell geometry at BOL. For thicknesses of 0.25, 0.5, and $1.0\text{ }\mu\text{m}$ at $1\text{E}18$ doping, no significant effect was observed at 1 sun. The FSF effectiveness is relatively constant over a rather broad range around $1\text{E}17$ to $1\text{E}18\text{ cm}^{-3}$, decreasing below this level due to the weakness of the electric field and decreasing above this level due to increased Auger recombination. As will be

Ex. 1008, p. 15
(cited in POR, p. 30)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Petitioner Misreads Marvin

Q And, Dr. Holman, you understand that Marvin also discloses that the ideal dopant concentration is five times 10 to the 18th per cubic centimeter, correct?

A No, I do not.

I'd probably like to spend a little bit more time with Marvin. I see the sentence that

Ex. 2037 (Holman Depo.), 32:10-14, 39:19-20
(cited in POR, p. 30)



Granek Does Not Teach Less Than $2 \times 10^{18} \text{ cm}^{-3}$ Is Preferred

Table 7-5 *I-V-parameters for the best solar cells with different front surface field diffusion profiles. Solar cells with base resistivity of $1 \Omega \text{ cm}$ and pitch of $1800 \mu\text{m}$ 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

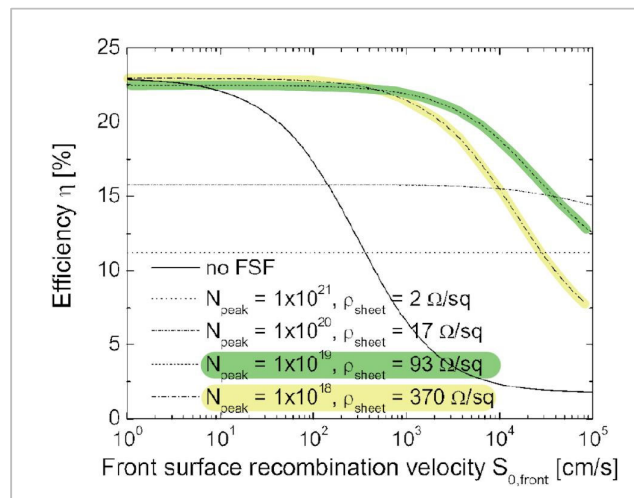
Ex. 1010, p. 132 (Table 7-5)
(cited in POR, p. 33)

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

Profile	Type	ρ_{sheet} [Ω/sq]	N_d [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, p. 126 (Table 7-1)
(cited in POR, p. 34)

Granek Does Not Teach Less Than $2 \times 10^{18} \text{ cm}^{-3}$ Is Preferred



Ex. 1010, p. 121 (Figure7-1)
(cited in POR, p. 35)

Granek Does Not Teach Less Than $2 \times 10^{18} \text{ cm}^{-3}$ Is Preferred

The structure used in all simulations consisted of a 300 μm thick p-doped c-Si wafer with either a constant rear side recombination velocity of 1000 cm/s (a typical value for an oxide-covered c-Si surface) for the calculations using ATLAS, or with a 1 nm thin wide-gap semiconductor as insulating, SiO_2 -like layer on the back ($E_g = 5 \text{ eV}$, i.e. below E_{g,SiO_2} , for increased numerical stability) for the AFORS-HET simulations. Regarding the simulation results, both types of back

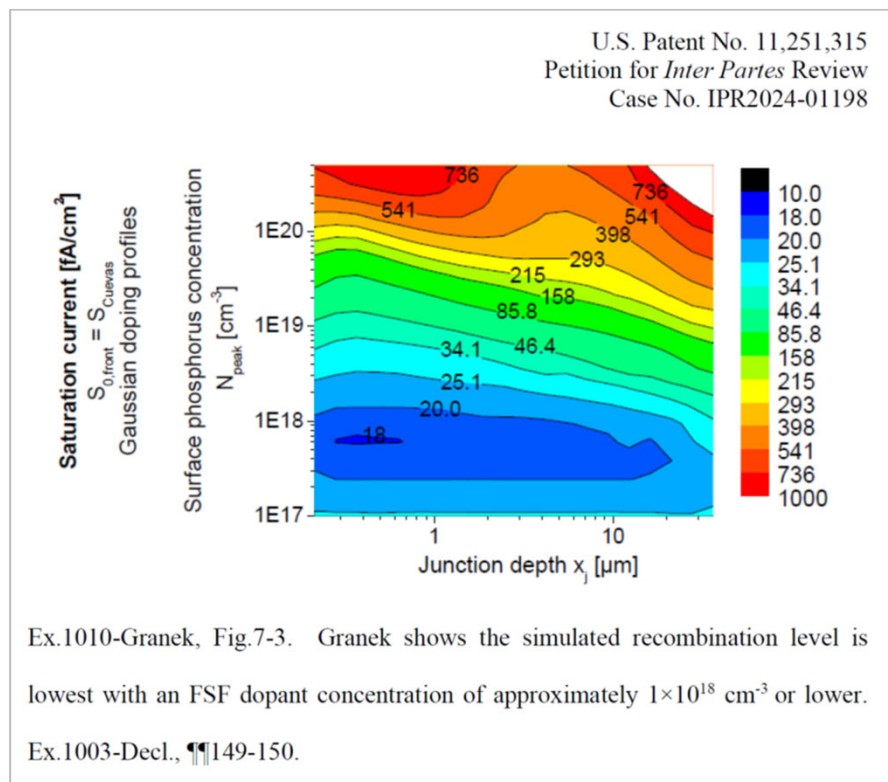
Ex. 2035, p. 6397
(cited in POR, p. 35)

Table 1. Constant Cell Design Parameters

Electrode width	25 μm
p ⁺ doping concentration	5E18 cm^{-3}
n ⁺ doping concentration	5E18 cm^{-3}
p doping concentration	1.40E15 cm^{-3}
p Auger recombination	1.2E-31 cm^6s^{-1}
n Auger recombination	1.7E-31 cm^6s^{-1}
Hole mobility	475 $\text{cm}^2/\text{V}\cdot\text{s}$
Electron mobility	1380 $\text{cm}^2/\text{V}\cdot\text{s}$
Front surface recombination	1E3 cm/s
p ⁺ /oxide recombination	1E4 cm/s
N ⁺ /oxide recombination	1E6 cm/s
Metal contact resistance	0
Front surface reflectivity	0

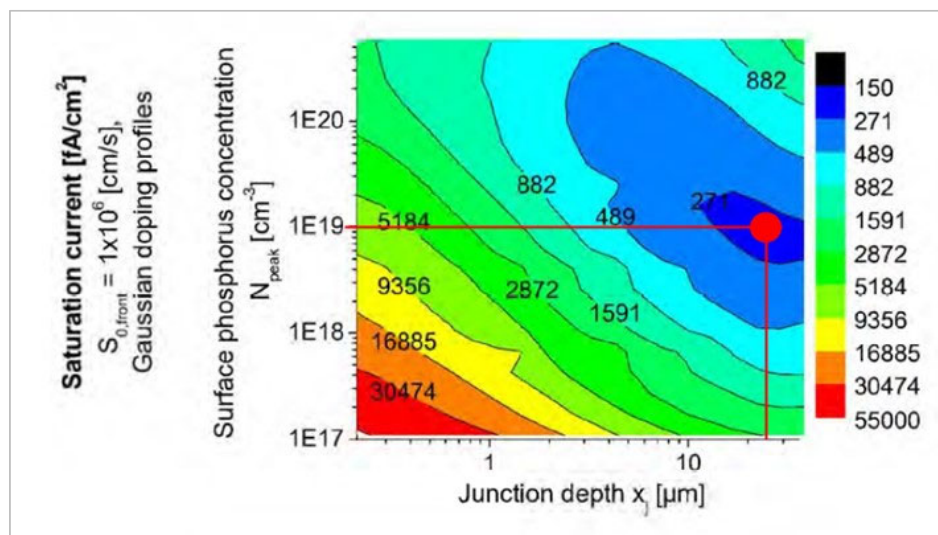
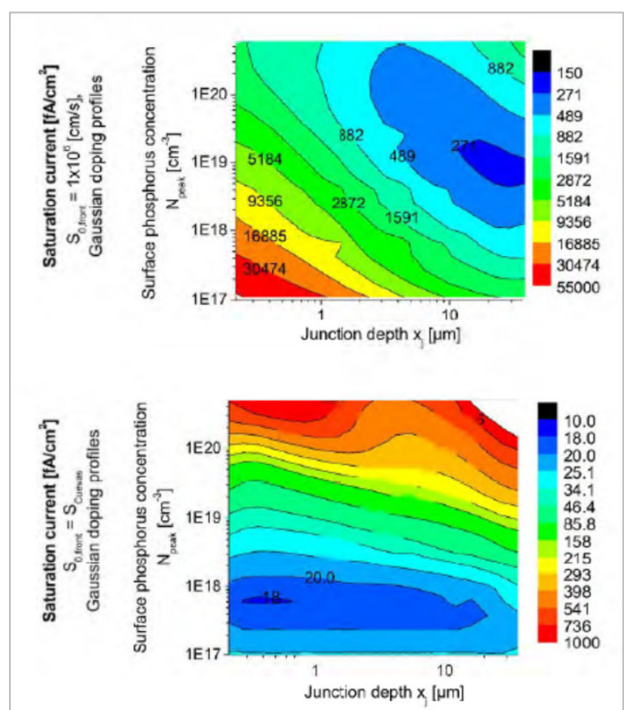
Ex. 1008, p. 10
(cited in POR, p. 35)

Petitioner Omits Half of Granek's Figure 7-3



Petition, p. 30

Petitioner Omits Half of Granek's Figure 7-3



Ex. 1010 (Granek) Fig. 7-3 (annotated)
(cited in POR, p. 40)

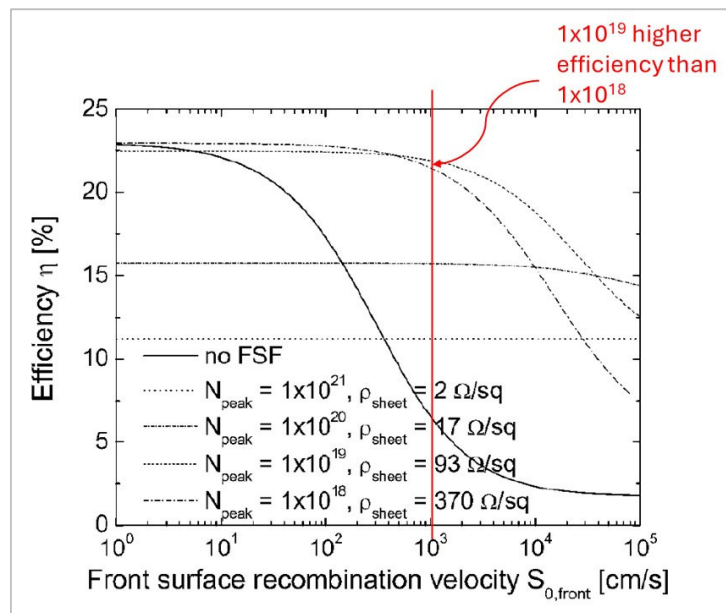
Choi/Cousins Do Not Teach “Well-Passivated” Surfaces



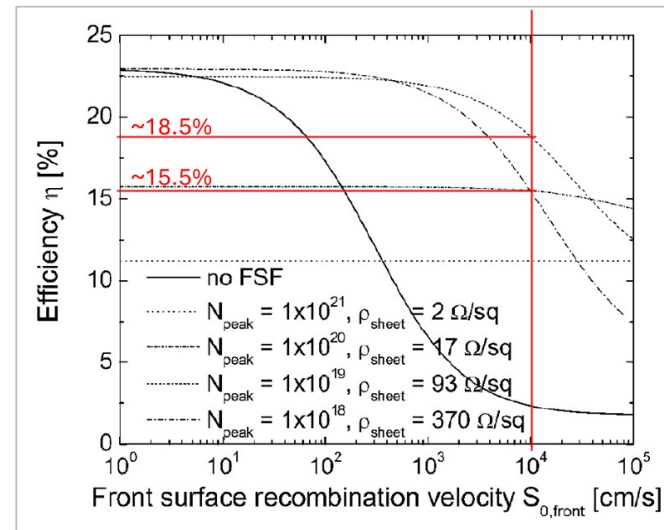
POR, 34-37. Maxeon incorrectly assumes a POSITA would have focused on the portions of Figure 7-1 corresponding to front surface recombination velocities (“SRV”) greater than 500 cm/s; however, Choi’s (and Cousins’) solar cells have well-passivated front surfaces with SRVs below 500 cm/s. Ex.1090-Schubert-Tr., 188:14-189:6; *see also* Ex.1118-Aberle-2000, 447; Ex.1041-Hermle, 1; Ex.1008-Marvin, 16-17. Maxeon ignores that Granek’s Figure 3-6 shows a dopant

Pet.’s Reply, p. 22

Granek Does Not Teach Less Than $2 \times 10^{18} \text{ cm}^{-3}$ Is Preferred

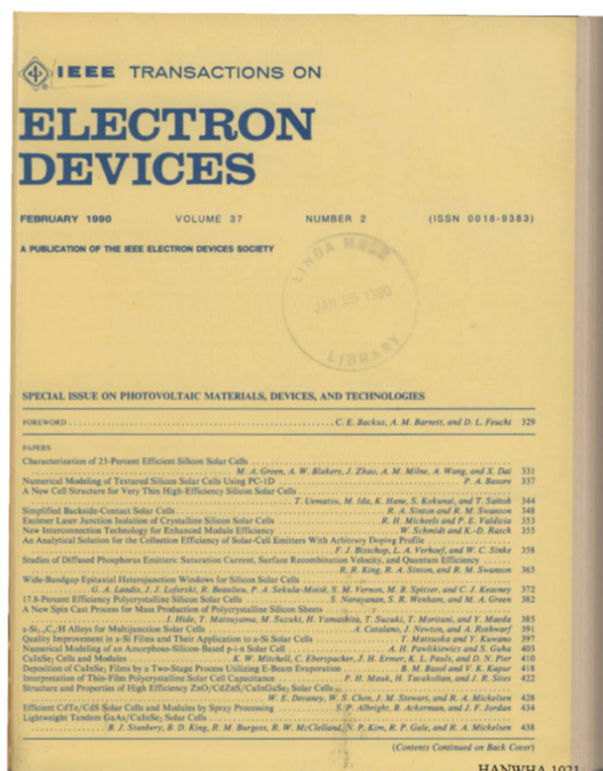


Ex. 1010, p. 121 (Figure7-1) (annotated)
(cited in POR, p. 36)



Ex. 1010, p. 121 (Figure7-1) (annotated)
(cited in POR, p. 37)

Achieving a Low Surface Recombination Velocity Is Difficult and Expensive



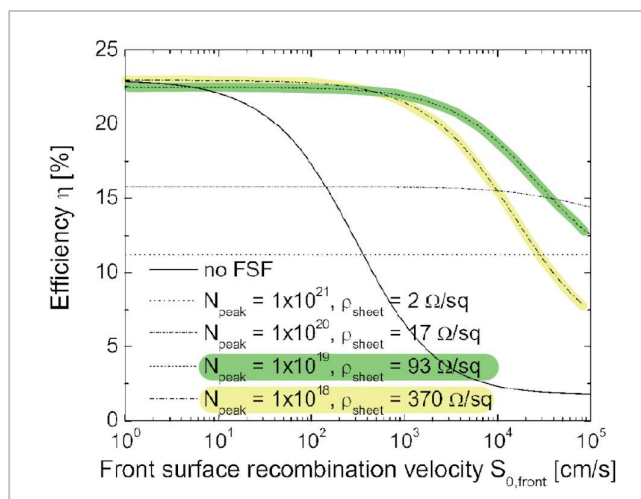
face dopant concentration N_{surf} . Unfortunately, s is strongly dependent on technological factors, some of which are difficult to control. For an oxidized silicon surface, s varies with surface roughness, surface contamination, oxidation temperature, ambient gases during oxidation, and postoxidation annealing. When contamination

Ex. 1021, p. 365
(cited in POR, pp. 38-39)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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A POSITA Would Seek to Avoid the Costs Required to Achieve a Very Low Surface Recombination Velocity



Ex. 1010, p. 121 (Figure7-1) (annotated)
(cited in POR, p. 35)

87. That a POSITA would try to avoid the cost required to achieve a very low front surface recombination velocity is especially true since the surface recombination velocity “is strongly dependent on technological factors, some of which are difficult to control.” Ex. 1021 (King) at p. 365. In particular, the following variables impact surface recombination velocity: “surface roughness, surface contamination, oxidation temperature, ambient gases during oxidation, and postoxidation annealing.” *Id.* Generally, efforts to control those variables to reduce surface recombination velocity (e.g., reduce surface roughness, reduce surface contamination, etc.) involve additional cost.

Ex. 2028 (Schubert Dec.), ¶ 87
(cited in POR, p. 39)

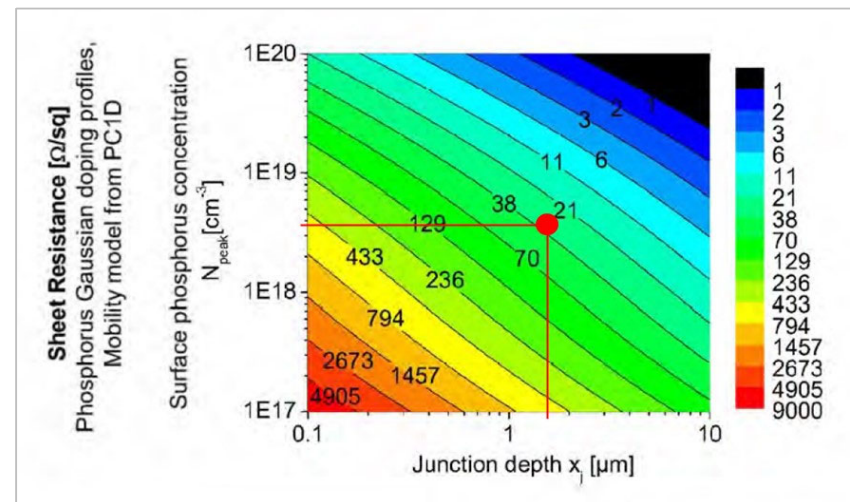


Granek's Figure 7-4 Reveals the Limitations of Granek's Simulations

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, p. 126 (Table 7-1) (annotated)
(cited in POR, pp. 51-52)



Ex. 1010, p. 123 (Figure 7-4) (annotated)
(cited in POR, p. 52)

Granek's Figure 7-4 Reveals the Limitations of Granek's Simulations

higher values. Typically when a model is wrong at some values, you don't necessarily look to it for guidance at other values.

Ex. 2037 (Holman Depo.), 150:12-14
(cited in POR, p. 53)



There Is No Optimal Doping Concentration

maxeon

IPR2024-01198 | U.S. Patent No. 11,251,315
Patent Owner's Response

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.

POR, p. 42

Optimization of p-type Screen Printed Interdigitated Back Contact Silicon Solar Cell with Aluminum Back Surface Field

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Abstract— Interdigitated Back Contact (IBC) solar cell has been routinely fabricated with efficiencies exceeding 20 %. However, due to the requirements of high-resolution alignment and multiple patterning layers, the IBC manufacturing costs are still high. In contrast, screen printed IBC solar cell is based on inexpensive processes utilizing conventional solar cell equipment. Although the screen printed IBC solar cell is easier to fabricate, however its efficiency is poor. In this paper, the performance constraints on screen printed IBC solar cell based on conventional aluminum metallic diffusion paste were investigated. Two-dimensional modeling was carried out using technology computer aided design (TCAD) tool of the commercial software from SILVACO. Critical process and device parameters impacting IBC solar cell performance including fabrication, configuration and material properties. With suitable meeting material, device configuration, and fabrication process, solar cell efficiency as high as 19% has been predicted. Higher efficiency is achievable with boron doping, however, aluminum metallic paste is chosen due to the fabrication simplification which will lead to inexpensive manufacturing.

Index Terms— IBC, Interdigitated back contact, Silicon solar cell, Two-dimensional solar cell model.

1. INTRODUCTION

It is well known that the efficiency of conventional silicon solar cell is limited by front surface shadow and series resistive losses. Ideally, the front grid contact and the busbar of conventional silicon solar cell must be minimized to reduce shadowing losses. Unfortunately, reducing the contact grid and busbar dimensions increases ohmic resistive losses. Also, the series resistance issues extend to solar modules where many solar cells are interconnected, thus decreasing efficiency of module as well. The tabbing size for solar cell interconnection in module fabrication is limited by the busbar size. Larger tabbing width will produce higher shadowing losses. Thicker tabbing may create stress during cell interconnection, thus affecting yield [1].

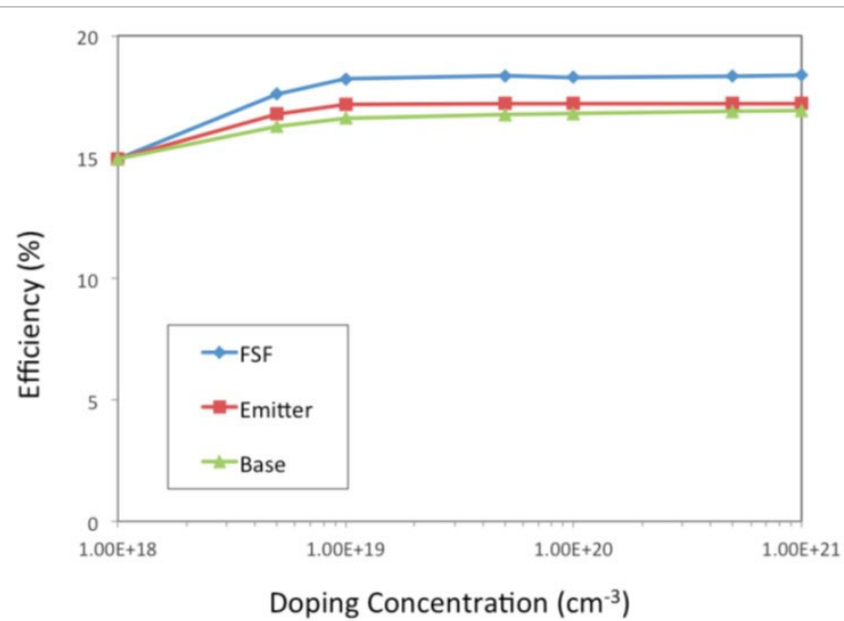
The IBC solar cell has all its contacts located at the rear side. Therefore, there is no trade off between shadowing and resistive losses. Shadowing losses are eliminated resulting in higher photocurrent. The finger and busbar dimensions can

now be significantly increased to reduce resistive losses. All these factors contribute to high conversion efficiency as demonstrated by large area IBC modules [2]. Moreover, cell interconnection becomes simpler since the solar cells can be connected in co-planar configuration. Other advantages include higher packing density resulting in a smaller module footprint for the same output in comparison with conventional module. Finally, with its uniform black/dark appearance IBC module is attractive for building integration.

As with other high efficiency structures, a major disadvantage of IBC solar cell is its complicated fabrication process. In IBC solar cell fabrication, a number of process steps and mask levels are needed. For example, separate process and masking steps are used to precisely define physically separate emitter, base, emitter contact and base contact regions. The precise alignment required for the above processes makes the fabrication process slower and expensive. As a result, the IBC solar cell is often fabricated using fine to sub lithography steps [3]. Lithography is an expensive process and hard to automate. Reducing lithography steps in the fabrication process makes an economic sense [4]. In addition, lithographically-defined emitter and base regions have other disadvantages as well. They require expensive metallization processes such as vacuum evaporation or sputtering to deposit the metal contacts.

Recent work has exhibited strong trend towards lithography-free fabrication process of IBC solar cell [5]. These widely different methods include the use of dielectric with laser ablation combined with screen printing [6], diffusion barrier paste [7, 8], diffusion paste [9] and laser scribing [10]. In terms of terminology, these techniques can be broadly categorized under the term "screen printed IBC" as the majority of the methods use screen printing for metal contact. While some of these methods have exhibited reasonable efficiency, others exhibit performance far below than the lithographically defined process. The reduced performance of screen printed IBC solar cell could be attributed to several factors including low lifetime, un-optimized device configuration, low shunt due to leakage, and high series resistances.

The objective of this paper is to investigate the potential of screen printed IBC solar cell by modifying conventional solar



Ex. 2003, p. 76 (Fig. 5(c))
 (cited in POR, p. 43)

TOWARDS 21% EFFICIENT N-CZ IBC BASED ON SCREEN PRINTING

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¹ECN Solar Energy, P.O. Box 1, NL-1755 ZG Petten, the Netherlands
²Silicon Renewable Energy, Department of R&D, Ciudad Politécnica de la Innovación - UPV, Camino de Vera, 14 (46022) Valencia, Spain
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ABSTRACT: Investigated Back Contact (IBC) cells have been fabricated at ECN laboratories with a best cell efficiency of 19.1%, using n-type Cz material and a process flow based on all-screen-printed patterning and metallization. Excellent current collection due to an optimized FSF is demonstrated by a ϕ_{eff} value as high as 41.5 $\mu\text{m}/\text{cm}^2$, corrected for spectral mismatch, and a F_{p} of 641 mV. The results show high Passby Fill Factors (PFF) of above 81% but lower Fill Factors (FF) of below 72%.
Keywords: back contact, silicon solar cell, high-efficiency

1. INTRODUCTION

Driven by market pressure to increase cell efficiencies and decrease production costs, we have developed a process flow for Investigated Back Contact (IBC) cells that is compatible with low-cost industrial processes. The process flow comprises conventional screen-printing steps for patterning and metallization, avoiding more expensive approaches such as lithography [1-3].

High efficiencies (>20%) can be achieved in IBC cells mainly because all current collection contacts are located at the rear, which eliminates the problem of front shading losses. A schematic cross section of the IBC cell can be seen in figure 1. Although optical shading losses are eliminated, recombination losses occur in the regions without emitter as the transport towards the emitter becomes comparable to the hole diffusion length. This effect is referred to as electrical shading [4]. To reach the high cell efficiencies, the device structure requires excellent surface passivation at the front and rear sides, as well as patterning of both n- and p-type regions at the rear of the cell and a high bulk lifetime (>1 ms). Narrow and abrupt contact areas will result in reduced resistive and lateral losses. These losses are determined by the minimum feature size, which is limited by the patterning method used. The top-down solution of lithography is able to achieve close to ideal contact regions but the current process is too expensive for high-volume manufacturing. On the bottom-up and screen-printing is well demonstrated in PV manufacturing and it is therefore important to evaluate the limits in the efficiencies of IBC cells fabricated using this approach.

Since the emitter in IBC cells is located at the rear, an almost ideal surface passivation is required at the front as most charge carriers are created close to that interface. The formation of a high-quality Front Surface Field (FSF) is necessary, which should provide a shielding field effect with no added Auger recombination and can be passivated using a dielectric layer.

In this paper we present the IBC cell made at ECN using solar furnace diffusion, wet-chemical, PECVD and screen-printing (patterning and metallization) process steps alone. The efficiency limits of the fabrication process presented are evaluated by studying the influence of the pitch and emitter fraction, and the effect of unpassivated contacts.

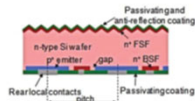


Figure 1: Schematic of an IBC cell, indicating the Front Surface Field (FSF), n+ Back Surface Field (BSF), p+ emitter, contacts and passivating layers. The definition of pitch and gap are also included. All contacts are located at the rear.

2. SOLAR CELL AND PROCESS DESCRIPTION

In figure 2 the process flow used to fabricate the IBC cells at ECN is shown. To enable optimal light confinement, the front surface of the cells is textured (random pyramids) using alkaline etching while the rear surface is smoothed which also improves passivation. This wet-chemical process is followed by the FSF diffusion, mainly to reduce the recombination at the front side [5]. After FSF diffusion, the steps include masking, diffusion and patterning of the bottom emitter and phosphorus BSF at the rear surface. The emitter and BSF are separated by a non-diffused gap, to avoid shading. To ensure high efficiencies, front and rear side passivation needs to be excellent. The IBC cells require a rear surface passivation solution for three different surfaces: the highly doped p-type emitter, the highly doped n-type back surface field and the lightly doped n-type base. For this, the full rear side is passivated using a stack of $\text{SiO}_2/\text{SiN}_x$. The front side is passivated using SiN_x coating on top of the FSF. Subsequently, metallization on the BSF and emitter regions is done by screen printing and sintering of both regions is achieved simultaneously by a short high temperature firing step. All patterning and metallization steps were executed using low-cost screen-printing methods. Contacting was achieved by so-called firing-through using an inline belt furnace. The metallization fraction on the rear side was varied between 7.5 and 11.3%, excluding busbars, depending on the pitch.

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transport. Recombination in the FSF should be minimal and the optimal doping level was found to be 3.10^{18} atoms/cm² [6-8]. Improved lateral transport by the FSF

Ex. 2002, p. 2
(cited in POR, pp. 42-43)

Lamers

20th European Photovoltaic Solar Energy Conference and Exhibition, 7-9 September 2011, Hamburg, Germany

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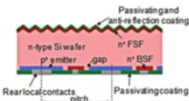


Figure 1: Schematic of an IBC cell, indicating the Front Surface Field (FSF), n-Back Surface Field (BSF), p⁺ emitter, contacts and passivating layers. The definition of pitch and gap are also included. All contacts are located at the rear.

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which is undesired. 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

Ex. 2002, p. 2
(cited in Pet.'s Reply, p. 24)

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

Ex. 2002, p. 4
(cited in Pet.'s Reply, p. 24)

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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PV Law

Granek (referenced by Lamers)

HIGH-EFFICIENCY BACK-CONTACT BACK-JUNCTION SILICON SOLAR CELLS

Dissertation
zur Erlangung des Doktorgrades
der Technischen Fakultät
der Albert-Ludwigs-Universität Freiburg im Breisgau

vorgelegt von

Filip Granek

Fraunhofer Institut für Solare Energiesysteme (ISE)
Freiburg im Breisgau

2009

HANWHA 1010

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 μm) phosphorus front surface field (FSF). The sheet resistance of the FSF (ρ_{FSF}) equals 148 Ω/sq . The diffusion profile of

Ex. 1010, p. 46
(cited in PO's Sur-Reply, p. 22)

Q Do you agree with that in that passage, Granek is stating that a concentration of 5 times 10 to the 18th per cubic centimeter is lightly doped?

...

A Yes, I think I've elaborated in my previous response.

Ex. 2040, 189:13-190:8
(cited in PO's Sur-Reply, p. 22)



Granek (referenced by Lamers)

HIGH-EFFICIENCY BACK- CONTACT BACK-JUNCTION SILICON SOLAR CELLS

Dissertation
zur Erlangung des Doktorgrades
der Technischen Fakultät
der Albert-Ludwigs-Universität Freiburg im Breisgau

vorgelegt von

Filip Granek

Fraunhofer Institut für Solare Energiesysteme (ISE)
Freiburg im Breisgau

2009

HANWHA 1010

Q Are you aware of any instances other than page 46 of Granek that use the phrase "lightly doped"?

...

A I guess I'm not aware of other instances of Granek using the word "lightly," but I do understand, as a POSITA would, that Granek has these other teachings of "lowly doped" that I think are the same.

We do have to remember that he's not a native English speaker. And while you and I might not say "lowly doped," I'm quite sure that he means the same as "lightly doped."

Ex. 2040, 191:10-192:13
(cited in PO's Sur-Reply, p. 22)



DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

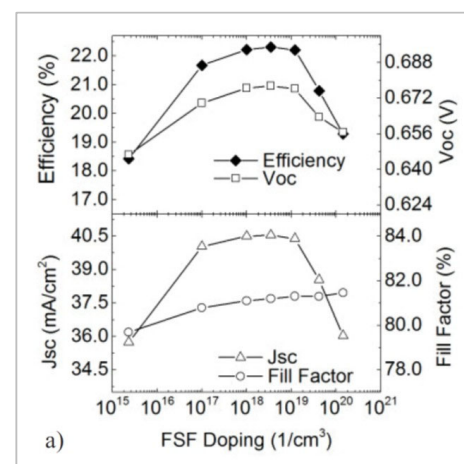
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PV/Law



exhibits a bell shape with a clearly identifiable optimum value for the three doping regions. In our simulated structure, the optimum values of peak doping are: $4.16 \times 10^{19} \text{ cm}^{-3}$ for emitter, $1.44 \times 10^{20} \text{ cm}^{-3}$ for BSF and $3.47 \times 10^{18} \text{ cm}^{-3}$ for FSF. The efficiency decrease observed at lower doping values is explained in terms of higher contact

Ex. 2005, p. 132
(cited in POR, p. 44)



Ex. 2005, p. 131, Fig. 4(a)
(cited in POR, p. 44)

Procel



Abstract— In this work, we performed a study of rear side geometry of a back-contact back-junction solar cell parameters: the emitter, the back surface field (BSF) and their gap distance by exploiting two-dimensional TCAD numerical simulations. All

The aim of this work is 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 under light conditions to understand the losses [4] that influence the overall figures of merit: short circuit current density (J_{sc}), open circuit voltage (V_{oc}) and fill factor (FF).

Ex. 1040, p. 15
(cited in PO's Sur-Reply, p. 23)

Procel



Q Would the findings as to the optimal values that Exhibit 1040 found have been any different if a different front surface field doping concentration had been used?

...

A Okay. So I think the answer to my question was, yes, because that optimum point is an optimum emitter pitch ratio if we look at Figure 2 and the x-axis of Figure 2. I would not expect that optimum to change if the calculation had been done for 3.47 times 10 to the 18 as opposed to 1 times 10 to the 18. I expect a similar result.

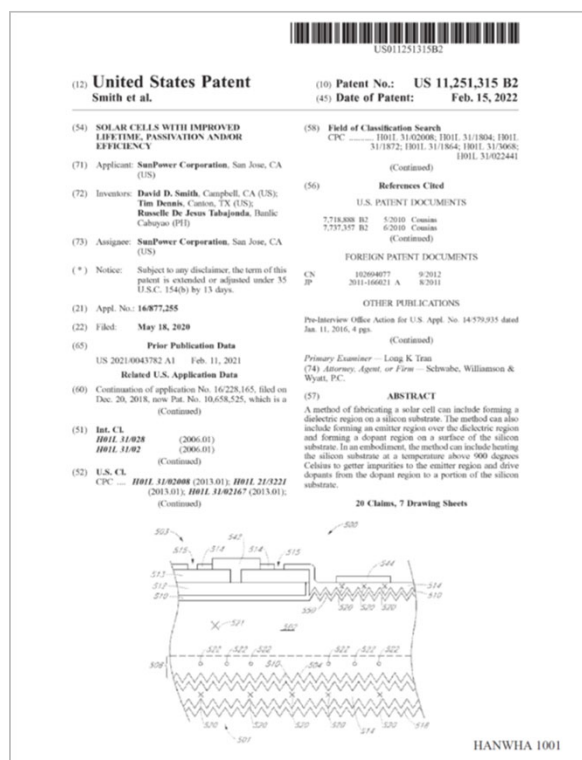
Ex. 2040, 220:1-19
(cited in PO's Sur-Reply, p. 23)



Claims 13 and 14 Would Not Have Been Obvious



Petitioner Fails to Show Claims 13 and 14 Would Have Been Obvious



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

a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to $2 \times 10^{18} \text{ cm}^{-3}$ and wherein the portion of the silicon substrate is formed at the front side of the solar cell;

a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar;

a first emitter region having metal impurities formed over the dielectric region; and

a first metal contact formed over the first emitter region.

13. The solar cell of claim 10, wherein the portion of the silicon substrate comprises P-type dopants.

14. The solar cell of claim 10, wherein the portion of the silicon substrate comprises boron.

'315 Patent,
claims 10, 13, 14

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

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PV/Law

Petitioner Fails to Show Claims 13 and 14 Would Have Been Obvious

Marvin, 16-17. Maxeon ignores that Granek's Figure 3-6 shows a dopant concentration of $1 \times 10^{18} \text{ cm}^{-3}$ would result in an SRV of 100 cm/s. Ex.1010-Granek, 42 (Fig.3-6); Ex.1089-Reply-Decl., ¶¶106-111.

Pet.'s Reply, p. 22

Ex. 1010 (Granek),
p. 42 (Fig. 3-6)
(cited in Pet.'s Reply,
p. 22)

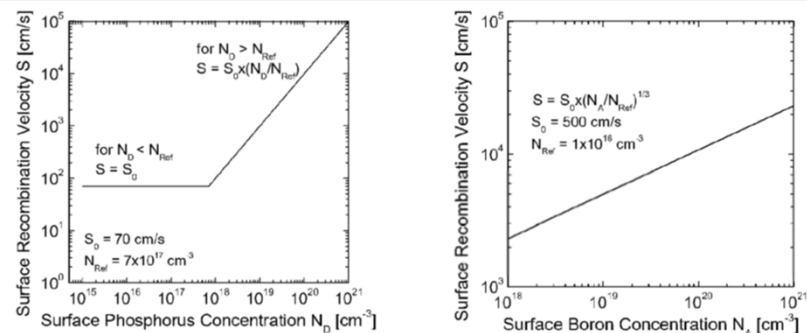
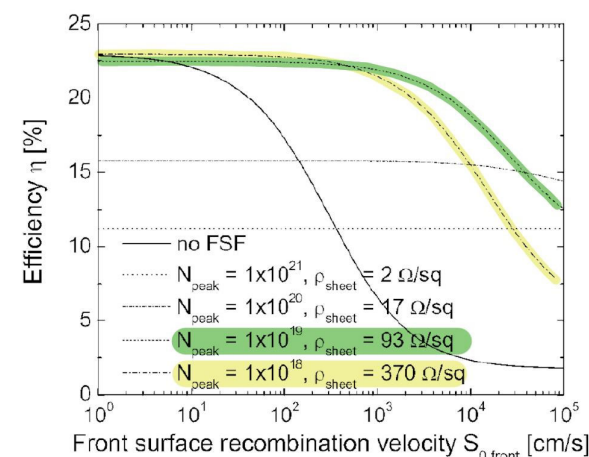
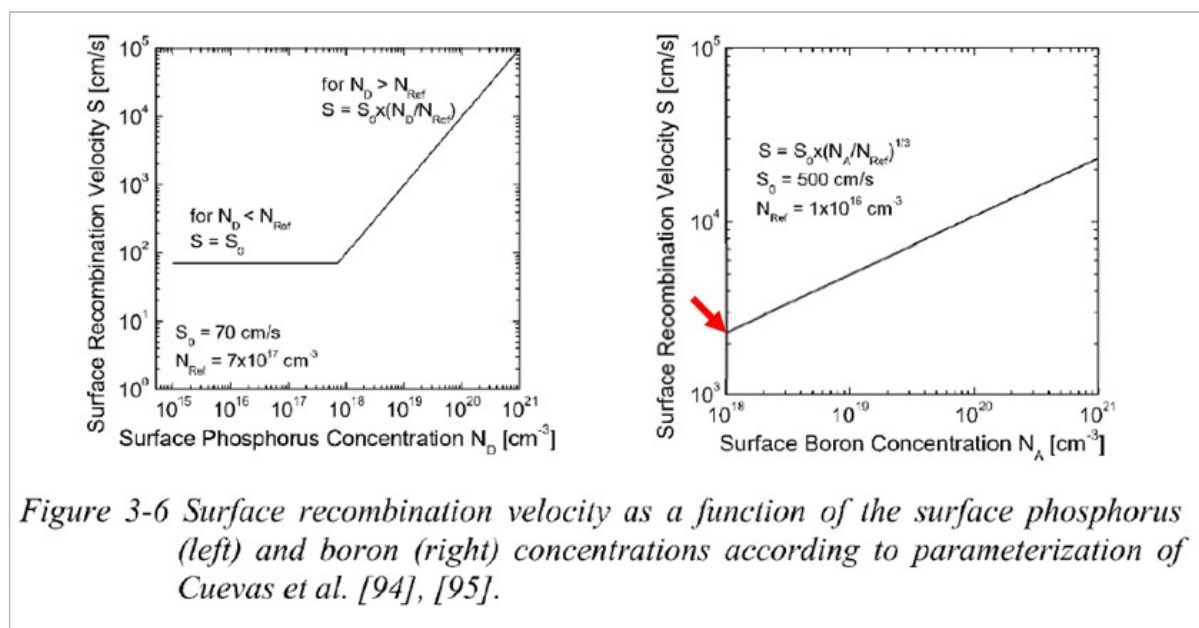


Figure 3-6 Surface recombination velocity as a function of the surface phosphorus (left) and boron (right) concentrations according to parameterization of Cuevas et al. [94], [95].

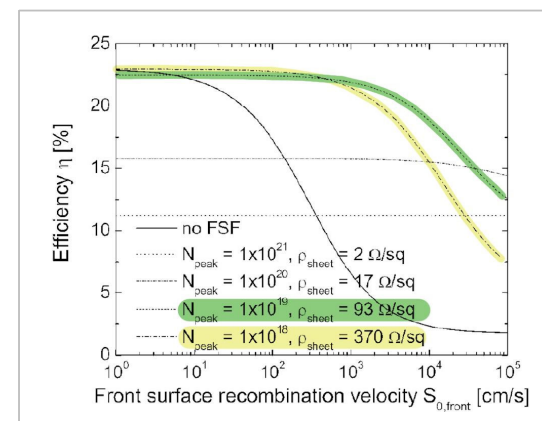
Ex. 1010, p. 121 (Figure7-1)
(cited in POR, p. 33; PO's Sur-Reply, p. 25)



Petitioner Fails to Show Claims 13 and 14 Would Have Been Obvious



Ex. 1010 (Granek), p. 42 (Fig. 3-6) (annotated)
(cited in PO's Sur-Reply, p. 25)



Ex. 1010, p. 121 (Figure 7-1)
(cited in POR, p. 33 ; PO's Sur-Reply, p. 25)

Petitioner Fails to Justify a Switch from n-type Si to p-type Si

The advantages of n-type Si when compared to p-type Si are as follows:

- The minority carrier lifetime in p-type boron-doped oxygen-contaminated silicon is strongly reduced under illumination or carrier injection [106], [107], [108]. Due to the lack of boron in n-type Si, no degradation occurs.
- n-type Si has a lower sensitivity to the prominent impurities (e.g. interstitial iron Fe_i) [109], [110]. This is due to strong asymmetry in capture cross section for electron and holes ($\sigma_n \gg \sigma_p$).
- For reasons mentioned above, the lifetime of the minority carriers in n-type Si is higher than in the case of p-type Si. For example, extremely high minority carrier lifetime in the range of milliseconds was already reported for n-type multicrystalline silicon by Cuevas et al. [111].

Ex. 1010, pp. 48-49
(cited in POR, p. 47)

Q Do you agree with each of the three
bullets there?

A (Reviewing.)

Yes, these are correct. So the first

Ex. 2037 (Holman Depo.), 79:18-11
(cited in POR, p. 47)

