

1 UNITED STATES PATENT AND TRADEMARK OFFICE
2 BEFORE THE PATENT TRIAL AND APPEAL BOARD

3 -----
4 HANWHA SOLUTIONS CORPORATION,
5 Petitioner

6 vs

7 MAXEON SOLAR PTE, LTD.,
8 Patent Owner
9 -----

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

12
13 Oral deposition of
14 ZACHARY HOLMAN, Ph.D.

15
16 VIA VIDEO/TELECONFERENCE
17 FRIDAY, SEPTEMBER 12, 2025

18 12:02 p.m. EASTERN TIME
19

20 Job No.: 598414

21 Pages: 1 - 239

22 Reported by: Lisa V. Feissner, RDR, CRR, CLR

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Oral deposition of ZACHARY HOLMAN, Ph.D., held
REMOTELY, via ZOOM, beginning at 12:02 p.m. Eastern
Time, pursuant to Notice, before Lisa V. Feissner,
RDR, CRR, CLR, Notary Public.

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1 A L S O P R E S E N T :
2 H E E S E O N G S O N G , H S C
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C O N T E N T S

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E X H I B I T S

(Attached to transcript)

DEPOSITION EXHIBIT	PAGE
(None marked.)	

1 P R O C E E D I N G S

2 ZACHARY HOLMAN, Ph.D.,

3 having been first duly sworn, was examined and
4 testified as follows:

5 EXAMINATION

6 BY MR. SNODGRASS:

7 Q Good morning, Dr. Holman.

8 A Good morning, Mr. Snodgrass.

9 Q Do you have four binders of hard copy
10 documents within your reach?

11 A I do.

12 Q Is one of those binders labeled IPR
13 2024-01198-Holman reply declaration?

14 A Yes, I see that binder.

15 Q Okay. And in that binder, is there a
16 copy of Exhibit 1089?

17 A Yes, there is.

18 Q And on page 99 of that exhibit, is that
19 your signature?

20 A Yes.

21 Q And I assume that prior to signing
22 Exhibit 1089, you had reviewed the contents of that

1 exhibit.

2 Is that right?

3 A I've more than reviewed. I have written,
4 edited, and reviewed in great detail. These are my
5 words, yes.

6 Q Okay. And you did not sign Exhibit 1089
7 knowing that there were any errors in it, correct?

8 A That is correct.

9 Q Since you've signed it, have you had a
10 chance to review it again, Exhibit 1089?

11 A Yes, I have.

12 Q And through that review, have you noticed
13 any errors?

14 A Yes, one.

15 Q Okay. Can you please direct me to that.

16 A Yes. One of the references that I
17 included had the correct name of the book chapter
18 and referred to the correct part of that book
19 chapter that I intended to, but the book title in
20 the reference was incorrect. And so this is in
21 Appendix D.

22 Q Okay. And Appendix D includes all of the

1 materials that you considered in forming the
2 opinions that you express in Exhibit 1089.

3 Is that right?

4 A Yes, it does.

5 Q Did you review all of the materials
6 listed in Exhibit D?

7 A I did.

8 Q Excuse me. I apologize. I meant to say
9 Appendix D. Did you understand I was referring to
10 Appendix D?

11 A I did, yes.

12 Q Dr. Holman, did you review the entirety
13 of each of the references listed in Appendix D?

14 A Not the entirety, no, because some of the
15 documents in Appendix D, for example, are
16 dictionaries. And in that case, I reviewed the
17 portion of the dictionary that was relevant to my
18 declaration.

19 But for the articles and book chapters,
20 et cetera, that I rely on for my arguments, yes, I
21 have reviewed those materials in their entirety.

22 Q But for the dictionaries, the entire

1 dictionary wasn't included as an exhibit, right?

2 A We can check each one if we'd like.

3 Q So far I believe 1108 and 1109 are two
4 examples of dictionaries.

5 A Yes, correct. Thank you for pointing me
6 to those.

7 Q And you reviewed -- did you review the
8 entirety of the excerpts that are included as
9 exhibits, at least in the case of 1108 and 1109?

10 A Yes.

11 Q I believe you already maybe answered
12 this. But for all of the technical papers and other
13 exhibits beyond dictionaries, you did review the
14 entirety of each one listed in Appendix D?

15 A For all of the technical papers and
16 patents, yes. I'm also seeing, for example, 1105
17 and 1106 are books in which I rely on definitions
18 introduced in those books. I did not read those
19 books in their entirety.

20 But the -- let me double-check if there's
21 any other papers or books that I see that I did not
22 read in their entirety, as I mentioned.

1 1134 and 1133 are also dictionaries. I
2 refer to excerpts and did not read the dictionaries
3 in their entirety.

4 The other articles and materials I have
5 read in their entirety.

6 Q Okay. Dr. Holman, turning to your
7 declaration, Exhibit 1089 -- and if I refer to your
8 declaration, will you understand I'm referring to
9 Exhibit 1089?

10 A Yes.

11 Q In footnote 1 on page 2, which is --
12 appears at the end of paragraph 5, you reference an
13 errata.

14 Do you see that?

15 A Yes.

16 Q And you had an opportunity to review the
17 transcript from your first deposition in this
18 matter, correct?

19 A Correct.

20 Q And in that errata, you memorialized all
21 of the errors that you noticed in that transcript.

22 Is that right?

1 A That is correct.

2 Q You didn't find any errors that you did
3 not note in the errata, right?

4 A I noted the errors that I saw.

5 Q You noted every error that you saw,
6 correct?

7 A I noted every error that I saw, that's
8 correct.

9 Q Moving forward to paragraph 6, it appears
10 that you've reviewed certain materials from another
11 IPR matter, specifically IPR 2024-01038.

12 Is that right?

13 A 01038, yes, that is correct. I believe
14 you're referring to the declaration submitted by
15 Dr. David Carroll as well as his deposition
16 transcript.

17 Q Yes. Did you review any other materials
18 from that proceeding?

19 A No. I have reviewed Dr. Carroll's
20 declaration and deposition transcript. I do not
21 believe I reviewed any other materials from that
22 proceeding.

1 Q Do you believe that you were able to
2 fully understand Dr. Carroll's declaration and
3 deposition transcript without reviewing any of the
4 other materials?

5 MR. SELWYN: Objection, form.

6 A I believe I was able to understand what
7 was communicated by Dr. Carroll in both his
8 declaration and deposition, yes.

9 Q And you reviewed the entirety of
10 Dr. Carroll's declaration and deposition transcript.
11 Is that right?

12 A Yes, I did.

13 Q I want to skip forward to paragraph 18 of
14 your declaration, Exhibit 1089. You state that
15 Dr. Schubert's expertise is principally in
16 light-emitting diodes.

17 Do you see that?

18 A Yes, I do.

19 Q And what's the basis for that opinion?

20 A He's included in his deposition -- excuse
21 me -- his declaration his CV which has a list of his
22 contributions to the research field, and includes

1 lists of papers and book chapters, and they
2 generally fall in the category of optoelectronics
3 and in light-emitting diodes in particular. His
4 publications is the short answer to your question.

5 Q Okay. Do you know what a light-emitting
6 diode is?

7 A Yes, I do.

8 Q Can you explain how it works?

9 A Yes. A light-emitting diode is typically
10 a diode or p-n junction structure in which electrons
11 and holes are supplied to that junction made of
12 semiconductor materials by applying an external
13 bias, voltage. The electrons and holes recombine
14 radiatively, articular form of recombination, that
15 emits light, and that light exits the light-emitting
16 diode device, usually for purposes of lighting or
17 displays or the like.

18 Q Do you believe that process to be the
19 reverse of a solar cell?

20 A It is similar to, although there are
21 differences, and there are differences in the design
22 and optimization of light-emitting diodes in solar

1 cells. They are Cousins; they are not the same.

2 Q Do you agree that Dr. Schubert's CV lists
3 work and publications that are not related to LEDs
4 and are, in fact, related to solar cells?

5 A Yes. And I have noted that in paragraph
6 18 of my declaration.

7 The work that Dr. Schubert has published
8 on has mostly been related to -- excuse me. The
9 work that Dr. Schubert has published on in the field
10 of solar cells and solar modules has mostly been
11 related to antireflection coatings, for example, on
12 the cover glass of a solar module or on the solar
13 cell, not on the device layers such as passivation
14 layers or junction forming layers or the like. And
15 I note that as well in paragraph 18.

16 Q Do you have experience on coatings of
17 solar cells?

18 A I do.

19 Q Do you believe that you are more
20 experienced with regard to solar cells than
21 Dr. Schubert?

22 A No, that's not a question I've asked. I

1 believe that I have extensive experience related to
2 the design and fabrication and characterization of
3 silicon solar cells, the layers that form those
4 solar cells, how they function, and the matters in
5 this case.

6 Q Do you have an opinion on that matter,
7 who is more experienced, you or Dr. Schubert?

8 A Experienced in what particularly?

9 Q Solar cells.

10 A Well, as I mentioned, I have extensive
11 experience related to silicon solar cells, including
12 crystalline silicon solar cells. I believe that
13 I've published more than Dr. Schubert in that field.
14 That is the field of this case.

15 Dr. Schubert has published extensively in
16 other areas, including, as I mentioned, LEDs and
17 other optoelectronic devices and has published in
18 the area of, for example, antireflection coatings on
19 solar cells.

20 Q You agree with me that someone can become
21 experienced in a field and publish or not publish in
22 that field, correct?

1 MR. SELWYN: Objection, form.

2 A Yes.

3 Q Okay.

4 A Yes, that's true.

5 Q So putting aside the prolificity of your
6 respective publications, do you believe that you are
7 more experienced with regard to solar cells than
8 Dr. Schubert?

9 A Perhaps I can back up and finish
10 answering the other -- the previous question.

11 Yes, I agree with you that a person can
12 become an expert without being published or prolific
13 in a field. However, experts in fields,
14 particularly within academia, tend to publish on
15 areas in which they're experts, and other experts
16 are aware of or can judge the expertise based on
17 their publication record. It is the currency of
18 expertise in our field.

19 And I have access to that information
20 through Dr. Schubert's CV. I have access to
21 Dr. Schubert's declaration and deposition transcript
22 and have read those extensively.

1 And as I mentioned, I believe that I have
2 published more in the area of silicon solar cells in
3 particular, and that Dr. Schubert has published
4 extensively in other areas.

5 Q Do you agree with me that one of three
6 things is true: You believe that you are more
7 experienced in solar cells than Dr. Schubert; you
8 believe that Dr. Schubert is more experienced in
9 solar cells than you; or you don't know? Do you
10 agree with me that one of those three things is
11 true?

12 MR. SELWYN: Objection, form.

13 A It seems like one of those three things
14 must be true, yes.

15 Q Okay. Can you tell me which of those
16 three things is true?

17 A I think I've already provided a clear
18 answer to the question. I believe that I have
19 published more extensively, and that that
20 publication, as I mentioned, is a reflection of
21 expertise, related to silicon solar cells.

22 If you ask me the question, is

1 Dr. Schubert more experienced than I am in
2 antireflection coatings for solar cells, I would say
3 I don't know.

4 So when you ask a question about who is
5 more experienced in solar cells, it's a bit too
6 vague for me to be able to give you one of your
7 three answers.

8 Q Okay. With regard to experience in
9 choosing a doping concentration for a front surface
10 field, you're not more experienced than
11 Dr. Schubert, though, correct?

12 MR. SELWYN: Objection, form.

13 A I disagree with that. I don't know the
14 answer to it. I know that I have made solar cells
15 and designed solar cells, silicon solar cells in
16 particular, that have doped layers on the front and
17 rear surfaces, and that I have adjusted those doping
18 densities. I've calculated what they should be.
19 I've done experiments and published on varying the
20 doping densities of layers on the front and back of
21 silicon solar cells.

22 I did not note or see in Dr. Schubert's

1 CV evidence of adjusting or studying doping density
2 in silicon solar cells.

3 Q With regard to diffused dopants in a
4 front surface field, do you have any experience?

5 A I have made solar cells that have
6 diffused regions. Those diffused regions were not
7 specifically used as front surface fields.

8 I have also done other work, not
9 specifically on the front surface field, on
10 back-contact solar cells that have front surface
11 fields.

12 So while I have not made a front surface
13 field via diffusion in a back-contact solar cell, I
14 do have extensive experience related to the devices
15 in which front surface fields appear and in the
16 doping processes that form diffusions and layers
17 such as front surface fields.

18 Q Have you used something called PC1D?

19 A Yes, I have.

20 Q Okay. And I'm referring to what's
21 referenced also in paragraph 18 of your declaration.

22 When did you -- okay, so you said you

1 used it?

2 A Yes.

3 Q So do you have a copy or a license to
4 that?

5 A A license isn't needed. It's freeware,
6 as indicated, for example, by Dr. Ruby in a previous
7 deposition.

8 Yes, I have a copy of it.

9 Q You have a copy on your computer?

10 A I do.

11 Q When is the first time you used PC1D?

12 A In 2010.

13 Q In paragraph 18, you cite Exhibit 1129.

14 Do you see that?

15 A Yes.

16 Q I've just circulated the Exhibit 1129.

17 You should have a copy as well, Dr. Holman, in one
18 of the binders, probably binder 4, which may be
19 labeled Exhibits Volume 3.

20 A Okay. Does it matter to you whether I
21 look at the electronic copy that you shared or the
22 paper copy?

1 Q Not at all, Dr. Holman. I want it to be
2 whatever is easiest for you. And I can also share a
3 screen if we're having trouble finding the right
4 spot where each of us is at.

5 A Okay. I have it in front of me. Thank
6 you.

7 Q Okay. At the very bottom of
8 Exhibit 1129, it says, Authorized license use
9 limited to Sally Charin.

10 Do you see that?

11 A I do.

12 Q Do you know who that is?

13 A I don't. That would be the -- referring
14 to the download of this paper.

15 Q Of the exhibit itself. I understand. It
16 has nothing to do with a license to the --

17 A Software license, that's correct.

18 Q I understand that completely.

19 So my question is, do you know anything
20 about this document, then?

21 A Of course. I read this document, and I
22 was familiar with this document years ago. As I

1 mentioned, I have been a regular user of PC1D.

2 But the university doesn't have access to
3 all old conference publications, and you'll see that
4 this is a conference publication from 1997.

5 And so in select instances when I
6 identify documents, if I'm not able to download them
7 myself, I ask if counsel's library can download them
8 for me.

9 Q Okay. So in the lower right-hand corner,
10 it says, 26th PVSC.

11 Do you see that?

12 A Yes. That stands for Photovoltaic
13 Specialist Conference. It is the most popular and
14 widely attended conference on solar in the U.S. I
15 myself have served on the organizing committee and
16 have been chairs of a session and symposia. I've
17 also won the Young Investigator Award at that
18 conference in 2019 or so, if I remember correctly.
19 I'm very familiar with the conference. I've gone
20 more than a dozen times.

21 Q And you also in that paragraph 18
22 reference Exhibit 1135. So I'm going to turn to

1 that real quick.

2 A Yes.

3 Q Is this a printout of a web page that's
4 available at www.pvlighthouse.com?

5 A That's correct. PV Lighthouse is a
6 business and web page that was created by a couple
7 of Australians, Keith McIntosh is one of them,
8 Malcolm Abbott is another one, about 15 years ago
9 now.

10 And they provide information and
11 services, including software freely available and
12 for sale to the PV community. And over the past 15
13 years, they've become the most useful go-to resource
14 for -- online resource for calculators, data, and
15 simulators for the solar cell community.

16 And so for example, PC1D, which was
17 originally created, I think 1985 was the Donald
18 Clugston article we were just looking at, is now
19 provided by, maintained, made available on
20 PV Lighthouse. And this web page printout is the
21 information that's provided on PV Lighthouse when
22 you go to download a copy of PC1D.

1 I have, by the way, provided data to the
2 PV Lighthouse website. So up at the top, you would
3 see that link that says SIM, there's a database of
4 refractive indices from solar cells, and you'll find
5 my name listed there with data.

6 And you'll also find that I have
7 published papers with the creators of PV Lighthouse,
8 for example, Keith Macintosh. So my own words you
9 would find available contributing to the community
10 on this web page.

11 Q Okay. I'm going to skip forward to
12 paragraph 24 of your declaration. There you
13 reference a Wiley Electrical and Electronics
14 Engineering Dictionary, Exhibit 1109.

15 Do you see that?

16 A Let me catch up with you here. Yes.

17 Q Do you have a copy of this dictionary at
18 your office?

19 A In your volume 3 binder, I've just found
20 it. Thank you.

21 Q And Exhibit 1109 is an excerpt of a
22 dictionary, correct?

1 A That is correct.

2 Q Do you own a copy of the dictionary from
3 which this excerpt came?

4 A No, I do not.

5 (Cross-talk.)

6 Q Go ahead.

7 A Sorry. At this point in time, I don't
8 own very many physical books. I'm able to get the
9 information I need online.

10 Q Is there an online version of this
11 dictionary?

12 A This is a copy from 2004. I didn't
13 check. I don't know.

14 Q Do you know if there's an online copy of
15 any version of this dictionary, even if more recent?

16 A I suspect that there is, but I didn't
17 check.

18 Q Have you ever consulted the Wiley
19 Electrical and Electronics Engineering Dictionary in
20 hard copy form or online?

21 A Not prior to this case, to my knowledge,
22 to my recollection.

1 Q Do you believe this dictionary to be --
2 let me start over.

3 Do you believe this dictionary to
4 competently reflect the meanings of terms?

5 A I do --

6 MR. SELWYN: Objection, form.

7 A I do, in general, in the fields of
8 electrical and electronics engineering, which is
9 also the field in which I teach, by the way.

10 And part of the reason that that's the
11 case is because this is published by the IEEE Press.
12 IEEE is the premier professional organization for
13 electronics and electrical engineers.

14 So when you find documents, particularly
15 something like a dictionary, published by IEEE, this
16 would be the authoritative document in that field.

17 If IEEE was publishing about biology or
18 boats, that wouldn't necessarily make a lot of
19 sense. But IEEE knows electronics and electrical
20 engineering, and their dictionary would be the go-to
21 resource.

22 Q This excerpt, Exhibit 1109, does not

1 include the dictionary's definition for
2 "contaminant."

3 Is that right?

4 A That is correct. "Contaminant" is not a
5 word that appears in one of the claims. "Impurity"
6 is.

7 This dictionary excerpt covers two pages
8 of words that start with I. "Contaminants" doesn't
9 start with I.

10 It does include "impurity"; it includes
11 "impurity band"; it includes "impurity
12 concentration"; it includes "impurity level"; it
13 includes "impurity scattering"; and it includes
14 "impurity semiconductor," all of which are known
15 terms of art in electrical engineering in
16 semiconductors, in solar, those being subfields
17 respectively of electrical engineering, and all of
18 which would be things that the undergraduates that
19 take my junior level solid state course would
20 understand.

21 They know what an impurity band is; they
22 know what an impurity level is; they know what

1 impurity scattering is. And these definitions are
2 consistent with what every junior undergraduate
3 electrical engineer who's taken a semiconductor
4 course or a solid state course knows.

5 Q Did you not think it important to
6 understand the IEEE dictionary's definition of
7 "contaminant"?

8 A "Contaminant" is not a word that appears
9 in any of the claims, and I understand that this
10 matter is about the validity of the claims. And so
11 I focused on the words that appear in the claims.

12 Q Have you taken any efforts since your
13 first deposition to become more acquainted or
14 familiar with what the word "contaminant" means?

15 MR. SELWYN: Objection, form.

16 A I have read the '315 patent in many
17 instances since my previous deposition. I have
18 looked for definitions related to "impurities,"
19 found them all consistent with what is already known
20 in the field and common in the field as it's a term
21 of art a POSITA would recognize.

22 I did not look in great detail or look

1 for additional information on the word
2 "contaminant."

3 But there are many, many words in the
4 '315 patent that don't appear in claims, and I
5 didn't specifically seek out additional information
6 on them. I have taken their plain and ordinary
7 meaning when I understood what that was and looked
8 to context for the -- from the '315 patent
9 otherwise.

10 Q So I have a copy of the Wiley dictionary
11 that I believe the excerpt came from.

12 A Okay.

13 Q And I'll represent to you that the
14 definition of "contaminant" in this dictionary is,
15 An undesired material or substance that can
16 adversely affect the properties of a component,
17 circuit, device, piece of equipment, system,
18 material, or medium.

19 Do you have a problem with that
20 definition?

21 MR. SELWYN: Objection, form.

22 A I'd probably like to hear it again. But

1 on first pass, that sounds very reasonable. I
2 believe you asked me about "contaminant" in the
3 first deposition, and I said that that is not a term
4 of art in our field that has a specific plain and
5 ordinary meaning that all electrical engineers would
6 know, but that it sounded like it had a bad
7 connotation. I believe those were my words, and
8 that's consistent with the definition you've just
9 read.

10 Also, as I explain in my declaration, an
11 impurity, per this dictionary, per other
12 dictionaries, per textbooks, per really any resource
13 you could pick up related to solid-state
14 semiconductors, solar or electrical engineering, an
15 impurity is any element that's foreign to the
16 elements in a material. So in silicon, it would be
17 any non-silicon atom is an impurity.

18 And that would be inclusive of
19 contaminant necessarily, including contaminant as
20 defined per your -- the definition that you just
21 read.

22 Q Okay. And I'm happy to read it again.

1 And you had mentioned something about you would like
2 to read it again or like to hear it again. So I'll
3 just read it again.

4 A Sure.

5 Q An undesired material or substance that
6 can adversely affect the properties of a component,
7 circuit, device, piece of equipment, system,
8 material, or medium.

9 Do you have any problems with that
10 definition?

11 A No, I don't. I don't believe
12 "contaminant" has been construed by Maxeon, and I
13 think it doesn't appear in the claim. "Impurity"
14 does.

15 The definition you just read of
16 "contaminant" sounds like a reasonable definition to
17 me.

18 And as I mentioned, I think highly of the
19 IEEE and think that their dictionary has good
20 definitions for things that are used for electrical
21 and electronics engineering.

22 Q Does "contaminant" have a strict

1 definition?

2 MR. SELWYN: Objection, form.

3 A "Contaminant" is not a word of art that
4 is used in our field. A word of art is one that is
5 understood by all of the people in the field to have
6 a specific meaning, like "dopant," like "impurity,"
7 like "semiconductor." Contaminant is not such a
8 word.

9 I've worked in this field for 20 years,
10 and there is no specific definition of "contaminant"
11 that one electrical engineer or solar researcher or
12 solar POSITA talking to another would understand to
13 be inclusive of some elements, for example, and
14 exclusive of others.

15 Q Are you able to explain the presence of
16 "contaminant" in the IEEE dictionary?

17 MR. SELWYN: Objection, form.

18 Q Definition?

19 A I didn't say it doesn't have a
20 definition. I said that it's not a term of art that
21 is understood by scientists and engineers operating
22 in this field to have a specific definition that

1 would, for example, include some elements and
2 exclude others.

3 I would be surprised if it was not in the
4 IEEE dictionary, as it is a word that's used. We
5 find it not only in the '315 patent but in other
6 documents as well.

7 Q Documents that are cited in your
8 declaration, correct?

9 A Yes.

10 Q Okay.

11 A But once again, "contaminant" doesn't
12 appear in any of the claims of the '315 patent.

13 Q Also in paragraph 24, you reference
14 Exhibit 1108. This is another excerpt of a
15 dictionary.

16 Do you see that?

17 A Yes.

18 Q It's an excerpt of A Dictionary of
19 Electronics and Electrical Engineering.

20 Is that right?

21 A Correct.

22 Q Do you have a copy of the dictionary from

1 which Exhibit 1108 is an excerpt?

2 A I have the exhibit in front of me. I do
3 not have a hard copy, for example, in my office.

4 Q Have you ever referred to this dictionary
5 prior to this case?

6 A I don't recall.

7 Q I want to look at paragraph 26 of your
8 declaration. You begin, Publications in the
9 semiconductor field consistently use "impurities" to
10 include intentionally introduced dopants, and then
11 you proceed.

12 I have a question about the word
13 "consistently" there.

14 A Sure.

15 Q Do you mean exclusively or always?

16 A All of the books and articles that I have
17 picked up use "impurities" to have the same meaning.
18 I have taught numerous introductory and advanced
19 courses on solid-state devices, semiconductors, and
20 solar cells. So I've reviewed many books and taught
21 from many books. And they all use "impurities" to
22 have the same meaning.

1 It is a well-defined and well-understood
2 term. It's not something that's subjective. It's
3 very clear what it means.

4 That being said, I haven't picked up
5 every book and every article related to electrical
6 engineering. So could there be another one that
7 has -- could there be an article out there that uses
8 "impurities" in a way that is not consistent with
9 the knowledge of the field? Sure, it could exist.

10 Q Are you saying every technical reference
11 that you have reviewed uses "impurities" to include
12 intentionally introduced dopants?

13 A Yes. I am saying that to the best of my
14 knowledge and memory, I have never reviewed a
15 document or book that used "impurities" -- defined
16 "impurities" to exclude dopants, for example.

17 Q Is that a little bit different than what
18 you say in your declaration?

19 MR. SELWYN: Objection, form.

20 Q In your declaration you say, Publications
21 in the semiconductor field consistently use
22 "impurities" to include intentionally introduced

1 dopants, right?

2 A I believe that's the same as what I just
3 said, unless I accidentally misspoke.

4 Q I believe you said that none of them
5 explicitly exclude dopants. Do you see a difference
6 there?

7 A I mean the same thing in both cases. I
8 mean that the definition of "impurities" includes
9 dopants because the definition of "impurities" is
10 foreign elements in a host material. Again, for
11 silicon, that would be any non-silicon atom.

12 I have included numerous references that
13 show this, and I could provide you with a thousand
14 more, if you would like, because it is the
15 definition of "impurities."

16 Q Have you ever seen the word "contaminant"
17 used to refer to a dopant?

18 A Yes, I have. Dopants are atoms that
19 create an energy state in the bandgap of a
20 semiconductor that is close to the conduction band
21 or the valence band.

22 Dopants, however, are not always

1 intentionally introduced.

2 And so, for example, when I was a
3 postdoc, I worked in a lab that regularly made a
4 flavor of material that in the lab we called NID.
5 That stood for non-intentionally doped.

6 And in that case, the dopants in there
7 were referred to by some of my colleagues, and I can
8 find this in papers for you if you would like, as
9 contaminants.

10 Dopants are not always intentionally
11 introduced.

12 Q Is there any exhibit in this proceeding
13 that uses the word "contaminant" to refer to a
14 dopant?

15 MR. SELWYN: Objection, form.

16 A I don't know. I would have to
17 double-check the references. There are many.

18 Q In paragraph 29, skipping forward just a
19 little bit in your declaration, the last two lines
20 of page 14 states, Unlike "impurities," the term
21 "contaminant" does not have a well-established
22 meaning in the semiconductor or solar fields.

1 Do you see that?

2 A Yes.

3 Q Did you consult technical dictionaries in
4 order to arrive at that opinion?

5 A No. I relied on my, again, 20 years of
6 experience in this field, including teaching of
7 courses in semiconductor and solar fields, and my
8 review of textbooks and other materials over those
9 20 years.

10 Q In paragraph 30, you state, Further, a
11 POSITA would not understand "impurities" to be
12 synonymous with "contaminants" -- let me start over.

13 Further, a POSITA would not understand
14 "impurities" to be synonymous with "contaminants" as
15 used in the '315 patent because the specification
16 uses those terms inconsistently.

17 Do you see that?

18 A Yes, I do.

19 Q In your opinion, how would a POSITA have
20 understood the word "impurity"?

21 (Cross-talk.)

22 MR. SELWYN: Objection, form.

1 Q As used in the '315 patent.

2 A Understood. Thank you for the
3 clarification.

4 MR. SELWYN: Jacob, why don't you ask the
5 question again because you were talking over each
6 other.

7 Q Dr. Holman, in your opinion, how would a
8 POSITA have understood the word "impurities" as used
9 in the '315 patent?

10 A A POSITA would have understood the word
11 "impurity" according to its plain and ordinary
12 meaning, of which there is one, and which is
13 consistently used in both dictionaries and textbooks
14 and papers.

15 And that meaning is, an element that is
16 foreign to the elements in another material. For
17 example, in silicon, anything other than silicon is
18 an impurity. In gallium arsenide, anything that is
19 not gallium or arsenic is an impurity.

20 Q In your opinion, how would a POSITA have
21 understood the word "contaminants" as used in the
22 '315 patent?

1 A I expect that a POSITA would have a
2 similar reaction to mine, which is, these are some
3 subset of elements, a subset of impurities that --
4 for which there is a negative connotation, for
5 which, for example, in a silicon wafer, one would
6 not want them in the silicon wafer.

7 However, a POSITA would not have
8 understood, as I did not understand, what elements
9 were contaminants and what were not besides iron,
10 nickel, and chromium, which are explicitly listed in
11 the '315 patent.

12 Q In your opinion, would a POSITA have
13 understood iron to be a contaminant for purposes of
14 the '315 patent?

15 A A POSITA would have understood iron to be
16 an impurity, and that's the word that appears in the
17 claim.

18 I believe that a POSITA would likely have
19 also assumed that iron was in the subset of
20 contaminants as iron was well-known as of 2014 and
21 before to cause recombination in silicon, which
22 decreased solar cell performance. It was pervasive

1 in silicon solar wafers and problematic.

2 And a large area of activity in the
3 field, both within research labs and in
4 manufacturing lines, was figuring out how to move
5 iron out of the wafer.

6 And so iron did have a bad connotation.
7 It still does in the silicon solar field.

8 And so I believe that a POSITA would have
9 included iron also in the subset of contaminants in
10 his or her mind.

11 Q I want to skip forward to paragraph 36 of
12 your declaration. And you reference an exhibit I
13 just circulated, which is Exhibit 1036.

14 A Yes. Do I also have a paper copy of
15 that?

16 Q Yes, you do. It is in Exhibits Volume 1.

17 A I'm looking at Exhibit 1036.

18 Q Okay. And you rely on this exhibit in
19 forming your opinion that -- in forming your
20 opinions as to the meaning of the term "metal
21 impurities," correct?

22 A I would say I rely on this exhibit as

1 evidence that the examiner of a patent application
2 to which the '315 patent claims priority, and
3 Maxeon, at the time SunPower, in producing this
4 application, understood that "impurity" includes
5 dopant.

6 Q I believe you cite page 76 of this
7 exhibit. I'm looking at the next to the last line
8 on page 18.

9 A Yes, that's correct.

10 Q And actually, let me ask a different
11 question.

12 Are you familiar with what a prosecution
13 history is?

14 A I am.

15 Q Have you prosecuted patents before, or
16 patent applications?

17 MR. SELWYN: Objection, form.

18 A I have been an inventor on many patents
19 and have participated in their prosecution,
20 including reviewing rejections, for example, working
21 with counsel to respond to those objections,
22 et cetera. I, of course, am not an attorney, so I

1 haven't filed documents to the USPTO, for example.

2 Q Under your understanding, is a file
3 history the record of the back and forth between an
4 applicant and the Patent Office?

5 A Yes, that's how I understand it.

6 Q Okay. And this page 76 that you cite, in
7 the upper left-hand corner, it says, First Action
8 Interview Pilot Program, Pre-Interview
9 Communication.

10 Do you see that?

11 A I do.

12 Q Do you know what that is?

13 MR. SELWYN: Objection, form.

14 A I don't know what the first action
15 interview pilot program is. I am familiar with
16 interviews, if I'm understanding correctly, in
17 which, for example, an applicant may have a phone
18 call with an examiner.

19 And I would presume that a pre-interview
20 communication is information -- it appears that it's
21 information provided by the examiner, in this case
22 Long Tran, perhaps in advance of an interview.

1 But I'm not sure. I'm hypothesizing
2 based on my understanding of the document I'm
3 looking at.

4 Q Does anything on this page, page 76,
5 indicate to you what the examiner thought in the
6 prior art corresponded with the quote, unquote metal
7 impurities in the claims at that time?

8 A Yes.

9 Q And what is that?

10 A In particular -- in particular, in the
11 second table with the title Expanded
12 Discussion/Commentary, the examiner, referring to
13 claim 1, refers to Yelundur, Figures 1 through 6 and
14 all relevant text, and discloses a solar cell having
15 a front side -- yada, yada, yada, I'm skipping a
16 bit -- and at the end, a first emitter layer 15,
17 paragraphs 55 and 61, having me...

18 And now we have an unfortunate document,
19 I don't know if this is a transcription problem or
20 what, but it's cut off, but I understood that the
21 examiner was referring to metal impurities,
22 particularly if we look at paragraphs 55 and 61 of

1 Yelundur, which is describing dopant atoms in the
2 emitter, and describes dopant atoms that can be
3 metals, in particular gallium, indium, aluminum,
4 antimony, or arsenic.

5 Q You don't have any knowledge regarding
6 the examiner's beliefs beyond what's in this
7 exhibit, correct?

8 A I have the entire prosecution history to
9 inform me of the examiner's belief.

10 This part here is directed towards
11 indicating to the applicant that claim 1 of the
12 application being prosecuted, which had language
13 about a first emitter region having metal
14 impurities, the examiner has identified that
15 Yelundur discloses that feature.

16 Q Well, just looking at the document, the
17 examiner says, looking at the last line of that
18 first cell that you were referencing, a first
19 emitter region, and then in parentheses is
20 identifying what in Yelundur allegedly corresponds
21 with that, correct?

22 A That's correct. Layer 15 is the first

1 emitter region, and it's described in paragraphs 55
2 and 61. And the examiner is cut off. I'm not sure
3 why. But I believe the following text would have
4 said, having metal impurities, it says, having me...

5 And the language in the claim, in claim 1
6 to which the examiner is referring to, is one
7 having -- or says, a first emitter region having
8 metal impurities.

9 Actually, if you have access to a version
10 of this document where the examiner's thoughts are
11 not cut off, that would be much appreciated.

12 Q I don't. So I guess I'm just -- just
13 confirming I guess that you don't have anything
14 beyond a truncated expression here.

15 You agree with me that the examiner does
16 not even say the word "metal impurities" in this
17 paper?

18 MR. SELWYN: Objection, form.

19 A The word "metal impurities" does not
20 appear because it's been truncated. But the
21 examiner is -- says, a first emitter region having
22 me... and the examiner is referring to claim 1,

1 that's how the cell starts, claim 1. And claim 1
2 has language, a first emitter region having metal
3 impurities.

4 So while it is truncated, I do think it's
5 reasonable to understand that the rest of the
6 truncation was, "m-e" -tal impurities, particularly
7 because the examiner cites to the part of Yelundur
8 why Yelundur describes exactly this limitation of
9 the claim, namely, emitter region that has metal
10 impurities, gallium, indium, aluminum, antimony, and
11 arsenic. Those are listed by Yelundur.

12 So I believe the examiner found this and
13 was included it in there, and Maxeon, then SunPower,
14 in the reply did not dispute this, did not amend
15 this, but instead added other features or
16 limitations to the claim unrelated to metal
17 impurities.

18 Q You're actually assuming a couple of
19 things. One is that the examiner meant to say metal
20 impurities, or, in fact, did and it's just truncated
21 and we can't see it.

22 That's one assumption. I'm more

1 interested in the second assumption.

2 You're also assuming, are you not, that
3 the examiner would have cited the same paragraphs of
4 Yelundur in alleging that the metal impurities
5 limitation was satisfied.

6 Are you making that assumption?

7 A No, I don't believe I have to. I think
8 that the examiner has cited the relevant portions of
9 Yelundur where a first emitter region having metal
10 impurities is disclosed. The citation is already
11 there. And that citation, those paragraphs, we can
12 look at them, disclose a metal impurity having --
13 excuse me -- an emitter region having metal
14 impurities.

15 Q You're not surprised that the examiner
16 wouldn't have said, a first metal region having
17 metal impurities, and then point to the portion of
18 Yelundur that allegedly discloses that?

19 MR. SELWYN: Objection, form.

20 A The examiner may have done that, in fact.
21 We don't know because it's truncated.

22 But even before --

1 (Cross-talk.)

2 Q We know the examiner didn't do that
3 because the examiner did not do that, right? I
4 mean, the examiner said, a first emitter region, and
5 then cited something in Yelundur and then perhaps
6 proceeded to identify something about metal
7 impurities.

8 MR. SELWYN: Objection, form.

9 Q Probably not the same disclosure as
10 Yelundur; otherwise, we would have seen all that
11 stuff together, right?

12 MR. SELWYN: Objection.

13 Q We would have seen the examiner group the
14 claim features that allegedly correspond with that
15 disclosure in Yelundur, right?

16 MR. SELWYN: Objection, form.

17 A I don't know what was truncated. I don't
18 feel that I can answer your question.

19 I know that we have a truncated document,
20 but in the part that persists, there is indication
21 by the examiner of a first emitter region having
22 "me" where we believe that "me" extends to metal

1 impurities, and a reference to the portion of
2 Yelundur describing a first emitter region having
3 metal impurities.

4 I believe all of that information is
5 clearly before my eyes here.

6 I don't know what the examiner wrote
7 thereafter.

8 Q You suspect the examiner meant to write
9 "metal impurities."

10 Is that fair?

11 A I do, yes. That's the language that's in
12 the claim.

13 Q Okay. Do you suspect that the examiner
14 included a citation to the prior art after "metal
15 impurities" was meant to be?

16 MR. SELWYN: Objection, form.

17 A I don't know. I'm not an examiner. I
18 don't know exactly what their normal practices are.
19 That seems very possible. But I don't know.

20 Q You also state in paragraph 36 -- and you
21 may have said it today as well. Here I am looking
22 at the top of page 19, the second line, In response,

1 the patentee did not argue that Yelundur does not
2 disclose -- I'm sorry, let me start over.

3 In response, the patentee did not argue
4 that Yelundur does not disclose the claimed metal
5 impurities. And then you proceed.

6 Do you see that?

7 A Correct.

8 Q What is the basis for your opinion that
9 the patentee did not argue that Yelundur does not
10 disclose the claimed metal impurities?

11 A I saw no evidence in the remainder of the
12 patent history of that -- of a discussion or
13 acknowledgment or rebuttal or adjustment from the
14 applicant, but rather, the addition of other
15 features unrelated to metal impurities in the
16 emitter as the approach to overcoming what was
17 identified by the examiner as a likely source of a
18 rejection.

19 Q I want you to please look at page 83 of
20 Exhibit 1036.

21 A I'm there.

22 Q It states, The following remarks are

1 provided in response to the First Action Interview
2 Pilot Program Pre-Interview Communication mailed
3 January 11, 2016.

4 Do you see that?

5 A Yes.

6 Q So this is in response to the document we
7 were just looking at, right, on page 76?

8 A That's what I understand.

9 Q Okay. It then proceeds, The applicants
10 have reviewed the Office Action and respectfully
11 disagree with the examiner's rejections.

12 Do you see that?

13 A Yes.

14 Q Did you consider that in forming your
15 opinions?

16 A Yes. That's, I believe, standard
17 language. I think every response that my counsel
18 has ever submitted to the USPTO includes that
19 sentence or one like it.

20 And then typically there's an
21 elaboration, you know, giving basis for this
22 disagreement with the rejections.

1 And then there's typically -- either
2 those disagreements are such that the claims remain
3 the same but there is an argument to the examiner of
4 why they should be allowed as is or the claims are
5 modified in response to the rejections.

6 And I believe that the applicant pursued
7 the latter approach here with a modification of the
8 claims that was unrelated to the emitter and metal
9 impurities.

10 Q Do you know why the applicants disagreed
11 with the examiner's rejections?

12 A I do not. I do not have access to that
13 information.

14 Q Could it have been that the applicants
15 did not believe that Yelundur disclosed the metal
16 impurities limitation?

17 MR. SELWYN: Objection, form.

18 A I think that's unlikely as the applicants
19 made changes elsewhere that had nothing to do with
20 the metal impurities in the emitter. But I can't
21 say for sure. I don't have, for example, the
22 transcript from the interview.

1 Q So you don't know what the applicants
2 argued to the examiner, do you?

3 MR. SELWYN: Objection, form.

4 A No. I don't believe any of us know what
5 the applicants argued to the interviewer. I just
6 know what steps they took next in pursuing -- in
7 prosecuting this patent, and that was to make
8 modifications to the claim that were unrelated to
9 the emitter and metal impurities.

10 Q So returning to your declaration, when
11 you say, the patentee did not argue that Yelundur
12 does not disclose the claimed metal impurities,
13 what's the basis for that?

14 A I believe that in this paragraph 36, I'm
15 referring to the prosecution history. That's how
16 the first sentence of paragraph 36 starts.

17 And within the prosecution history, the
18 patentee or the applicant does not make an argument
19 that's documented, as I state in paragraph 36.

20 Q The applicant made some argument.

21 Do you agree with me on that?

22 MR. SELWYN: Objection, form.

1 Q There was an interview. The applicant
2 argued something, argued the claims were allowable
3 as is, right?

4 MR. SELWYN: Objection, form.

5 A I don't know what was said on that phone
6 call. In paragraph 36, I'm referring to the
7 hundreds of pages of the prosecution history that
8 are documented and that are available for me to
9 review.

10 Q Okay. So the applicant could have argued
11 that Yelundur does not disclose the metal impurities
12 limitation.

13 Do you agree with me on that?

14 MR. SELWYN: Objection, form.

15 A I don't know what was said on the phone
16 call. The applicants could have argued many things.
17 But I do know what actions were taken next. And
18 that was a modification of the claims unrelated to
19 the first -- the emitter region and impurities.

20 Q Do you feel like you have solid footing
21 to make the contention that the patentee did not
22 argue that Yelundur does not disclose the claimed

1 metal impurities?

2 A Yes. As I've mentioned before, this
3 paragraph, you must read it in its context, and it
4 starts, the prosecution history. I am reviewing the
5 documents that I have access to. And the document I
6 have access to, that statement is correct. If read
7 within its proper context, it is true. I don't
8 know about --

9 (Cross-talk.)

10 Q Do you understand what an examiner
11 interview is?

12 A I do. I have participated in them.

13 Q Are arguments made from an applicant to
14 an examiner?

15 A Yes. But in the ones that I've
16 participated in, it's common then in the response
17 from the applicant to the USPTO to reference
18 relevant portions of the interview, you know, thank
19 you for the interview, during this time we discussed
20 this, based on that discussion, blah, blah, blah, in
21 your response.

22 And there is no such documented reference

1 to emitter region or metal impurities in the
2 response.

3 Q So what did they talk about?

4 MR. SELWYN: Objection, form.

5 A Your guess is as good as mine. There are
6 many rejections or bases for rejections identified
7 by Examiner Tran on page 76. They could have talked
8 about any of them or all of them. I don't know.

9 Q So they could have talked about the fact
10 that Yelundur does not disclose metal impurities.

11 Do you agree?

12 MR. SELWYN: Objection, form.

13 A I think I've been consistent throughout
14 this discussion and in my declaration that the
15 prosecution history, which is a written document,
16 it's a document you and I both have access to, does
17 not have evidence or any discussion of the applicant
18 arguing to the examiner that a rejection based on
19 Yelundur or metal impurities is inappropriate.
20 That's what it says. That's what I have been
21 saying.

22 What private communications the applicant

1 had between themselves and what unrecorded
2 communications the applicant had with the examiner,
3 I can only guess about, and I don't care to.

4 Q But I think you just did in your
5 declaration, did you not? You assumed that it
6 wasn't the metal impurities limitation. You made
7 that assumption, correct?

8 MR. SELWYN: Objection, form.

9 A No, that's not clear -- sorry, that's not
10 correct.

11 As I've said multiple times, my
12 declaration, in particular paragraph 36, is about
13 the prosecution history. That is a written
14 document. It's a document that you and I both have
15 access to. We can both read it. And what I say
16 about it is true.

17 I never -- I don't say, for example, in
18 paragraph 36, let me surmise about what conversation
19 the applicant and examiner had. That would be
20 inappropriate.

21 I am reviewing a written document of the
22 prosecution history.

1 Q So it would be wrong for someone to
2 interpret paragraph 36 as suggesting your
3 observations as to what the applicant actually
4 argued; rather, it's your observations as to what
5 actually is on the papers in Exhibit 1036.

6 Is that right?

7 MR. SELWYN: Objection, form.

8 A The papers are documentation of the
9 formal back and forth -- I believe you suggested
10 that language -- the formal back and forth between
11 the applicant and the USPTO.

12 And in that formal back and forth, which
13 is codified in writing here, the patentee did not
14 argue that Yelundur doesn't disclose the claimed
15 metal impurities. I think that is factually
16 correct.

17 My declaration says, in response. In
18 response to what was raised by the examiner. My
19 document also says in paragraph -- the prosecution
20 history. I'm referring to this document.

21 As I mentioned, I don't know what the
22 applicants discussed amongst themselves or with the

1 examiner in a phone call.

2 MR. SNODGRASS: I'm going to shift gears.
3 I'm happy to keep on going. I know it's been over
4 an hour.

5 MR. SELWYN: You're changing subjects?

6 MR. SNODGRASS: Yes.

7 MR. SELWYN: So why don't we take a few
8 minutes.

9 MR. SNODGRASS: Okay.

10 (Recess from 1:14 p.m. until 1:23 p.m.)

11 BY MR. SNODGRASS:

12 Q Dr. Holman, I'm going to discuss
13 paragraph 39 of your declaration. Towards the
14 middle, you state that, For example, while aluminum
15 was commonly used as a dopant in 2014, it was also a
16 known impurity.

17 Do you see that?

18 A Yes, I do.

19 Q In what part or parts of a solar cell was
20 aluminum used as a dopant?

21 A It was commonly used in the back surface
22 field at the rear of a solar cell. That was a

1 standard use of it at the time.

2 However, in 2014 and in the probably
3 decade leading up to that time, there was lots of
4 innovation and exploration of solar cell structures,
5 n-type wafers, p-type wafers, putting the emitter at
6 the front, putting the emitter at the back,
7 multicrystalline wafers, gallium doping, et cetera.

8 So there are examples of aluminum used as
9 a dopant both at the front side and the back side of
10 solar cells.

11 Q And then you cite Exhibit 1119.

12 Do you see that?

13 A Yes. Gianluca Coletti.

14 Q And I want to ask a couple questions
15 about that exhibit.

16 I guess the first two sentences -- I'll
17 give you a minute.

18 A Okay, I'm there.

19 Q Okay. The first two sentences under
20 introduction, it states, Impurities in crystalline
21 silicon can be classified into two categories,
22 dopants and contaminants. Generally, dopants are

1 intentionally added to modulate the resistivity,
2 while contaminants are unintentionally incorporated
3 during the material processing.

4 Do you see that?

5 A Yes, I do.

6 Q Do you agree with those statements?

7 A I think that that's Gianluca's take and
8 codification.

9 I think that they are mostly accurate but
10 not universally accepted.

11 He correctly understands and uses
12 impurities to be -- to mean any foreign element in a
13 host material, and that it's inclusive of dopants
14 but not only inclusive of dopants.

15 What I disagree with about this statement
16 is that it doesn't indicate that the two categories
17 may and, in fact, were overlapping. It doesn't say
18 they're not overlapping, but it's not clear that, in
19 fact, they do.

20 Q On page 83 of Exhibit 1119, there's a
21 table, Table 3-1.

22 Do you see that?

1 A Yes.

2 Q Do you agree with the information
3 conveyed in this table?

4 MR. SELWYN: Objection, form.

5 A This table is -- I would say generally,
6 yes, and this table is showing different ways of
7 making silicon. Czochralski and float zone make
8 monocrystalline wafers. These other two methods
9 make multicrystalline wafers.

10 And then some of the sources of
11 contaminants in those, aluminum, for example, is
12 included, as I've indicated in my declaration, along
13 with transition metals, which is a very large
14 category of metals.

15 Q So this table conveys different types of
16 creating a crystalline structure, or crystalline
17 product; what that product is; and how contaminants
18 may be introduced and what those contaminants are.

19 Is that right?

20 MR. SELWYN: Objection, form.

21 A That is generally the aim of the table,
22 that's correct, to simply in tabular form describe

1 these four main methods of forming crystalline
2 silicon that is -- yeah.

3 Q I want to shift forward to paragraph 44
4 of your declaration.

5 A Okay, I'm looking at it.

6 Q And you cite Exhibit 1047 in that
7 paragraph. So I'll want to look at that exhibit as
8 well. That should be towards the end of Exhibits
9 Volume 1.

10 It sounds like you're at the exhibit.
11 Okay.

12 And you reviewed all of Exhibit 1047,
13 correct?

14 A I did.

15 Q This is titled, Iron contamination in
16 silicon technology.

17 Is that right?

18 A Yes.

19 Q Do you have an understanding as to what
20 "contamination" means in that title?

21 A Yes. I believe it means incorporation of
22 iron into silicon and crystalline silicon in

1 particular. We previously described -- I previously
2 described, when you asked about the '315 patent and
3 its use of "contaminants," that iron was a bad
4 element in silicon. Still is. Causes
5 recombination.

6 And so a POSITA would expect that
7 contaminants would include iron likely, that iron
8 would be amongst them.

9 And, in fact, in many papers of the time,
10 you find the use of the word "contamination" used
11 with iron, for example.

12 Q Okay. On page 489, which is that first
13 page, the right column, first full paragraph,
14 there's the following. I believe it's the third
15 sentence. Therefore, the unintentional iron
16 contamination level in wafers is usually higher than
17 that of other metal impurities.

18 Do you see that?

19 A I do.

20 Q Do you agree with that statement?

21 A That's not always true. But here the
22 author uses "usually," and it was the case that in

1 wafers for solar in particular, iron contamination
2 was a common prevalent problem in the wafer supply
3 chain as of 2014.

4 Q So that sentence uses the expressions
5 "iron contamination," and then relates that to other
6 metal impurities.

7 Do you see that?

8 MR. SELWYN: Objection, form.

9 A Yes, I do.

10 Q Do you believe that that sentence conveys
11 an equivalency between contaminants and impurities?

12 MR. SELWYN: Objection, form.

13 A Certainly not. Contaminants, as I
14 described previously, is a subset of impurities.
15 How large the subset is, I don't know, because there
16 are elements like aluminum that can be unwanted and
17 may be called a contaminant.

18 As a matter of fact, Gianluca Coletti
19 did, just a moment ago in the same table we were
20 looking at, those same elements are also
21 purposefully introduced as dopants, as we were
22 describing before that.

1 So impurities means any element that is
2 foreign to a host material. Contaminants
3 necessarily is some subset of that. It is a subset
4 without a well-defined boundary.

5 Q I want to ask you about something on
6 page 492. This will be the left column, the second
7 full paragraph, at the very beginning.

8 Slicing and mechanical lapping are,
9 according to [69], very dirty operations, which may
10 badly contaminate wafers with a variety of
11 impurities.

12 Do you see that?

13 A Yes.

14 Q Do you agree with that statement?

15 A Yes. It is absolutely correct. Again,
16 contaminants being a subset of impurities.

17 Q Do you believe that that sentence equates
18 contaminants and impurities?

19 A Certainly not. As I mentioned, one is a
20 subset of the other, and this sentence is entirely
21 consistent with the known plain and ordinary meaning
22 of "impurities" and the less well-defined meaning of

1 "contaminant" but that it is a subset of impurity.

2 Q The next two sentences state,
3 Fortunately, the wafers are sliced and lapped at
4 room temperature, where the diffusivity of most
5 transition metals (with the only exception of
6 copper) is so low that the metals do not penetrate
7 into the bulk of silicon. Thus, almost all of the
8 contamination can be easily removed in the
9 subsequent chemical cleaning step.

10 Do you see that?

11 A I do.

12 Q That subsequent chemical cleaning step is
13 not a gettering step, correct?

14 A I believe that the authors are referring
15 to a wet processing step that is not a gettering
16 step.

17 It is worth noting that the -- this is
18 talking about impurities which may badly contaminate
19 the wafer that are introduced during slicing and
20 mechanical lapping. So that is a cutting of the
21 wafer.

22 There are, of course, many other

1 processes that introduce metal impurities, and I
2 have documented those with extensive references in
3 my declaration.

4 Q In the right column on the same page, the
5 first full paragraph states, Cleaning processes can
6 paradoxically be not only a remedy against
7 unintentional contamination, but also one of the
8 major sources of impurities in silicon wafers.

9 Do you see that?

10 A Indeed. And I, in fact, describe this in
11 my declaration that -- beginning on paragraph 58,
12 the section titled Metal Impurities Introduced By
13 Solar Cell Fabrication, and paragraph 60 describes
14 wet chemical cleaning processes and the fact that
15 the wet chemical baths can essentially become a soup
16 of impurities, where, if some wafers go in that have
17 impurities that are removed, they may stay in the
18 bath and redeposit on subsequent wafers. I describe
19 the same thing.

20 Q Do you read the sentence from
21 Exhibit 1047 that we just looked at as equating
22 impurities with things that contaminate?

1 A Which sentence are you referring to?

2 Q It's the first sentence on the first full
3 paragraph of the right column on page 492 beginning,
4 Cleaning processes.

5 A No. My answer is the same as all
6 previous times, that impurities can be sources of
7 contamination because contaminants are a subset
8 necessarily of impurities. And this sentence, like
9 all of the others, is consistent with those plain
10 and ordinary meanings of impurities and contaminants
11 being a subset of that.

12 Q I want to look at page 501, the right
13 column, the second full paragraph. About halfway
14 down that paragraph, there's a statement, Thus, a
15 single DLTS measurement may not be representative of
16 the total contamination level of the wafer, if the
17 impurity is not -- I'll start over.

18 Thus, a single DLTS measurement may not
19 be representative of the total contamination level
20 of the wafer, if the impurity is nonuniformly
21 distributed.

22 Do you see that?

1 A I do.

2 Q Does this estimate equate an impurity
3 with something that causes a contamination level?

4 A No, it doesn't equate them. An impurity
5 can cause contamination. An impurity can also be
6 phosphorous or boron. Once again, this is entirely
7 consistent with how "impurity" is used in the field,
8 and I myself would write a sentence like that.

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

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

19 Q You also -- were you finished?

20 A I am, thank you.

21 Q So also in paragraph 44, you cite
22 Exhibit 1033. I've circulated that. That will be

1 in that same binder, Exhibits Volume 1.

2 A This is the one titled, Gettering of
3 impurities in solar silicon. Is that correct?

4 Q Yes.

5 A Okay. I'm looking at it.

6 Q I want to focus on the second page,
7 page 316.

8 A Okay.

9 Q Second full paragraph, second sentence,
10 Although the number of steps required to realize
11 solar cells is low compared to integrated circuit
12 devices, the material can be also
13 unadvertently [sic] contaminated by metallic
14 impurities.

15 Do you see that?

16 A Yes.

17 Q Do you believe that this is an instance
18 of a reference stating that impurities result in
19 contamination?

20 A It is a sentence that says that material
21 can be contaminated by metal impurities. It in no
22 way implies that all impurities contaminate. That

1 would be a silly thing to write because metallic
2 impurities include dopant atoms such as aluminum,
3 gallium, antimony, et cetera.

4 So once again, those that contaminate are
5 a subset of impurities, impurities being all
6 elements that are foreign to a host material. And
7 some elements that are foreign to silicon are bad,
8 like iron, because they cause recombination that
9 reduces solar cell efficiency. That is what this is
10 saying.

11 Q Does Exhibit 1033 ever use the word
12 "impurity" to refer to a dopant?

13 A The short answer is, I don't know without
14 reading it again in detail, which I can do if you
15 would like.

16 Q No, thank you. You've read it in its
17 entirety already, correct?

18 A I have, but never with the question,
19 which is a rather specific question, that you asked
20 in mind.

21 Q Well, you've represented in your
22 declaration that -- and through your prior testimony

1 today that every publication that you have reviewed
2 in the semiconductor field consistently uses
3 "impurities" to include intentionally introduced
4 dopants.

5 A That is correct.

6 Q You stand by that?

7 A I do. The definition of "impurities"
8 includes dopants.

9 Q So we've just looked at two so far -- we
10 might get to some others -- publications that are
11 using the word "impurities" but they don't talk
12 about dopants, right?

13 A Not talking about dopants, though, is
14 different from saying that the definition of
15 "impurities," which is well-known to POSITAs and has
16 been for decades, does not include dopants.

17 Q I'll read this statement again. The word
18 "definition" doesn't appear in this statement. This
19 is 26 from your declaration.

20 A Yes.

21 Q Publications in the semiconductor field
22 consistently use "impurities" to include

1 intentionally introduced dopants.

2 Got that?

3 A Yes.

4 (Cross-talk.)

5 Q The word "definitions" isn't in there.

6 The word "definitions" is not in there, correct?

7 A No. It's about the use of the word
8 "impurities." That's correct.

9 Q Right. So we just looked at two
10 technical publications that you've included -- or
11 cited in your declaration that use "impurities,"
12 correct? They use the word "impurities"?

13 A They do.

14 Q But they don't include intentionally
15 introduced dopants, do they?

16 A The -- well, first of all, dopants don't
17 need to be intentionally introduced.

18 But more to the point of your question --

19 Q I'm just using your words, Dr. Holman.

20 MR. SELWYN: Just let him finish his
21 answer, please.

22 Q "Intentionally introduced," those are

1 your words.

2 MR. SELWYN: Let him finish his answer.

3 You can follow up.

4 A Yes. I stand by my words to be
5 "impurities" means any foreign element in a host
6 material. Every undergraduate that has taken a
7 junior level course in solid-state physics or
8 semiconductors or solar cells would know this. This
9 is a term that is used ubiquitously throughout the
10 field. It's understood by all practitioners.

11 And it means an element that is foreign
12 to a host material, that includes dopants. We see
13 that in books, such as that of Dr. Schubert,
14 Maxeon's expert. All other books that I have
15 reviewed use it in the same way.

16 And all of the publications that we've
17 looked at today are consistent with that usage.
18 They use the word "impurity" in a way that means all
19 foreign elements in a host material, and that is
20 inclusive of dopants.

21 It does mean contaminants as well, but it
22 also means dopants. It's any foreign element in a

1 host material.

2 Q Let's look at a few more. You cite
3 Exhibit 1137 [sic] in paragraph 44 of your
4 declaration --

5 (Reporter interruption.)

6 Q I'm sorry. Exhibit 1139 and paragraph
7 44.

8 So Exhibit 1139, Dr. Holman, should be in
9 Exhibits Volume 3 towards the end.

10 A 1139, you said?

11 Q Yes.

12 A I'm looking at it.

13 Q I want to focus on the conclusion on
14 page 192, the first sentence, Our ICP-MS measurement
15 results of metal impurities in mc-Si for solar cell
16 applications have shown significant amounts of Cu
17 and Ni contamination, partially higher than Fe,
18 which is normally regarded as the most abundant
19 metal impurity in such materials.

20 Do you see that?

21 A I do.

22 Q Here we see "impurities" and "impurity,"

1 both words, also used in the same sentence that
2 "contamination" is used, right?

3 A Yes. This is a common thing to do as
4 contaminants are a subset of impurities. So
5 impurities can act as recombination sites, may be
6 called contaminants, including copper, nickel, and
7 iron.

8 Q Does Exhibit 1139 use "impurities" to
9 include intentionally introduced dopants?

10 A Yes, it does.

11 Q Where is that?

12 A First two sentences of the abstract. The
13 first sentence says, The concentration of 42 metal
14 impurities in these various types of silicon have
15 been measured. The third sentence, excuse me, not
16 the second, says, We could measure aluminum,
17 titanium, chromium, manganese, gallium.

18 So at least two of those, aluminum and
19 gallium, are dopants.

20 So this publication does use the word
21 "impurities" to refer to dopants, which is not
22 surprising because the definition of "impurities" is

1 an element in a -- that's foreign to a host material
2 and therefore includes dopants.

3 Q Does the word "dopant" appear in
4 Exhibit 1139?

5 A Don't know without reading it again to --
6 in its entirety. There is mention of p-type and
7 n-type, so I would guess it probably does.

8 Q So gallium is a dopant, not an impurity,
9 right?

10 MR. SELWYN: Objection, form.

11 A No, that was not a correct statement
12 because dopants are subsets of impurities.

13 Q So it's not a contaminant. Sorry, go
14 ahead.

15 A I think I've answered your question.

16 Q I'll re-ask it.

17 So gallium is, in your opinion, a dopant,
18 not a contaminant.

19 Is that right?

20 A No, it can be either. And remember when
21 we were looking at Gianluca Coletti, I said that
22 there was overlap between atoms that can appear or

1 elements that can be dopants or contaminants.

2 So gallium is used as a dopant. I'd be
3 happy to show you papers in which that's the case.

4 It could also be a contaminant that
5 induces unwanted recombination. So it might be
6 called a contaminant because of that. And
7 particularly if it's present, for example, at too
8 high a concentration.

9 The same is true of aluminum, and I've
10 cited references in my declaration in which aluminum
11 is -- acts as a dopant and in other cases is
12 purposefully removed.

13 Q So maybe I misunderstood your prior
14 testimony. I thought you said that the third
15 sentence of Exhibit 1139 reveals an instance in
16 which "impurities" is used to refer to a dopant.

17 Did I get that wrong?

18 A That's correct. That's correct. The
19 first sentence talks about the identification of 42
20 impurities, and the third sentence identifies some
21 of those impurities as including aluminum, gallium,
22 both of which are known dopants in silicon.

1 That doesn't mean that they might not
2 also be referred to as contaminants, as I've said
3 many times.

4 "Contaminant" is not a word of art that
5 has specific boundaries, and there are elements that
6 may act as dopants or as contaminants. That is to
7 say, we understood "contaminant" to mean unwanted or
8 undesirable or causing negative effects in a solar
9 cell.

10 So aluminum and gallium are dopants.

11 Q And they're also contaminants?

12 A And they're referred to as impurities.
13 They may be -- a POSITA may refer to them as
14 contaminants, particularly if they're present in too
15 high concentration, for example, or if they're
16 present in a part of the solar cell that was not
17 designed to be doped.

18 Q Okay. So is there any indication that
19 tells you that the way gallium and aluminum are
20 referenced in the third sentence of Exhibit 1139
21 means that they are dopants and not contaminants?

22 MR. SELWYN: Objection, form.

1 A There's no indication that they are
2 either. In this particular paragraph, they're
3 identified as impurities. And once again,
4 "impurity" has a particular meaning. It means a
5 foreign element, which all of these are.

6 "Dopant" is about the -- "dopant" doesn't
7 refer to -- certain elements when incorporated
8 behave as dopants. Aluminum and gallium are amongst
9 those for silicon.

10 Certain atoms, when included, cause
11 recombination, some more than others. That's
12 undesirable for solar cells.

13 Some of these publications -- not in this
14 abstract that I'm looking at, but some of the other
15 publications refer to elements that cause unwanted
16 recombination as contaminants.

17 Q I want to shift forward to paragraph 51
18 of your declaration. Here you talk about, among
19 other things, Dr. Carroll's opinions.

20 Do you know Dr. Carroll?

21 A I do not.

22 Q Do you know of him?

1 A A little bit. And some of my colleagues
2 know him. But I don't know him personally.

3 Q Do you believe that he is more qualified
4 in the field of solar cells than Dr. Schubert?

5 MR. SELWYN: Objection to form.

6 A I believe that Dr. Carroll has a
7 publication record that is more extensive in the
8 field of silicon solar cells, which is what this
9 case is about.

10 Q Okay. So I'm looking at the sentence
11 that bridges pages 26 and 27. And you have a
12 citation at the end of that sentence to page 25,
13 line 2 to page 26, line 18 of Exhibit 1092.

14 Do you see that?

15 A I do.

16 Q Exhibit 1092, which we'll probably
17 reference, is -- should be in Exhibits Volume 2. I
18 believe you're citing that portion of his deposition
19 transcript because you believe it relates to the use
20 of silicon with impurities.

21 Is that fair?

22 A Give me just one moment to get there,

1 please.

2 Q Sure.

3 A Yes. In pages 24, 25 and 26, I believe
4 Dr. Carroll gives an accurate representation of the
5 silicon solar industry and wafers as of 2014.

6 Q So that includes his statement at
7 page 25, lines 17 through 18 where he states, You
8 don't have to do that. You can use the
9 higher-quality stuff, but it will cost you more.

10 Correct?

11 A Yes. But he continues to say, And since
12 the primary driver in the solar industry today is
13 dollars per watt, then it doesn't make sense to use
14 really expensive silicon.

15 And he goes on to say, This changed
16 sometime in the 2000s, the early 2000s, where we
17 began to go lower and lower quality silicon and
18 using more and more post processing. So today, if
19 you go and buy one, the silicon that you begin with
20 is not very high quality. But it is made to perform
21 like a high-quality silicon boule of the post
22 processing, which is similar in some ways, right.

1 This is the so-called gettering that is part of the
2 proceedings that we're discussing now.

3 So what Dr. Carroll is saying is
4 consistent with what I said in my first declaration
5 and elaborated on in my reply declaration, that the
6 quality of silicon used for the solar industry began
7 as relatively low quality, that is to say, it had
8 impurities such as iron in it, and that there were
9 techniques that were developed decades before,
10 starting in the microelectronics industry, and were
11 routine and commonplace in silicon solar cell
12 fabrication to reduce the impact of that initial
13 low-quality silicon, techniques such as gettering.

14 And Dr. Carroll is right when he says,
15 You don't have to do that. You could instead use,
16 for example, semiconductor-grade silicon. But
17 nobody did that for solar cells.

18 I myself have purchased
19 semiconductor-grade silicon, and I paid about \$75
20 for one wafer that was this size (indicating), that
21 was the going rate, whereas a solar cell wafer,
22 silicon solar wafer, is more like \$1. No one can

1 compete in the market paying the prices used for
2 semiconductor wafers if they were making solar
3 cells.

4 MR. SNODGRASS: I'm going to object to
5 everything after "yes" as nonresponsive.

6 Q I want to shift forward --

7 A Sorry. I don't know if that was a
8 question. But I thought you had asked me about what
9 Dr. Carroll's transcript said. So I just read from
10 it.

11 Q You did lots of things. It's just an
12 objection. It's really nothing to be --

13 (Cross-talk.)

14 MR. SELWYN: You can proceed.

15 Q So paragraph 52, you reference some
16 contaminant concentrations that are both mentioned
17 by Dr. Carroll and found in some reference.

18 Is that right?

19 A Yes, I do that in paragraph 52, and then
20 I elaborate in paragraphs 56 for monocrystalline
21 wafers and 57 for multicrystalline wafers.

22 Q Do you have any independent knowledge as

1 to what impurity concentrations were in silicon
2 wafers for solar cells in 2014?

3 A What do you mean by "independent
4 knowledge"?

5 Q Just without referencing Dr. Carroll,
6 without referencing this exhibit, do you just happen
7 to know through your experience?

8 A I guess I'm confused by the question. I
9 haven't -- I didn't measure in 2014 iron levels, if
10 that's what you're asking. But I, like many
11 practitioners and POSITAs, am informed by the
12 teachings from papers, from conferences, from
13 communications, and I've given examples of those
14 communications which form the basis for my knowledge
15 and would have done for a POSITA as well.

16 Q Do you know what a low level of
17 contamination would have been in 2014?

18 A For which impurity?

19 Q Let's talk about iron.

20 A Yes, I do.

21 Q What was that?

22 A So I'm going to maybe flip the question a

1 little bit and say that a significant level was one
2 that caused recombination in such a manner that it
3 would reduce the efficiency of the solar cell, and I
4 provide evidence, including plots, showing that
5 values as low as 10 to the 10th per cubic
6 centimeter, iron atoms per cubic centimeter, cause
7 deleterious effects.

8 So somewhere below 10 to the 10th,
9 perhaps below the measurable amount of iron
10 depending on the technique used, would be low enough
11 such that there wouldn't be a noticeable effect.

12 But as I refer to in these paragraphs 52,
13 56, and 58, the wafers of the day had much higher
14 iron levels than that, orders of magnitude.

15 Q You say measurable limits -- or I forget
16 the expression you used. You used the word
17 "measurable," right?

18 A Mm-hmm.

19 Q What level is measurable; what level is
20 not measurable?

21 A That depends on the impurity and the
22 technique used.

1 In paragraph 54, for example, of my
2 declaration, I refer to Shabani and Figure 7 of
3 Shabani. And in this figure, Shabani measures on
4 the x-axis wafers that had iron concentrations down
5 to 1 times 10 to the 11th and finds that even at
6 that value, there's a decrease in the lifetime of
7 the wafer, which is what happens if there's excess
8 recombination.

9 So here's one data point saying that with
10 a technique used by Shabani for iron in silicon, 10
11 to the 11th was measurable, as were higher
12 concentrations.

13 It may be that the technique could have
14 extended further down than that. I am not sure.

15 Q Are you referencing the figure at the top
16 of page 29 of your declaration?

17 A Yes, I am.

18 Q Okay. So at a contamination
19 concentration of 1 times 10 to the 11th of iron, the
20 lifetime is approximately 200 microseconds.

21 Is that right?

22 A Something like that, that's correct.

1 Q Okay. And that's 0.2 milliseconds,
2 right?

3 A That's correct.

4 Q And then I guess on the preceding page,
5 you have a Figure 3.7 from Exhibit 1119. I'll just
6 get these exhibits in the chat real quick.

7 And that shows that at an iron
8 concentration of 1 times 10 to the 10th per cubic
9 centimeter, the lifetime is slightly over
10 200 microseconds, right?

11 A So we have to be careful with that one
12 because in this plot here, there are iron -- this
13 plot is calculated based on a model called the
14 Shockley-Read-Hall recombination model. It's a
15 model recombination, for example, if there were
16 impurities in silicon.

17 And there are two different instances of
18 how iron can be incorporated in silicon. One is
19 indicated in the legend by Fe, right, just iron, and
20 the other is FeB, because this is p-type silicon
21 doped with boron, also an impurity, and it is
22 possible for the iron to hook up with the boron and

1 create a defect that is different from iron alone.

2 And so there's two different lines to
3 look at, depending on how the iron incorporates.
4 One of them, you point out correctly, is around
5 200 milliseconds -- 200 microseconds, excuse me, for
6 a concentration of 1 times 10 to the 10th.

7 The other one is the dash-dotted line,
8 which I believe is more like 1 millisecond or
9 1,000 microseconds for an iron concentration of
10 1 times 10 to the 10th.

11 In reality, the iron may have
12 incorporated in one or other or most likely some
13 hybrid of those two different configurations.

14 Q In paragraph 55 of your declaration, you
15 state, Metal impurities were present in significant
16 amounts in the types of silicon substrates
17 contemplated by Choi and Cousins; monocrystalline
18 silicon and multicrystalline silicon wafers.

19 Do you see that?

20 A Yes.

21 Q Was it also the case where there were
22 instances where metal impurities were not present in

1 significant amounts in those types of substrates?

2 MR. SELWYN: Objection, form.

3 A Metal impurities were present in
4 significant amounts, that is, amounts that caused
5 unwanted recombination, in wafers that were used in
6 solar cells. And Choi and Cousins describe in their
7 patents that they use silicon wafers to make solar
8 cells.

9 A POSITA implementing Choi or Cousins
10 would, like everybody else, use solar wafers.
11 Those, as I say here and I provide evidence, have
12 significant concentrations of, for example, iron,
13 "significant" being much above the amounts that were
14 known to negatively impact solar cell performance.

15 Q So by "significant," do you mean an
16 amount that negatively impacts a solar cell?

17 A Yes, I do.

18 Q So numbers-wise, what does that come out
19 to for iron?

20 MR. SELWYN: Objection, form.

21 A Yeah, it's going to depend on -- sorry,
22 did you finish your question?

1 Q Yeah, I did. Go ahead.

2 A Okay. It's going to depend on the metal
3 impurity. I believe you asked about iron in
4 particular. And what I'm showing from the figure at
5 the top of page 29 is that a POSITA would understand
6 that 10 to the 11th per cubic centimeter of iron
7 atoms cause negative effects in solar cells.

8 Modeling on the previous page by Coletti
9 showed that even 10 to the 10th per cubic centimeter
10 caused negative effects of solar cells. Statements
11 by Coletti and others say 10 to the 12th is known to
12 be problematic.

13 So I don't have an exact number where I
14 can say, if you're above 9 times 10 to the 9th, it's
15 bad, and everything below that is okay. But we know
16 as low as 10 to the 10th or 10 to the 11th per cubic
17 centimeter of iron was deleterious to silicon solar
18 cells.

19 Q What is it in particular about those
20 figures that tell you that?

21 A Yeah. So as you move from one point --
22 any point to the right on either of those graphs,

1 you're increasing the concentration of iron, and the
2 increased concentration of iron corresponds to a
3 lower lifetime on both graphs.

4 And lifetime influences the J_{naught}
5 value. I know we've talked about J_{naught} in other
6 discussions, perhaps not today. And J_{naught}
7 influences the open circuit voltage of a solar cell.
8 And the open circuit voltage is one of three
9 parameters that are multiplied together to calculate
10 the efficiency of a solar cell.

11 And a POSITA understands these things.
12 These are basic operational physics of solar cells.
13 So a lower lifetime will lead to a lower VOC, open
14 circuit voltage, which will lead to a lower
15 efficiency solar cell.

16 So any time these plots say that, hey,
17 you know, if you're at 10 to the 11th and you move
18 any to the right, any higher concentration, your
19 solar cell is going to take a hit.

20 Q And at least in the case of Exhibit 1139,
21 there are some dots and then a line on the graph,
22 right?

1 A I'm sorry. Which one was Exhibit -- oh,
2 Shabani?

3 Q Yes.

4 A That's correct. The dots are
5 experimental measurements, I believe, and I believe
6 the line is a fit to those.

7 Q Looks like they have extrapolated on the
8 right-hand side, right?

9 A It does look that way.

10 Q Do you believe that an extrapolation on
11 the left-hand side would be appropriate?

12 A I would be cautious in doing that. And
13 perhaps that's why the authors haven't extrapolated.
14 Because we know that at some point in time, the iron
15 would become so dilute, so little iron, that the
16 lifetime would be limited by other things, not by
17 defect recombination at iron. That is to say, there
18 must be a plateau somewhere on the left side of the
19 graph.

20 So I would be careful with a linear
21 extrapolation because one knows a priori that that
22 extrapolation must end.

1 Q But at least for the ranges that they've
2 done the best fit line, there's a linear
3 relationship, at least on the log-log scale, of
4 contamination levels versus lifetime, right?

5 A That's right. A linear relationship on a
6 log-log --

7 (Reporter interruption.)

8 A A linear relationship on a log-log scale
9 is a power law relationship. And we could say
10 perhaps simpler that there is a monotonic dependence
11 of lifetime on iron concentration, at least between
12 concentrations of 10 times -- 1 times 10 to the 11th
13 to mid-10 to the 14ths. That's what Shabani shows
14 with this data.

15 Q Okay. So Cousins is one of the primary
16 references you rely on, correct?

17 A That's correct.

18 Q And this is Exhibit 1007, which I believe
19 you have. You should have it in Exhibits Volume 1.
20 Cousins teaches a long lifetime, correct?

21 MR. SELWYN: Objection, form.

22 A One second while I pull up Cousins,

1 please.

2 So Cousins teaches an n-type silicon
3 substrate for the purpose of making a solar cell.
4 So an n-type silicon solar wafer. And it goes on to
5 say that the -- that substrate may comprise a long
6 lifetime, 2 to 5 milliseconds, n-type silicon wafer.

7 So Cousins at least teaches the
8 possibility of the n-type silicon substrate for
9 silicon solar cells having a lifetime of between
10 2 and 5 milliseconds.

11 Cousins doesn't say whether that is the
12 lifetime measured of the incoming wafer or at the
13 end of fabrication, for example, after
14 post-gettering, but does indicate that at some time,
15 the wafer may have 2 to 5 millisecond lifetimes.

16 Q Okay. And comparing that to the charts
17 that are at pages 28 and 29 of your declaration,
18 that lifetime is not shown, right? That lifetime is
19 too high?

20 A 2 to 5 milliseconds exceeds the lifetimes
21 on the y-axes of Shabani's Figure 7, for example,
22 but Shabani's Figure 7 is for p-type wafers, not

1 n-type wafers, which is what Cousins is referring
2 to. And n-type wafers tend to have higher lifetime
3 than p-type wafers, everything else being the same.
4 I described this in my first declaration.

5 Q And what type of wafer is Coletti,
6 Exhibit 1119?

7 A I can double-check, but I believe it's a
8 p-type wafer, because as we described previously,
9 Coletti simulates iron linked up with boron, and
10 boron is a p-type dopant.

11 Q Looking at paragraph 56 of your
12 declaration, you state in the second sentence, Iron
13 was an abundant contaminant.

14 Do you see that?

15 A Yes.

16 Q And you stand by that, right?

17 A Yes. I give evidence for that. It was
18 present at values between, say, 10 to the 13 and 10
19 to the 16 in silicon solar wafers. I believe
20 Dr. Carroll suggested a number of 10 to the 15th.
21 That's in paragraph 52.

22 Q In paragraph 57, you cite Exhibit 1031.

1 That citation is going to be at the end. So I want
2 to pull up Exhibit 1031.

3 A Oh, Bultman. Okay.

4 Q On the first page, the right-hand column,
5 the first full paragraph, the first sentence, it
6 states, For the majority of commercial solar cells
7 the wafer is p-type, but there is an increasing
8 interest in n-type silicon. Reasons for the
9 interest in n-type silicon are the absence of
10 light-induced degradation due to boron-oxygen
11 complex formation and the lower sensitivity to
12 impurities of n-type silicon compared to p-type
13 silicon.

14 Do you see that?

15 A Right, yes.

16 Q Does the use of the word "impurities"
17 there mean contaminants?

18 A The use of the word "impurities" means
19 the plain and ordinary meaning of "impurities." It
20 means a foreign element in a host material.

21 In this particular instance, I believe
22 that Bultman is describing something that I also

1 described in my first declaration, and I just
2 provided to you in my previous answer, which is that
3 lifetimes tend to be higher in n-type silicon than
4 p-type silicon.

5 And one of the reasons is, for the same
6 concentration of iron or of chromium or of nickel in
7 a p-type wafer or an n-type wafer, the n-type wafer
8 will usually suffer from less recombination caused
9 by those impurities and therefore have higher
10 lifetime.

11 I believe that's what Jan Bultman is
12 referring to here, although that level of detail is
13 not provided.

14 Q But having lower sensitivity to something
15 is beneficial if that thing is a contaminant,
16 correct?

17 MR. SELWYN: Objection, form.

18 A Having lower sensitivity is beneficial if
19 that impurity is causing unwanted recombination,
20 like iron, yes.

21 Q Would it make sense to have a greater
22 interest in n-type silicon because it has a lower

1 sensitivity to dopants?

2 MR. SELWYN: Objection to form.

3 A Yes. And lots of the industry was
4 interested in n-type silicon as of 2014. I believe
5 I described that in my first declaration.

6 But there was a challenge, and that was
7 that the majority of the supply chain was p-type,
8 and I provide evidence for that in my reply
9 declaration.

10 It's later in the document where I show a
11 graph from the ITRPV, International Technology
12 Roadmap for Photovoltaics -- that was a roadmap that
13 came out in every year -- showing that in 2014,
14 about 95 percent of the silicon solar supply was
15 p-type, and there was a prediction that there
16 wouldn't be a switch to predominantly n-type wafers
17 until at least 2018.

18 And indeed, that came to pass. It was
19 only really in the last three or four years that the
20 wafer supply switched in the solar industry and
21 n-type silicon became widely available.

22 So n-type was known to be a great

1 substrate for making high-quality silicon solar
2 cells, but it wasn't very available, and it was more
3 expensive.

4 Q Dr. Holman, is it your opinion that the
5 authors of Exhibit 1031 used "impurities" in the
6 portion that I just recited to refer to dopants?

7 A No. I think that this use of
8 "impurities" is probably referring to elements like
9 iron that don't act as dopants but do cause unwanted
10 recombination. And that's consistent because iron
11 is an impurity, as are dopants. Once again, it's a
12 foreign element in a host material.

13 Q Also in Exhibit 1031, on page 72, the
14 right column, the last paragraph, second sentence.

15 A Which page was that? Sorry.

16 MR. SELWYN: 72.

17 THE WITNESS: 72.

18 Q Right. 72, right column, last paragraph,
19 second sentence, it begins, Highly doped.

20 Are you there?

21 A Highly doped. Sorry, I must have missed
22 it again. Page 72, rightmost column, second

1 paragraph, I see, it begins with, Standard
2 diffusion.

3 Q No, I'm sorry. In specific cases. It's
4 the next paragraph.

5 A Got it. I'm with you.

6 Q So let me read that sentence. Highly
7 doped (distorted) layers may act as sinks for
8 impurities during gettering.

9 Do you see that?

10 A Yeah.

11 Q Do you believe "impurities" refers to
12 contaminants?

13 A In fact, the next sentence elaborates on
14 what the authors mean. They clarify, At high
15 temperatures, lifetime-degrading impurities in the
16 base of the cell become mobile.

17 So I think they're specifically talking
18 about lifetime-degrading impurities.

19 Q In other words, contaminants, right?

20 MR. SELWYN: Objection to form.

21 A That's your suggestion of the use of
22 "contaminants." As I mentioned -- I will say yes,

1 contaminants are commonly -- a common way to use
2 that word would indicate impurities that cause
3 lifetime degradation.

4 Q Okay. Or another way of looking at this,
5 the authors certainly didn't mean to be referring to
6 dopants in that passage, right?

7 MR. SELWYN: Objection to form.

8 A No. The authors are referring to
9 lifetime-degrading impurities in the base of the
10 cell. I do not believe they're referring to
11 dopants. But dopants are impurities.

12 And I don't know whether the authors
13 refer to dopants as impurities in this paper. They
14 may. It's a common thing to do because dopants are
15 impurities, as you find, for example, in
16 Dr. Schubert's book.

17 Q Okay. There may be, like, an extra
18 negative in our prior exchange, so I just want to
19 kind of re-ask the question.

20 In this passage that we've just discussed
21 on page 72, do you agree with me that the authors
22 are using "impurities" to refer to contaminants but

1 not dopants?

2 A Yes. The authors elaborate that they are
3 referring to the gettering of, quote,
4 lifetime-degrading impurities, unquote.

5 And so I believe they're referring to
6 things like iron in that instance.

7 Dopants are also impurities, but they
8 clarify that they're talking about impurities that
9 are in the base that become mobile and that are
10 being gettered.

11 Q I want to shift --

12 A As a matter of fact -- sorry. As a
13 matter of fact, in the next sentence they even say,
14 the impurities may end up primarily in the emitter
15 (they are gettered).

16 Q I want to look at paragraph 59 of your
17 declaration. About halfway through that paragraph,
18 you state, This sawing process causes mechanical
19 damage to the wafer surface and can introduce metal
20 impurities below the surface.

21 Do you see that?

22 A Yes.

1 Q Are you suggesting that gettering is
2 required to remove those impurities that are
3 introduced below the surface?

4 A It may be. So if they're introduced
5 below the surface, then a number of things can
6 happen.

7 If a subsequent step etches off more
8 silicon or a greater depth of silicon than the depth
9 at which these introduced impurities reside, then
10 that may have removed the introduced impurities.

11 If a high temperature step is used,
12 however, the impurities may diffuse deeper into the
13 bulk of the wafer and then gettering would be
14 required.

15 So it depends. But I will note that this
16 is one source of impurities, the sawing process.
17 And as I've described, there are many sources of
18 impurities, both upstream of this step, for example,
19 in the making of the wafer, and downstream of this
20 step, for example, in subsequent diffusion.

21 So the short answer to your question is,
22 it may.

1 Q And actually, the reference that you
2 cite, Exhibit 1120, says that etching is used to
3 remove those impurities, correct?

4 A Why don't we go ahead and look at that
5 reference, if we could.

6 Q It should be in your Volume 3.

7 A Yeah. Yeah. If I can quote from page 8
8 where my declaration refers to, Indeed the
9 mechanical damage -- and it's referring to that from
10 the sawing process -- even at a microscopic scale,
11 can introduce impurities below the surface of the
12 wafer. If these impurities are not thoroughly
13 removed by proper etching procedures, they can
14 diffuse deep into the wafers during the following
15 high temperature processes or contaminate chemical
16 baths employed in solar manufacturing.

17 So that's, I think, exactly what I
18 explained in my previous response about gettering
19 may be required, particularly if they diffuse deep
20 into the wafer.

21 It's also useful, I think, to look at
22 page 9 of Coletti, the last paragraph that says --

1 could be the second to last, looks like there's a
2 line break or line spacing missing. It says, In
3 conclusion, the impurity source is not only the
4 quartz employed by impurities are also introduced
5 during the silicon refinement process and during the
6 fabrication of ingots and solar cells. Therefore,
7 refinement, removal and passivation mechanisms
8 occurring along the overall production chain are
9 crucial for the final performance of the solar cell
10 and are integral part of the silicon refinement
11 process.

12 Q Returning to page 8, the paragraph that
13 you were quoting from, it concludes, Therefore, high
14 importance should be given to the cleaning steps,
15 cleaning of baths and of vessels, and the purity of
16 the de-ionized water employed in order to avoid
17 replating effects and consequent bulk contamination
18 during high temperature processes.

19 Correct?

20 A Yes, that's right. Again, per the
21 paragraph that I read on page 9, it's -- Gianluca
22 Coletti is saying that it's important all along the

1 supply chain to try to minimize the integration of
2 and facilitate the removal of lifetime-degrading
3 impurities, and he identifies the cleaning step as
4 an opportunity to get rid of impurities that were
5 introduced during sawing, and also a risk, because
6 if you don't do it well, that you can exacerbate the
7 problem, diffusing impurities deep or contaminating
8 your baths.

9 Q So page 8 of this exhibit doesn't teach
10 gettering. In fact, it teaches the opposite of
11 gettering, right? It teaches you better etch and
12 you better etch well so you don't have problems
13 later on, correct?

14 MR. SELWYN: Objection to form.

15 A No. Etching is certainly not the
16 opposite of gettering. Both are techniques that
17 were used in the solar industry to achieve the same
18 purpose, in fact, which was to try to remove
19 elements such as of iron that reduce lifetime.

20 Q Okay. Etching does not take contaminants
21 from one part of a solar cell and put them into
22 another, correct?

1 A Etching happens before there is a solar
2 cell. It's usually done on the wafer before there's
3 additional layers.

4 And what it would do is it would remove
5 silicon, and if there are impurities in that
6 silicon, they would be removed as well.

7 And so to the extent that it removes
8 impurities that cause recombination from the wafer,
9 it achieves the same thing as gettering. They both
10 remove impurities that degrade lifetime from the
11 wafer; in the case of a chemical bath, removes it
12 into the chemical bath; in the case of gettering,
13 usually removes it into something like an emitter.

14 Q So if someone is following the teachings
15 of the exhibit that you're citing right here, 1120,
16 they are not going to run into a situation where
17 they are gettering metal impurities from a substrate
18 into a polysilicon emitter layer later, correct?

19 MR. SELWYN: Objection, form.

20 A No. I disagree. So the very next
21 sentence on page 8 of Gianluca's thesis here says,
22 Impurity gettering and defect passivation take place

1 during emitter formation. Impurity gettering -- and
2 he cites papers -- is a kind of solid/solid
3 segregation process caused by the higher
4 solubilities of impurities in the phosphorus (used
5 as emitter p-type wafers).

6 So Gianluca Coletti is aware, like me and
7 like POSITAs, that multiple steps are used, again,
8 all along the supply chain or the value chain of
9 solar to try to mitigate the introduction of
10 lifetime-reducing impurities and remove them. He
11 says that on page 9.

12 And he understands that both etching and
13 gettering are techniques, particularly they're
14 techniques happening during solar cell fabrication,
15 that are important to use in order to achieve this.

16 So Gianluca is not contrasting or saying,
17 use cleaning, not gettering. He's pointing out that
18 both of these are important techniques for achieving
19 a common goal.

20 Q Isn't he saying, use cleaning to remove
21 the impurities that are introduced as a result of
22 sawing?

1 MR. SELWYN: Objection, form.

2 A Yes. And he's also saying, use gettering
3 as well. These are both techniques needed and
4 useful to remove lifetime-degrading impurities.

5 Q Does he suggest to use gettering to
6 remove the impurities that are introduced as a
7 result of sawing?

8 A Yes, I believe he does. He points out
9 that impurities introduced by sawing could -- they
10 can diffuse deep into the wafer. And he talks then
11 about gettering, particularly for fast and
12 relatively fast diffusing impurities, iron,
13 chromium, copper, nickel, and diffusing those --
14 sorry -- gettering those.

15 He doesn't say that impurities introduced
16 in step X must be removed via step Y. He says,
17 impurities can be introduced at these eight
18 different steps or so. He has a whole diagram about
19 it, right, on page 4, all of the different steps
20 along the supply chain in which impurities can be
21 introduced. And then he says, there are ways of
22 removing these. One of them is cleaning; one of

1 them is gettering.

2 MR. SELWYN: Jacob, when you get to a
3 good stopping place, let's take another five.

4 MR. SNODGRASS: Now works.

5 MR. SELWYN: Okay.

6 (Recess from 2:40 p.m. until 2:50 p.m.)

7 BY MR. SNODGRASS:

8 Q Dr. Holman, I want to continue our
9 discussion on gettering with reference to paragraph
10 63 of your declaration.

11 You say that, Gettering was a commonly
12 used process used during -- excuse me. Gettering
13 was a commonly used process during solar cell
14 fabrication.

15 Do you see that?

16 A Yes.

17 Q How many different kinds of gettering are
18 there?

19 MR. SELWYN: Objection, form.

20 A I'm not sure what you mean by the
21 question. There are different physical mechanisms
22 that can be at play in a gettering process, but we

1 refer to all of them as gettering.

2 Q Do you know what chemical gettering is?

3 A That's not a word that we -- that's not a
4 phrase that we typically use together. But you may
5 be referring to gettering because of the presence of
6 certain elements like phosphorous in a polysilicon
7 layer, for example.

8 Q Well, I was referring to Exhibit 1047,
9 which I believe I've already circulated, page 518.
10 There's a section 6.6, Chemical gettering.

11 Do you see that?

12 A Ah, he's referring to chlorine gettering
13 in particular. Yes, I see it.

14 Q Okay. But you're not familiar with the
15 phrase "chemical gettering."

16 Is that fair?

17 A It's not always or very commonly called
18 chemical gettering. It's often referred to the
19 element that's used to facilitate it. So for
20 example, you see the previous section is called,
21 Phosphorous gettering, which was my go-to when you
22 said "chemical gettering." In the previous section

1 before that, it's called aluminum gettering.

2 So I typically refer to in here "chlorine
3 gettering" rather than "chemical gettering" as a
4 term used to refer to chlorine gettering in
5 particular.

6 Q Do you know what backside mechanical
7 damage gettering is?

8 A I'm sorry, which type?

9 Q Backside mechanical damage gettering.

10 A Yes, I do know what that refers to. It's
11 a broader class of -- it's part of a broader class
12 of gettering in which a damaged typically
13 crystalline layer has a greater solubility of, for
14 example, iron than if it was perfectly crystalline.
15 And, in fact, the mechanism gettering into
16 polysilicon is an example of this.

17 Q Do you agree with Dr. Carroll's testimony
18 that gettering includes the introduction of atoms to
19 interact with a contaminant so that they no longer
20 have adverse effects?

21 MR. SELWYN: Objection, form.

22 A It can be. And so, for example, I

1 mentioned phosphorous gettering. It's one of the
2 sections of this paper on page 518. And the
3 efficacy of a gettering process can be enhanced, for
4 example, by phosphorous. And so one could say that
5 the introduction of phosphorous is part of the
6 gettering process.

7 Q Do you also agree with Dr. Carroll that
8 interfaces between layers can act as sinks for
9 impurities?

10 MR. SELWYN: Objection, form.

11 A Yes, that is the case. The interface
12 between two layers is necessarily a defect, and it's
13 an extended defect in space. And defects can be a
14 place at which elements or impurities like iron
15 accumulate, for the same physical reasons that I was
16 just saying a moment ago where polysilicon or other
17 structurally damaged layers cause impurities to
18 accumulate.

19 Q I want to shift forward to paragraph 65
20 of your declaration. You make the statement,
21 Dr. Carroll and I agree that gettering was necessary
22 for solar cell fabrication as of 2014.

1 Do you see that?

2 A Yes.

3 Q Do you believe that is Dr. Carroll's
4 opinion?

5 A Well, we can look at the transcripts.
6 Looks like it's Exhibit 1092.

7 So yes, I believe that's Dr. Carroll's
8 opinion on page 25 of Exhibit 1092, his transcript
9 at the bottom of the second full paragraph. He
10 says, In order to accommodate that -- referring to
11 lower quality silicon being used -- excuse me --
12 higher quality silicon being gobbled up by the
13 semiconductor industry.

14 He says, In order to accommodate that,
15 the silicon solar industry typically uses a lower
16 grade of silicon, and so post processing is
17 necessary in order to make these materials perform
18 better.

19 Then he goes on to elaborate on the next
20 page, But it is made to perform like a high-quality
21 silicon boule because of the post-processing,
22 referring back to what he said was necessary on the

1 previous page. And then the next sentence is, this
2 is the so-called gettering.

3 So yes, I believe that Dr. Carroll
4 believes that and has clearly communicated that in
5 his deposition.

6 Q So just now you skipped over something.
7 I just want to be sure you didn't skip it over when
8 you read it before.

9 The sentence after the sentence you were
10 quoting on page 25 states, You don't have to do
11 that. You can use the higher-quality stuff, but it
12 will cost you more.

13 Did you see that when you were
14 formulating your opinions?

15 A Yes. And, in fact, we've already
16 discussed it during this deposition today. And
17 Dr. Carroll goes on to elaborate, You can use the
18 higher-quality stuff -- he's referring to
19 semiconductor-grade silicon which he mentions in the
20 previous paragraph -- but it will cost you more.
21 And since the primary driver in the solar industry
22 today is the dollar per watt, then it doesn't make

1 sense to use really expensive silicon.

2 So Dr. Carroll says silicon solar
3 industry doesn't use semiconductor-grade silicon,
4 and I agree with him on that.

5 And I've told you that I have personal
6 experience buying semiconductor-grade silicon
7 between 2010 and 2012, and I'm aware that it costs
8 about a factor of 100 more than solar-grade silicon,
9 and that would have been known to a POSITA as well.

10 And so then he goes on to state what I
11 already read, saying, the post-processing, the
12 post-processing that he said was used in the solar
13 industry to clean up the silicon, is gettering.

14 MR. SELWYN: I'll move to strike
15 everything after "yes."

16 Q Do you believe that it would make sense
17 to use the higher-quality stuff in space
18 applications?

19 MR. SELWYN: Objection, form.

20 A It could. That is to say, space has a
21 higher tolerance for high costs. Much lower volume
22 of solar cells are consumed by the space industry

1 but much higher cost.

2 However, the space environment often
3 commonly degrades the silicon that was put in it in
4 solar cells, and so it didn't always make sense to
5 start necessarily with high-quality silicon if it
6 was going to degrade.

7 Short answer is, space industry could
8 tolerate the higher cost, but didn't necessarily
9 use -- didn't necessarily have other motivations to
10 use electronic-grade silicon over solar-grade
11 silicon.

12 And, in fact, the space industry stopped
13 launching silicon solar cells in the '90s with a
14 switch to III-V-type solar cells. And a lot of the
15 solar-grade silicon that we're talking about emerged
16 after this stop of using silicon for space.

17 Maybe a different way of saying that is,
18 the space industry wasn't using silicon as of 2014
19 for other reasons.

20 Q In paragraph 66 of your declaration, you
21 state, Dr. Schubert reads my testimony out of
22 context to assert as if I admitted that gettinging

1 was not necessary for solar cell fabrication if
2 using wafers with less than significant levels of
3 metal impurities.

4 Do you see that?

5 A Yes, I do.

6 Q I'm sure you know what comment you made
7 that he's referring to there, correct?

8 A I do, yes.

9 Q Do you stand by your original comment,
10 that gettering was only required in solar cells with
11 significant metal impurity levels in the wafer?

12 MR. SELWYN: Objection to form.

13 A If you'll just give me one moment, I'm
14 going to that section of my first declaration.

15 Q So this is Exhibit 1003.

16 A Paragraph 83, yep.

17 Q Yeah.

18 A Yes. I stand by what I wrote both in my
19 first and my reply declarations. So if we look at
20 my first declaration, this is in the background
21 section, I'm talking about semiconductors generally,
22 I'm talking about solar cells, talking about the

1 physics of recombination, haven't yet started
2 talking about wafers.

3 And I make a statement that, Gettering
4 was only required in solar cells with significant
5 metal impurity levels in the wafer.

6 I think that is tautologically correct
7 because the point of gettering is to remove metal
8 impurities that cause recombination. If there were
9 no metal impurities or if they were insignificant,
10 they wouldn't need to be gettered. That's what my
11 sentence says.

12 But the question is, what is significant?
13 And in my reply declaration, I elaborate and
14 describe that anything above 10 to the 10th or 10 to
15 the 11th of iron, for example, is significant
16 because it reduces solar cell efficiency. We had
17 that discussion.

18 And then I also elaborate that wafers
19 used in the solar industry had higher levels of iron
20 typically by orders of magnitude.

21 And indeed, on the next paragraph of my
22 original declaration, paragraph 84, I go on to say,

1 Gettering was particularly relevant in the solar
2 cell industry, which, as of the filing date of the
3 patent, oftentimes used lower grade silicon wafers.

4 So these are consistent. I have
5 elaborated, and I stand by these statements.

6 MR. SELWYN: I'll move to strike as
7 nonresponsive.

8 Q You accuse Dr. Schubert of taking your
9 testimony out of context, correct?

10 A I wouldn't say I accuse. I write that he
11 has read my testimony out of context. And I just
12 gave you the context, you know, given by the next
13 paragraph and given by my reply declaration.

14 Q Okay. So the context that he omitted to
15 include was the following paragraph, paragraph 84 of
16 your declaration.

17 Is that right?

18 A Well, it's more than paragraph 84. I
19 continue to elaborate through the end of paragraph
20 93 of my original declaration about the state of the
21 art -- or state of silicon wafers as of 2014 in the
22 solar industry, and I show that there were

1 significant levels of metal impurity at the time.

2 Q Do you contend in your reply declaration
3 that the substrate of Choi would necessarily have
4 had iron or copper?

5 MR. SELWYN: Objection, form.

6 A I contend that Choi teaches silicon solar
7 cells made on silicon wafers, and that the silicon
8 wafers used in the solar fabrication had iron
9 impurities and could also have copper impurities.

10 I do not contend --

11 (Cross-talk.)

12 MR. SELWYN: Let him finish his answer,
13 please.

14 MR. SNODGRASS: I thought he was
15 finished.

16 A My apologies. I paused.

17 I do not contend that Choi says, use
18 wafers with iron impurities. That was unnecessary.
19 A POSITA understood the state of wafers in 2014. I
20 was attending conferences at the time, and this was
21 a big topic that you couldn't miss.

22 MR. SNODGRASS: I'm going to move to

1 strike as nonresponsive.

2 Q Is the answer to my question no? Your
3 reply declaration does not contend that the
4 substrate of Choi would necessarily have had iron or
5 copper?

6 MR. SELWYN: Objection, form.

7 Q I'll ask a new question.

8 In your reply declaration, do you contend
9 that the substrate of Choi would necessarily have
10 had iron or copper?

11 MR. SELWYN: Objection to form.

12 A No, my reply declaration does not contend
13 that Choi teaches that one must use a wafer with
14 iron or copper. Rather, Choi teaches using silicon
15 wafers for the solar industry. It was well-known
16 what the state of those were. And I elaborate on
17 that.

18 Q Do you contend in your reply declaration
19 that Cousins has a substrate that necessarily
20 includes iron or copper?

21 A My answer is the same as for Choi, but
22 with the additional information that Cousins does

1 contemplate and teach that metal contamination --
2 that he understands that metal contamination was
3 problematic at the time, and that one should take
4 steps to reduce metal contamination. And I think
5 we've talked about the quote in -- the text in
6 Cousins that refers to that.

7 Q You're referring to cleaning, right?

8 A I'm referring to Cousins' mention of
9 metal contaminations.

10 Q Which is removed by cleaning, not
11 gettering, right?

12 MR. SELWYN: Objection, form.

13 A Cousins' statement says, The damage etch
14 step may also include cleaning of the substrate 101
15 to remove metal contamination, which, similar to our
16 discussion of Coletti, is one of several steps that
17 could be used to reduce metal contamination.

18 So Cousins understands that the wafer may
19 have metal contamination.

20 Q And Cousins understands that that metal
21 contamination can be removed before there's anything
22 put on the substrate, right?

1 A Cousins teaches that one way to remove
2 metal contamination is through a damage etch step of
3 the wafer. This was well-known and routine, as was
4 gettering.

5 Q And done before any other layer was
6 placed on substrate 101, correct?

7 A The chemical etching step is done on bare
8 wafers, that is correct. Gettering is typically
9 done in a high-temperature step, usually concurrent
10 with diffusion.

11 Q So the portion of Cousins that you're
12 referring to cannot possibly result in metal
13 impurities being transmitted into anything that
14 could be construed as an emitter, right?

15 MR. SELWYN: Objection, form.

16 A I disagree. In this section, Cousins is
17 warning about metal contamination, which, as we've
18 discussed, was a problem along the silicon wafer in
19 solar cell fabrication supply chain.

20 And as we've discussed from other
21 references, that cleaning through a damage etch step
22 can remove metal contamination if it's on the

1 surface, but metal contamination can also go into
2 the bulk of the wafer, and the metal contamination
3 can also go into the bath and contaminate subsequent
4 wafers, you know, after which gettering is
5 necessary, as it was for solar wafers that were
6 incoming into the solar fab anyway.

7 And so what I'm pointing out is that
8 Cousins understands, as every POSITA did at the
9 time, that silicon solar wafers struggled with metal
10 contamination, and that metal contamination came
11 from multiple sources, all the way from the sand
12 that the silicon was made from to some of the last
13 processing steps of the wafer, and there were
14 multiple ways to remove the metal contamination,
15 amongst them gettering, and also etching.

16 And you find these described, for
17 example, in Gianluca Coletti's thesis, which
18 describes the whole scope of metal impurities that
19 cause recombination in silicon. And you find
20 reference to that in Cousins' patent application.

21 Q So I want to get -- I want to make sure I
22 got this right.

1 So column 4, lines 23 through 34,
2 describes the receipt of substrate 101 and a
3 subsequent cleaning process.

4 Do you agree with me so far?

5 MR. SELWYN: You're referring to which
6 exhibit?

7 Q This is Cousins, Exhibit 1007.

8 A Let me get that back in front of me.
9 Just one moment, please.

10 Oak, I'm looking at Cousins, column 4.

11 Q Lines 23 through 34.

12 A Yes, I'm looking at lines 23 through 34.

13 Q It talks about a damage etch step, right?

14 A Correct.

15 Q Is it your testimony that that damage
16 etch step may result in impurities being transmitted
17 from a silicon substrate into an emitter layer?

18 A It is my testimony that this text
19 describes Cousins' concern about metal
20 contamination, and it was known by all POSITAs that
21 metal contamination during damage etching can result
22 in metals in the baths or in wafers, which would

1 make gettering -- which was commonplace, ubiquitous,
2 I think we've heard said by Maxeon experts -- would
3 make such a gettering step even more critical.

4 So I do not claim that Cousins says
5 "getter" in this testimony here -- sorry, in this
6 text here. It's clear that he doesn't. He doesn't
7 need to. He says that the specification is not
8 limited to those things that are said within it.

9 And I understand that claims are meant to
10 be understood in the context of what a POSITA knew
11 at the time, and it was common knowledge that wafers
12 had metal contamination and could receive additional
13 metal contamination during fabrication, as Cousins
14 indicates.

15 MR. SNODGRASS: I'm going to move to
16 strike as nonresponsive.

17 Q Dr. Holman, is it your testimony that the
18 damage etch step referenced in column 4, lines 23
19 through 34 of Exhibit 1007 could possibly result in
20 impurities from a substrate being gettered into a
21 polysilicon emitter layer?

22 MR. SELWYN: Objection to form.

1 A Unless I misunderstood, I think that was
2 the same as the previous question, which I answered.

3 Q Was that a yes or a no, just for my
4 convenience?

5 MR. SELWYN: Objection to form.

6 A I can answer again if you'd like.

7 It's my testimony that Cousins, in this
8 text between 23 and 35, describes metal
9 contamination which is consistent with what a POSITA
10 understood at the time, that wafers coming into
11 solar cell processing commonly had metal
12 contamination and could pick up additional metal
13 contamination during the solar cell fabrication, and
14 that it was known that there were ways to try to
15 mitigate or remove that metal contamination, one of
16 which is etching, and that's described by Cousins in
17 this text.

18 Another of which, which was ubiquitous,
19 was gettering, and that metals that, for example,
20 weren't exclusively on the surface or went from bath
21 to bath or wafer to wafer or were diffused
22 throughout the wafer in subsequent high-temperature

1 steps would require gettering to remove, and the
2 most common place to getter metal impurities was
3 into the emitter because it typically contained a
4 dopant, could be made of polycrystalline which
5 enhanced gettering. All was this was routine.

6 Q Are you finished?

7 A I am. Thank you.

8 MR. SNODGRASS: Move to strike as
9 nonresponsive.

10 Q Dr. Holman, I'm going to give you another
11 opportunity to answer my question. If you don't
12 know, you don't know. We can move on.

13 Is it your testimony --

14 MR. SELWYN: Hold on, Jacob. No
15 speeches. I think he is being responsive. You're
16 entitled to follow up on the answer, but you
17 shouldn't be critical.

18 MR. SNODGRASS: I'm entitled to ask
19 questions and get answers. I'm asking questions.
20 I'm not getting answers.

21 MR. SELWYN: Well, objection.

22 MR. SNODGRASS: I'll give him an

1 opportunity to answer again. I've let him give his
2 speech two times.

3 MR. SELWYN: It's not a speech. It's a
4 response to your question.

5 MR. SNODGRASS: Make your objection, and
6 then we'll move on, okay? No speeches from you
7 either.

8 MR. SELWYN: I have. I'm just saying you
9 shouldn't be -- you shouldn't express criticism of
10 the witness. You can move to strike. That's your
11 right. But it's not proper to express criticism of
12 a witness.

13 MR. SNODGRASS: I'm trying to ask a
14 question.

15 MR. SELWYN: Why don't you proceed.

16 Q Dr. Holman, again, just -- I'm just
17 trying to make this easy on you. If you don't know,
18 you don't know, and we can move on.

19 Do you have the opinion that the
20 disclosure at column 4, lines 23 through 34
21 disclosing a damage etch step could result in metal
22 impurities being gettered from a silicon substrate

1 to a polysilicon emitter layer?

2 A I do know the answer to the question.

3 I've given the answer. I will try one more time.

4 It's clear, I think, to both of us that
5 this text refers to the possibility of metal
6 contamination. Also a procedure that one could and
7 should use to remove metal contamination, a damage
8 etch step. This was well-known, and I have cited
9 references in my reply declaration that talk about
10 this.

11 A POSITA also understood at the time, and
12 a POSITA has his or her, you know, ordinary
13 ingenuity and also breadth of knowledge in reading
14 patent applications, that a damage etch step could
15 actually spread contaminants between wafers, or it
16 might not remove all of the impurities. Gianluca
17 Coletti talks about this. I'm happy to provide
18 other resources if you want.

19 And a POSITA reading this would
20 understand that Cousins' concern about metal
21 contamination is a common concern of the industry,
22 and that, you know, incomplete removal of

1 contamination during an etch step would make a
2 gettering process, which was also standard, more
3 important.

4 It's also the case, as I've elaborated
5 both in my original declaration and my reply
6 declaration, that the most common way to getter in
7 the solar industry was to getter elements like iron
8 from the wafer into the emitter.

9 And so a POSITA reading Cousins would
10 understand this additional context about metal
11 impurities in wafers.

12 Indeed, even without this paragraph from
13 Cousins, a POSITA would understand these things,
14 that wafers had metals that needed to be gettered if
15 they were wafers for silicon solar cells.

16 Cousins acknowledges as well that metal
17 contamination is important.

18 Q Are you finished?

19 A I am, yes.

20 MR. SNODGRASS: All right. Move to
21 strike as nonresponsive.

22 Q Dr. Holman, are you not going to answer

1 my question yes or no?

2 A I believe I have answered it three times.
3 I've done my best.

4 Q Is it yes or is it no?

5 A Do you want to ask your question one more
6 time? I'll try once again.

7 Q Is the answer to my question yes or no?

8 MR. SELWYN: Objection.

9 Q The answer that you provided three times,
10 is that a yes or is it a no?

11 MR. SELWYN: Objection, form.

12 A I've -- I think I've answered the
13 question three times now.

14 (Cross-talk.)

15 Q Go ahead.

16 A Not all questions have answers that are
17 yes and no with nothing afterwards. Sometimes they
18 need to be couched within context. I'm trying to
19 provide the context based on the knowledge of a
20 POSITA as of 2014 and what he or she would have
21 understood in reading Cousins.

22 Q Can you give me the yes or the no? I

1 already have the context. Can you give me the yes
2 or the no as well?

3 A I feel that it's appropriate for the
4 answer to be -- I don't think the answer is as
5 simple as yes or no. I think -- because I think
6 that the question doesn't have a simple yes or no
7 answer.

8 I can tell you what is stated in Cousins,
9 and I can tell you what a POSITA knew and would
10 understand as reading Cousins. I think I've done
11 that, though.

12 Q I can read Cousins as well. So I don't
13 need you to read Cousins to me. And you've --

14 A What I know --

15 (Cross-talk.)

16 A My apologies. Go ahead.

17 Q I want you to focus on my question. I
18 want you to focus on my question.

19 Do you have the opinion that what is
20 disclosed at column 4, lines 23 through 34 of
21 Cousins is a step by which metal impurities can be
22 gettered from a substrate to a polysilicon emitter

1 layer?

2 MR. SELWYN: Objection, form.

3 Q That is my question.

4 A I think you've actually asked a different
5 question this time.

6 Q No. That's the question I've been
7 asking, perhaps not verbatim. Do you have that that
8 opinion is my question. Do you agree with me that
9 you either have the opinion or you don't, right?
10 You either have the opinion or you don't, right?
11 You agree with me or not, right?

12 MR. SELWYN: Just ask the question.

13 Q No. We're not getting anywhere with
14 that. We have to break this down.

15 MR. SELWYN: No, you've --

16 (Cross-talk.)

17 MR. SELWYN: Objection, form. I don't
18 know what you're asking.

19 A Maybe I'll try again.

20 So you said something interesting, which
21 is that we can both read Cousins, and I agree with
22 that. But I believe I bring something in addition

1 as an expert witness, which is what a POSITA knew.
2 And since we can both read Cousins, I'm trying to
3 provide information about what a POSITA knew.

4 You asked this time what I think is a
5 slightly different question, which is, does this
6 text describe a gettering process. And the answer
7 to that is, no, it does not describe a gettering
8 process in this text.

9 What it describes is the presence of
10 metal contamination and a removal step which may
11 accentuate the need for gettering which was already
12 used throughout the industry and which was known to
13 be necessary by POSITAs. I feel like I've answered
14 it the same way. But perhaps that's helpful for
15 you.

16 Q Do you agree with me that you either have
17 an opinion on a matter or you do not? Do you agree
18 with that?

19 MR. SELWYN: Objection, form.

20 A Yes, I agree with that.

21 Q So here's my question. My question is
22 going to be whether you have an opinion. Okay? So

1 it can be answered yes or no. If you don't think
2 so, tell me why. But I think it can be answered yes
3 or no.

4 Do you have the opinion that what is
5 described at column 4, lines 23 through 34 of
6 Exhibit 1007 is a process by which contaminants from
7 a substrate can be gettered into a polysilicon
8 emitter layer?

9 A Let me try phrasing this for you.

10 No, I do not have the opinion that this
11 text is describing a gettering process.

12 I have the opinion that this text is
13 describing metal contamination, an etching step that
14 is one of multiple known by a POSITA at the time to
15 remove impurities, and it is a step that may make it
16 more important to use another impurity removal step,
17 gettering. And a POSITA understood and knew this as
18 of 2014 and would read this in that context.

19 Q Do you have the opinion that the damage
20 etch step discussed at column 4, lines 23 through 34
21 is a process by which contaminants from a substrate
22 would be transmitted to a polysilicon emitter layer?

1 A No, I do not have the opinion that the
2 damage etch step will transfer impurities into an
3 emitter.

4 I have the opinion that the damage etch
5 step may transfer impurities into the wafer and even
6 other wafers, or it may not fully remove existing
7 impurities from the wafer, and those impurities will
8 be transferred to an emitter during a subsequent
9 step in which they are gettered, a step that was
10 ubiquitous and known to POSITAs as of 2014.

11 Q In paragraph 66 of your declaration, you
12 make the statement that -- this is at the top of
13 page 35, first full sentence, As I explained above
14 in paragraphs 48 through 62, solar-grade wafers as
15 of 2014 typically contained significant levels of
16 metal impurities.

17 Do you see that?

18 A Yes.

19 Q What do you mean by "typically"?

20 A I mean if one was to go purchase silicon
21 wafers for making solar cells, one would expect that
22 they have significant levels of metal impurities

1 because when they arrived, that's normally what you
2 got.

3 Q You're not suggesting that that was
4 necessarily going to be -- let me start over.

5 You're not suggesting that as of 2014,
6 all solar-grade wafers contained significant levels
7 of metal impurities, are you?

8 MR. SELWYN: Objection to form.

9 A Per my declaration, I've given lots of
10 evidence of the common problem of impurities, and I
11 have given lots of references that describe those,
12 references that say that they're ubiquitous, that
13 gettering is necessary, et cetera.

14 I can't say with confidence that there
15 wasn't a wafer out there on the market that didn't
16 require this, but as I've mentioned, and as I mean
17 by "typically," POSITAs would expect that the wafers
18 they received had impurities and needed to be
19 gettered because that was their experience.

20 Q In your opinion, a POSITA would know that
21 significant levels of metal impurities had to be
22 gettered, right?

1 A That significant levels of metal
2 impurities were present in the wafers that they were
3 ordering and that gettering would be required. Both
4 of those things, yes.

5 Q To lower the level of impurities below a
6 significant level, right?

7 A To move those impurities to a place
8 within the solar cell where -- such that their
9 concentration within the wafer where they cause
10 recombination was no longer significant.

11 Q So to a point below some number that
12 we're not sure of, but below 10 to the 10, right?

13 MR. SELWYN: Objection, form.

14 A Ideally. Ideally. It might be that
15 impurity gettering doesn't get you all the way down
16 to an insignificant level, but its purpose is
17 certainly to reduce.

18 Q So a POSITA would know that they could
19 have a significant level of metal impurities, but
20 the best course is not to try to getter them out.

21 Is that right?

22 MR. SELWYN: Objection, form.

1 A I'm sorry. No. That doesn't make sense.

2 A POSITA understood that the wafers come with
3 significant levels of impurities and that a
4 gettering step would reduce them and reduce their
5 effect, and that that was commonly done.

6 Q But a person of ordinary skill would not
7 have been motivated to remove every impurity in the
8 substrate, right?

9 A A person of ordinary skill in the art
10 would have been motivated to try to reduce the
11 levels below those that are significant; that is,
12 those that cause deleterious recombination.

13 The technology didn't necessarily exist,
14 depending on the starting wafer, to be successful in
15 every instance of getting all the way down to
16 insignificant levels. But that was the aim.

17 Q Do you have a ballpark as to what those
18 levels were?

19 MR. SELWYN: Objection to form.

20 A I'm sorry.

21 Q What's your best guess as to what the
22 dividing line was between significant levels of

1 metal impurities and insignificant levels?

2 MR. SELWYN: Objection, form.

3 A Well, as I've mentioned previously, it
4 depends on the metal impurity. We could take iron,
5 for instance. We haven't talked a lot about this,
6 but it also depends on where those metal impurities
7 are located in the wafer. For example, if they're
8 close to the front surface, they could be more
9 detrimental than at the rear surface because the
10 generation rate of electron-hole pairs is higher at
11 the front surface than the rear surface because
12 greater absorption of sunlight occurs at that
13 surface.

14 So I probably need a bit more detail
15 about where in the wafer they are present. But as I
16 mentioned for iron, getting below 10 to the 10th per
17 cubic centimeter would be a good target.

18 Q I want to shift forward to paragraph 77
19 of your declaration.

20 MR. SELWYN: Jacob, just for planning
21 purposes, we're on a slightly different meal
22 schedule than you are. So at some point, in the

1 next half hour, if we can take a break for lunch.

2 MR. SNODGRASS: I can break now. But I
3 have no problem breaking mid-whatever. So if you
4 guys want to --

5 MR. SELWYN: What's your preference? Do
6 you want to go on, or do you want to break now?

7 THE WITNESS: Maybe another 15 minutes or
8 so.

9 MR. SELWYN: Does that work?

10 MR. SNODGRASS: Okay.

11 A Paragraph 77, did you say?

12 Q 77, yeah.

13 A Okay, I'm looking at it.

14 Q We have Istratov, the Istratov reference
15 being cited in this paragraph.

16 Do you see that?

17 A Yes.

18 Q Do you agree that the motivation behind
19 the efforts of Istratov was to getter impurities
20 from a device layer to a substrate?

21 A Istratov's motivation is to study the
22 physics of gettering. And that's why Istratov

1 reports things like diffusion coefficients.
2 Istratov is trying to advance the state of the art
3 in what is known about gettering physics,
4 particularly for the case of iron in a silicon,
5 silicon oxide, polysilicon structure.

6 Istratov motivates the study, his
7 interests about physics of gettering, with a device
8 of relevance from the semiconductor industry for
9 which the -- that had or that could have impurities
10 in a polysilicon layer that a practitioner might
11 want to accumulate in a crystalline silicon layer.

12 But the physics of moving through the
13 oxide layer is the same, and it's those physics
14 that's Istratov's purpose.

15 Q Have you studied Istratov closely,
16 Dr. Holman?

17 A Yes, I have.

18 Q So with your expertise and your review of
19 the documents, do you agree that the motivation
20 behind the efforts of Istratov was to getter
21 impurities from a device layer to a substrate?

22 A Can you ask your question one more time?

1 I was just re-familiarizing myself with certain
2 passages of Istratov.

3 Q Do you agree that the motivation behind
4 the efforts of Istratov was to getter impurities
5 from a device layer to a substrate?

6 A No, I wouldn't say it that way. I would
7 say what I said before, which is that I think that
8 Istratov is motivated to study the diffusion of
9 iron --

10 (Reporter interruption.)

11 (Technical interruption.)

12 A That Istratov was motivated to study the
13 diffusion of iron in this structure, and that's why,
14 if you look at Istratov's figures, for example,
15 Figure 1 is diffusivity. Figure 2 and Figure 3 are
16 about collection of iron in polysilicon layers. 4
17 and 5 are about copper in polysilicon layers. And
18 then there's a whole modeling section after that.

19 So I think Istratov's purpose is to study
20 the physics of these metal movements in the
21 structure. I think that Istratov provides an
22 example in the introduction and some in the

1 conclusion of an application of Istratov's
2 teachings. And that application comes from the
3 microelectronics industry.

4 I know that a POSITA would also read this
5 in the context of other microelectronic devices and
6 semiconductor devices, including solar cells. And,
7 in fact, Istratov wrote other papers on solar cells.
8 And Istratov's Ph.D. advisor, the last author that
9 is referenced here, is one of the premier solar
10 researchers in the U.S.

11 MR. SNODGRASS: I object to everything
12 after the word "no."

13 Q In paragraph 77 of your declaration, you
14 state, Istratov's experiments and simulations
15 gettered metal impurities from a silicon wafer
16 through an oxide layer into a polysilicon layer.

17 Do you see that?

18 A Yes.

19 Q I believe the experiments are in
20 section 3 of Istratov.

21 Is that right?

22 A Yes, that's correct.

1 Q Where are the simulations that you
2 reference?

3 A Okay. So in section 4, Istratov does
4 modeling of the diffusion process and describes the
5 structure that is modeled, which is a wafer with a
6 150 nanometer thick oxide layer and a 100 nanometer
7 thick silicon layer on top.

8 And Istratov describes distributing iron
9 in this structure in three different ways in his
10 model; one in which it's uniform throughout the
11 whole structure, one in which the iron is in the
12 device layer only, which I read to be the
13 100 nanometer silicon, and one in which the iron is
14 distributed in the substrate only, which I read to
15 be the 725 micron thick substrate that is the wafer.

16 And so that is what I'm referring to when
17 I say that Istratov's experiments and simulations
18 getter from a silicon wafer through an oxide layer
19 into a polysilicon layer.

20 Q What experiment is Istratov undertaking
21 in section 3?

22 A In section 3, Istratov has a silicon

1 wafer on which is grown a silicon oxide layer
2 approximately 197 nanometers thick, on top of which
3 is grown a polysilicon layer 370 nanometers thick.

4 Istratov then purposefully contaminates
5 the rear side of the wafer, that is, the side not
6 having the oxide and polysilicon, to introduce iron
7 or copper impurities.

8 Istratov then heats these substrates in
9 furnaces -- or these samples in furnaces and
10 measures the distribution of iron and copper as a
11 function of thickness through the sample after the
12 heating.

13 Istratov finds that the heating leads to
14 gettering of the iron and the copper, in particular
15 the iron and copper move all the way through the
16 silicon substrate from the back side, through its
17 thickness, goes through the oxide layer, and
18 preferentially accumulates in the polysilicon layer,
19 which is what we would expect as gettering from
20 wafers into polysilicon layers was long known and
21 practiced, but not necessarily with an oxide layer.
22 Istratov shows that the gettering works even through

1 an oxide layer. That's what section 3 of Istratov
2 teaches.

3 Q Do you agree with me that section 3 was
4 performed to determine or verify the materials
5 parameters to be used in subsequent modeling?

6 A Yes, that section 3 was performed per the
7 title, it says, Diffusivity and segregation
8 coefficient. So I think that in section 3, Istratov
9 performed these experiments in order to understand
10 the physics of gettering, which was my answer to
11 your first question about the purpose of Istratov,
12 in order to understand these -- in order to get
13 values for diffusivity and segregation coefficient.

14 Q You have reproduced a couple of figures
15 of Istratov in your declaration. I'm looking here
16 in paragraphs 74 and 75. You've highlighted some of
17 the curves in yellow.

18 Do you see that?

19 A Yes. I am looking at a black-and-white
20 version, but yes, I have them in color here. Thank
21 you.

22 Q And you've also highlighted some of the

1 arrows in color, in yellow.

2 Do you see that?

3 A Yes.

4 Q Why are you highlighting the arrows?

5 A Oh, to identify where the polysilicon
6 region is.

7 Q Are those arrows meant to direct the
8 reader to the correct y-axis?

9 MR. SELWYN: Objection to form.

10 A Yes, that is correct. That's correct.
11 So for iron in the first figure, it's Figure 2, one
12 should look at the left axis, iron concentration.
13 And for copper, that's Figure 5 in Istratov, one
14 should look to the -- again, the left axis, copper
15 concentration.

16 Q Those arrows are not meant to reflect the
17 direction of movement of any particular category of
18 atoms, correct?

19 MR. SELWYN: Objection, form.

20 A You are correct. They are not meant to
21 indicate movement. In fact, while we've been
22 talking here about the direction of diffusion,

1 diffusion is described as a random walk process.

2 It's Brownian motion.

3 So during diffusion, iron atoms will, in
4 fact, flow randomly, move randomly in all
5 directions. But as they do so, they may selectively
6 accumulate at an area that acts like a sponge.

7 And in this case, polysilicon acts like a
8 sponge. And so they accumulate in the polysilicon,
9 and there is this net movement from where they
10 started to where they ended, but it's not as if they
11 were directed there, which would be the case if they
12 were ions and it was an electric field or they were
13 electrons and it was an electric field. It's that
14 they take a random walk, and they all end up
15 congregating in this polysilicon sponge.

16 The arrows are not meant to indicate
17 anything about iron movement or copper movement.

18 Q It's been 15 minutes. Do you want a
19 break?

20 A Sure.

21 (Recess from 3:50 p.m. until 4:17 p.m.)

22 BY MR. SNODGRASS:

1 Q Dr. Holman, is there any testimony you've
2 given so far today that, upon reflection, you
3 realize is incorrect and you want to clarify?

4 A No.

5 Q Okay. I want to focus on paragraph 81 of
6 your declaration, Exhibit 1089. Is it fair to say
7 this paragraph talks generally about Choi and a
8 time-temperature combination?

9 A Yes, that's correct.

10 MR. SNODGRASS: And I guess just for the
11 record, I've circulated Exhibit 1012, which was
12 Istratov, we talked about before the break, and I'll
13 circulate now Exhibit 1006, which is Choi.

14 Q Okay. Your opinion is that, It was
15 within the level of ordinary skill for a POSITA as
16 of 2014 to calculate an appropriate temperature and
17 time for gettering.

18 Do you see that?

19 A Yes.

20 Q Then you say, Gettering simulation tools
21 were available as early as 2003.

22 Do you see that?

1 A Yes.

2 Q What parameters would a POSITA have
3 needed to entered into those tools in order to
4 determine a time and temperature?

5 A A POSITA would need to enter into the
6 tools input data like the thickness of a wafer, the
7 doping type of the wafer, and then structural
8 information like thickness of the oxide layer or
9 thickness of a polysilicon layer, doping density of
10 the polysilicon layer.

11 So basic input data about the structure
12 of the device that is being simulated, plus the
13 metal impurity of interest to the gettering.

14 Q Do you agree that most of those
15 parameters are not specified by Choi or Cousins?

16 A Choi and Cousins do not provide
17 limitations to those parameters. But Choi and
18 Cousins talk about silicon solar wafers. A POSITA
19 understood what a typical thickness of the wafer
20 was.

21 Choi and Cousins talk about -- Choi at
22 least talks about the thickness of the tunnel oxide

1 layer and gives a range of values. Doesn't
2 constrict it to one, but gives a range of values.

3 So the information that was new in Choi
4 and Cousins is specified in Choi and Cousins.
5 Information that was well-known in the field, like
6 what a typical wafer thickness is, is not
7 necessarily specified, and that's typical in patent
8 applications, in my experience.

9 Q Do you believe Choi is assuming a
10 terrestrial application?

11 A Let me turn to Choi for just a moment.

12 So Choi doesn't specify, and I don't
13 understand Choi's teachings to be limited to any
14 particular use case of the solar cell that Choi
15 describes.

16 But in the background section,
17 paragraph 5, for example, of Choi, Choi talks about
18 conventional energy resources such as petroleum and
19 coal being depleted, interest in alternative energy,
20 et cetera.

21 Petroleum and coal are used as energy
22 sources on earth, so I think that this paragraph

1 suggests that at least terrestrial use of solar
2 cells is contemplated by Choi. But again, there's
3 no limitation, I think, of how Choi's solar cell
4 might be used.

5 Q You believe Cousins discloses a
6 particular application, i.e., terrestrial or space?

7 A My answer is very similar to my answer
8 for Choi. I don't see anything in Cousins that
9 limits Cousins' teachings to a particular
10 application.

11 But I do see that column 1, the last
12 paragraph of the background of the invention
13 section, talks, for example, about power plants and
14 residential applications, from which I read that
15 Cousins was at least contemplating terrestrial
16 applications for his solar cell.

17 Q In order to use the simulation tools that
18 you reference in paragraph 81, would a POSITA have
19 also wanted to know the beginning concentration of
20 the contaminants as well as the desired ending
21 concentration of the contaminants?

22 A If a POSITA did know that, it would be

1 helpful, but it wouldn't be necessary. So a common
2 thing to do would be to treat that as a variable
3 parameter and to simulate for a range of initial
4 concentrations, sweeping, for example, between 10 to
5 the 13 and 10 to the 16 atoms per cubic centimeter
6 of iron, and looking at the results.

7 The optimum time-temperature combination
8 likely does not depend on the initial starting
9 concentration, but the final concentration in the
10 polysilicon and the amount that the concentration in
11 the wafer was reduced would, of course, depend on
12 the initial concentration.

13 Q And would the POSITA have been aiming to
14 achieve an ending concentration in the wafer?

15 A I think we described this a bit before.
16 The POSITA's ideal state would be values low enough
17 that he or she believed that there wouldn't be
18 substantial recombination. We described that
19 that's, say, 10 to the 10th or lower would be a
20 great target.

21 But a POSITA's preliminary goal before
22 that in, say, using these tools would say -- would

1 be to find out what time and temperature
2 combinations, likely not one, or only one, most
3 reduce the concentration in the wafer.

4 Q Would the ideal ending concentration in
5 the wafer depend on the thickness of the wafer?

6 A Not necessarily. Concentrations are
7 given in values of per cubic centimeter. And so a
8 thicker wafer that has 10 to the 15 per cubic
9 centimeter has more, say, iron in it overall than a
10 thinner wafer, but it has the same density. And the
11 recombination is the Shockley-Read-Hall
12 recombination, which is the recombination that
13 occurs at defects, including those from metal
14 impurities, depends on the concentration.

15 Q And all other things being equal, the
16 lower the contaminant concentration, the greater the
17 lifetime, correct?

18 A Correct. At least down to 10 to the 10th
19 per cubic centimeter for iron per that result that
20 we were looking at previously in the graph from
21 Shabani. As I mentioned, at some point in time, it
22 will be diminishing returns.

1 Q Even before you reach 10 to the 10th,
2 though, is it possible that you've achieved a long
3 enough lifetime that the hole or electron is going
4 to reach the emitter, or will likely reach the
5 emitter --

6 MR. SELWYN: Objection, form.

7 Q -- such that you've already reached
8 diminishing returns even before 10 to the 10th?

9 MR. SELWYN: Objection, form.

10 A Yeah, there's multiple facets to your
11 question. It is possible that you reach diminishing
12 returns before that if there are other sources of
13 recombination that become the dominant one.

14 So for example, if I have a solar cell
15 that has iron in it at 10 to the 12th per cubic
16 centimeter, but I have no surface passivation layer
17 on the front of my surface, it doesn't matter if I
18 further reduce the iron concentration because my
19 device performance is going to be limited by instead
20 surface recombination because of the lack of
21 passivation.

22 But, you know, the devices described by

1 Choi and Cousins, for example, have good surface
2 passivation and are otherwise described and
3 engineered to be good solar cells.

4 Q And in my question and in your answer, I
5 think each of us used the word "before." And I
6 intended to use that word coming from a higher
7 concentration to a lower concentration. So for
8 example, coming from the right-hand side of the
9 figures that you've reproduced at pages 28 and 29 of
10 your declaration.

11 Did you use the term "before" in a
12 similar manner?

13 A I don't remember exactly how I used the
14 word "before." But I did mean the same thing as
15 you, which is, as you move from the right-hand side
16 to the left-hand side of the figure on page 29 of my
17 reply declaration, it could become flat at
18 concentrations above 10 to the 11th if, for example,
19 there was another source of recombination in the
20 solar cell that was severe and dominant.

21 Q Okay. Do you have a best guess as to
22 what Cousins's initial iron concentration is?

1 MR. SELWYN: Objection, form.

2 A No, I don't have a best guess because the
3 wafer is not the innovative part of Cousins. He
4 doesn't spend a lot of time on it. I think he
5 assumes that, you know, a POSITA reading his patent
6 application will know everything that a POSITA knows
7 about wafers.

8 And so there's no specification or detail
9 of, thou shalt use this wafer in order to make my
10 invention work, and it must have below this metal
11 concentration or any other such thing.

12 Q Okay. But if one followed the teachings
13 to use a substrate with a long lifetime, e.g., 2 to
14 5 milliseconds, do you have a best guess as to what
15 the iron concentration would be in that wafer?

16 MR. SELWYN: Objection, form.

17 A I don't off the top of my head. The data
18 that we have been looking at that's in my
19 declaration is for p-type wafers, as came up.
20 Cousins is for n-type wafers. And as we've
21 discussed, n-type wafers are less sensitive.

22 The other thing that isn't clear to me

1 is, and I've mentioned this before, at what point
2 this statement is true, a long lifetime n-type
3 silicon wafer.

4 So ultimately, what you care about is the
5 lifetime after the solar cell fabrication. So I
6 don't know if this is the lifetime at the end of
7 cell fabrication after passivating the surfaces, for
8 example, after performing a gettering step, in which
9 case a wafer may have had relatively high metal
10 impurity concentrations to begin with.

11 And Cousins, I think, indicates that this
12 is a possibility when he says, hey, be careful about
13 metal contamination and make sure you use a damage
14 etch step, and that these lifetimes of 2 to 5
15 milliseconds are what you achieve at the end of cell
16 fabrication. But that's not clarified.

17 Q In certain of your opinions, you are
18 using a p-type wafer, though, correct, with regard
19 to certain dependent claims?

20 A Yes. Claims 13 and 14, I believe you're
21 referring to, consider a solar cell with a p-type
22 wafer and a p-type front surface field. Choi

1 considers, for example, that the wafer may be
2 p-type.

3 Q Okay. So in that circumstance where we
4 do have a p-type wafer, we have 2 to 5 millisecond
5 lifetime, per the graphs that you're including in
6 your declaration, the iron concentration is pretty
7 low, correct?

8 MR. SELWYN: Objection, form.

9 A Well, you're mixing and matching there.
10 So Choi teaches a p-type wafer; Cousins doesn't.
11 Cousins teaches 2 to 5 milliseconds, which makes
12 sense in the context of n-type wafers but doesn't
13 make sense in the context of p-type wafers.

14 I myself did work on the some of the
15 highest quality p-type wafers I could get my hands
16 on in the 2012 time frame, and they did not reach
17 2 to 5 milliseconds.

18 So Choi doesn't say anything about 2 to 5
19 milliseconds, and wouldn't in the context of p-type
20 wafers, because they simply wouldn't have reached
21 that lifetime for the supply that was available,
22 even if really the best wafers that money could buy.

1 Q Can't just take Cousins and swap out the
2 n-type wafer for a p-type wafer?

3 MR. SELWYN: Objection, form.

4 A I think you can take the teachings of
5 Cousins and apply those teachings to a p-type wafer.
6 I simply said that Cousins doesn't say, use a p-type
7 wafer and then give a lifetime the way that Cousins
8 says, you can use an n-type wafer and gives a
9 lifetime.

10 If Cousins were to have included a p-type
11 wafer explicitly in his patent application, I don't
12 expect he would have used the same lifetime range.

13 Q You've not endeavored to ascertain a
14 suitable time-temperature combination that could be
15 employed to either Choi or Cousins that would result
16 in gettering and would also not be detrimental to
17 the solar device, right?

18 A I haven't been asked to do that. As
19 mentioned, I would need to go ahead and pick a few
20 specific values from ranges described by Choi or
21 Cousins, like a silicon oxide thickness range, and
22 then some additional information like, are we going

1 with a pure n-type wafer.

2 And then I, like a POSITA, could use the
3 modeling tools available, which I've described in my
4 declaration, and provide you with time-temperature
5 combinations that would be suitable for reaching a
6 given solar cell efficiency.

7 Q And you're sure that those
8 time-temperature combinations would not be
9 detrimental to the solar cell?

10 A I am confident that it would be possible
11 to choose a time-temperature combination that would
12 not be detrimental to the solar cell.

13 Istratov teaches 1020 degrees C for eight
14 hours, which is a long time at a comparatively hot
15 temperature. But it's for a thick oxide layer,
16 many, many times thicker than that taught by Choi,
17 for example.

18 And a POSITA would have understood that
19 the diffusion process is one such that if you make a
20 layer thinner, then you can pass things through it
21 faster for the same temperature or at a lower
22 temperature for the same time.

1 And, in fact, I include in my reply
2 declaration another Istratov reference in paragraph
3 82 where Istratov himself points out, hey, based on,
4 you know, what's known about the diffusivity of iron
5 and silicon dioxide, you would be able to move iron
6 through a 10 nanometer oxide within several minutes
7 at a thousand degrees C.

8 So that alone right there suggests that,
9 you know, Istratov is going and doing the
10 calculations that I'm suggesting, and that a POSITA
11 would look at that and know to narrow in, okay, I
12 can go a thousand degrees Celsius shorter than
13 several minutes or I could stick at several minutes
14 or longer and I could drop the temperature further.

15 Q And putting aside your capabilities as an
16 expert, a POSITA would have to -- even using these
17 tools that you mentioned would have to engage in
18 protracted simulations and experimentation in order
19 to arrive at this time-temperature combination,
20 correct?

21 MR. SELWYN: Objection, form.

22 A A POSITA would need to use his or her

1 normal ingenuity in making the combination. But
2 these are routine things that POSITAs do in the
3 design, fabrication, manufacturing of solar cells.
4 These are not extraordinary hoops that we're talking
5 about.

6 Q I want to shift to paragraph 89 of your
7 declaration and the Marvin reference. Marvin is
8 Exhibit 1008. I'll drop that in the chat.

9 So Dr. Holman, let's look at Marvin, in
10 particular page 16.

11 A Okay, I'm looking at it.

12 Q I'm looking in the first paragraph,
13 second sentence. It begins, In cases where.

14 And my question is, do you agree that a
15 terrestrial environment and a space environment with
16 shielding are both low radiation environments?

17 A Yes. And I think that this makes -- this
18 sentence makes that clear. It says, In cases where
19 radiation exposure is not present as the result of
20 shielding or terrestrial use.

21 So terrestrial use is a subset of a low
22 or no radiation environment. But they are not

1 equivalent. Space with shielding is also a subset
2 of a low radiation environment.

3 Q Okay. And now I want to jump back to
4 your declaration, although I think we'll reference
5 Marvin here shortly. So if it's helpful, maybe you
6 could have both open.

7 I want to look at paragraph 91 of your
8 declaration. Next to the last sentence, which is
9 quite long, you make the statement -- and I'll just
10 try to pull out the relevant aspects of it. Let me
11 know if you think I'm doing so in a way that changes
12 its meaning.

13 But you state, the FSF design with a
14 doping concentration of 5 times 10 to the 18th per
15 cubic centimeter from patent owner's conclusion on
16 page 25 is optimal for 100 sun applications.

17 Do you see that excerpt?

18 A Yes, I do.

19 Q Do you agree that Marvin also teaches
20 that a doping concentration of 5 times 10 to the
21 18th per cubic centimeter is optimal for certain
22 1 sun applications?

1 A I didn't rely on whichever text you may
2 be referring to in my combination. Could you point
3 me to what you're looking at?

4 Q You're right. It's on page 25 of Marvin.
5 I guess it's the fourth sentence that says, The FSF
6 should be an approximately 0.5 micron step with
7 doping concentration of 5E18 per cubic centimeter.
8 And then the next sentence is, These parameters are
9 much more critical for 100 sun operation.

10 A Yes, I see that.

11 Q Okay. And then it goes on, The 1 sun
12 efficiency of IBC cells exceeds 15 percent, and it
13 proceeds, right?

14 A Yes, I see that.

15 Q Okay. So do you understand the sentence,
16 The FSF should be at approximately 0.5 micron step
17 with doping concentration of 5E18 per cubic
18 centimeter to refer to both 1 sun and 100 sun
19 applications?

20 A It's a little bit unclear to me. The
21 beginning of the paragraph talks about the solar
22 cells being for space use. So this isn't something

1 that I relied on in my combination because when
2 Marvin in this document is talking about space use,
3 he's been optimizing for end of life efficiency.

4 But I can tell from, The FSF should be in
5 approximately 0.5 micron step with doping
6 concentration of 5 times 10 to the 18th, these
7 parameters are much more critical for 100 sun
8 operation -- I can tell that it's important for 100
9 sun operation for space use to -- space use with a
10 low radiation environment, he clarifies, to use
11 that.

12 The next thing says what the 1 sun
13 efficiency is, but it doesn't tell me whether or not
14 that those parameters are optimal for that case.

15 I instead rely on the teachings on page
16 15 where he very clearly says that for beginning of
17 life and for 1 sun applications, the best FSF has 10
18 to the 17 to 10 to the 18 per cubic centimeter
19 doping density.

20 Q We also see these numbers, 10 to the 17,
21 10 to the 18, on page 25, right?

22 A Correct.

1 Q In the second paragraph, looking at the
2 fourth sentence of the second paragraph, The FSF is
3 graded over 15 microns with a peak doping
4 concentration of 1E17 to 1E18 per cubic centimeter.

5 Do you see that?

6 A Yes, indeed.

7 Q So is it just a coincidence that --
8 before we get there, you agree with me that the
9 second paragraph addresses a space application,
10 right?

11 A Yes. It says, high radiation
12 environment, which one wouldn't expect on earth
13 unless Armageddon cometh.

14 Q So it's a space application with no
15 shielding, right?

16 A Or insufficient shielding. It is what it
17 says, a high radiation environment.

18 Q It's certainly not terrestrial?

19 A Correct. I agree.

20 Q So this paragraph discussing the optimal
21 concentration for something certainly not
22 terrestrial happens to coincide with disclosure

1 elsewhere in this paper that you're relying on and
2 you're claiming relates to terrestrial, right?

3 A Well, they don't coincide. They have the
4 same optimum doping density. But that's not hugely
5 coincidental that two different situations may find
6 the same optimum peak doping density.

7 But you will note that there are other
8 things about them that are different.

9 So for example, this refers to a graded
10 FSF over 15 microns in the conclusion on page 25;
11 whereas the teachings that I rely on, which clearly
12 say they're for beginning of life and 1 sun
13 applications, are an abrupt surface field that is
14 somewhere between one-quarter and 1 micron.

15 So the peak doping density is the same
16 for these two different applications, but the shape
17 of the curve and the overall design of the front
18 surface field is different.

19 I don't rely on the teachings on page 25.
20 I agree with you that they are not relevant to
21 terrestrial applications as taught by Marvin.

22 Q So is it just a coincidence that the peak

1 doping concentrations for the space application on
2 page 25 is exactly the same as the -- as what you
3 claim to be the optimal concentrations for your --
4 what you read to be the terrestrial environment on
5 page 15?

6 MR. SELWYN: Objection, form.

7 A They are the same range. Whether you
8 call that a coincidence or simply the outputs of
9 Marvin's model, I suppose is up to you. It's not
10 terribly uncommon that two different simulations --
11 or simulations of two different environments might
12 produce results that have the same number for one
13 parameter, namely the peak doping density.

14 Q Do you think it's coincidental?

15 A By "coincidental" -- I guess I think what
16 I said, that Marvin has modeled a total of four
17 different scenarios, beginning of life, end of life,
18 and 1 sun and 100 sun. And it's, in more than one
19 scenario, identified the same peak doping density as
20 good.

21 Is that a coincidence, or does it have
22 some underlying physical meaning? I haven't

1 reproduced Marvin's simulations to probe that.

2 Q Are you surprised that the exact same
3 range is -- appears with regard to what is
4 unquestionably not a terrestrial environment on
5 page 25 and what you claim is a terrestrial
6 environment on page 15?

7 MR. SELWYN: Objection, form.

8 A It's not just that I claim that it's a
9 terrestrial environment. Marvin tells us it's
10 beginning of life and it's 1 sun. I know that that
11 is a representative of a terrestrial environment.

12 Was I surprised by this? No, not
13 particularly, because Marvin discloses that there
14 are other things about these two front surface
15 fields that are different. One of them is less than
16 a micron thick. The other is 15 microns thick.

17 I'm not surprised when I see two cars
18 driving down the street that have the same tires on
19 them.

20 I wasn't surprised here to find that the
21 same peak doping density was determined to be good
22 in two different scenarios. Other things about the

1 front surface fields are different. Marvin is clear
2 about that.

3 Q There's the expression BOL in the
4 disclosure on page 15 upon which you rely, correct?

5 A Yes.

6 Q Okay. And that's beginning of life,
7 before solar radiation has had an opportunity to
8 adversely impact the solar cell, correct?

9 A Yeah. That's the as-made solar cell.

10 Q You agree that solar cells in space
11 applications have challenges beyond just the damage
12 that they'll realize as a result of solar radiation,
13 for example, different electromagnetic radiation
14 spectrum, greater temperature swings?

15 MR. SELWYN: Objection to form.

16 A I think you used the word "challenge." I
17 would say that they can experience different
18 conditions from those on earth.

19 Q Fair enough. And then those different
20 conditions should -- I'll start over.

21 Would those different conditions likely
22 dictate different design parameters?

1 (Cross-talk.)

2 Q Go ahead.

3 A The different conditions can cause
4 different design -- can cause different designs. I
5 think we may have spoken about this in my first
6 deposition.

7 For example, the intensity of light
8 outside of our atmosphere can be greater than on
9 earth, and so more metal is typically needed in the
10 contacts or electrodes in order to collect that
11 current without serious resistance loss.

12 In addition, the temperature swings mean
13 that you have to be somewhat clever with the
14 packaging of the solar cell and do a solar module.
15 Doesn't change the solar cell design so much as the
16 solar module.

17 But the front surface field, which is
18 what Marvin is investigating, of a back-contact
19 solar cell has the purpose of reducing surface
20 recombination, and more particularly, if well
21 designed, it finds the balance between surface
22 recombination and Auger recombination.

1 And I can find the quote if it's helpful.
2 But Marvin himself says that and acknowledges that
3 he understands what a front surface field is
4 designed to do.

5 And these phenomenon, surface
6 recombination and Auger recombination, are both
7 present and the same in space and on earth for 1 sun
8 illumination intensities in space.

9 So for the design of this component of a
10 solar cell, the front surface field, a POSITA would
11 understand, based on Marvin's teachings of what the
12 component does, that a design that's optimal for
13 beginning of life, 1 sun, even if it's going to be
14 launched in space, is going to be similar optimum or
15 terrestrial conditions.

16 Q I want to look at the end of paragraph 92
17 of your declaration. This is at the bottom of
18 page 53.

19 A Okay.

20 Q You state, It was known that in IBC solar
21 cells such as Marvin's, the design of the front side
22 (optical side) and the back side (electrical side)

1 can easily be optimized separately.

2 Do you see that?

3 A Yeah. Those are the words of Pierre
4 Verlinden, a giant in the field who published a
5 paper reviewing back-contact solar cell technology,
6 yes.

7 Q So I assume you agree with that
8 statement?

9 A I do.

10 Q So are you saying that no matter what
11 dimensions are used for the carrier collection
12 regions in Marvin, the optimum front surface field
13 will be the same?

14 A Well, I agree with your statement
15 generally. I just -- it seemed a bit extreme when
16 it said, whatever dimensions are used.

17 Certainly it's possible to create a solar
18 cell where the collecting regions in the back are so
19 spread apart that the solar cell is terrible and
20 that therefore influences what the front side would
21 look like.

22 But under reasonable designs of

1 back-contact solar cells, which Marvin understood
2 and POSITAs understood and Pierre Verlinden
3 understood in 2012, these two sides of the solar
4 cell can be optimized independently.

5 Q So do you agree that Marvin's teaching
6 somewhere, we may disagree as to where it is, but
7 somewhere teaches an optimum doping concentration
8 for a terrestrial solar cell, irrespective of what
9 the dimensions are of the carrier collection
10 regions, within reason?

11 MR. SELWYN: Objection, form.

12 A I'm going to go with yes-ish. And the
13 "ish" because I don't think that Marvin teaches
14 specifically optimums for a terrestrial solar cell.

15 I think that Marvin teaches optimums for
16 a beginning of life solar cell under 1 sun
17 conditions, and this is on page 15, which a POSITA
18 would read and understand to inform terrestrial
19 solar cells because of the similarities of those
20 conditions to terrestrial conditions.

21 And those results on page 15 will use
22 Marvin's baseline cell design for the parameters

1 that aren't mentioned, including, for example, the
2 p-plus width and n-plus width.

3 Q So I want to shift forward then to
4 paragraph 99 of your declaration, a few lines down.
5 So we're now on page 59, looks like the third line
6 down, I have been informed that.

7 A Yes.

8 Q So the full statement is, I have been
9 informed that, for obviousness, the law does not
10 require that a particular combination must be the
11 preferred or the most desirable combination
12 described in the prior art.

13 Do you see that?

14 A Yes.

15 Q Is it your understanding that so long as
16 a POSITA could combine different teachings from the
17 prior art, obviousness is shown?

18 MR. SELWYN: Objection to form.

19 A I'm going to refer back to my first
20 declaration. Let me get the right binder.

21 Q Should be Volume 1.

22 A Yes, thank you.

1 Yes. So I elaborate on what I've been
2 told about obviousness beginning on paragraph 22 of
3 my initial declaration, and that includes that it's
4 not the case that the prior art needs to indicate
5 that a particular combination or feature is
6 preferred, desirable -- the most desirable, or
7 otherwise, but it is required that a POSITA must
8 have motivation to combine two references.

9 So the information needs to exist out in
10 the prior art. A POSITA must have the motivation to
11 combine two or more references and a reasonable
12 expectation of success in doing so.

13 Q Would it have been obvious to implement
14 Choi with the doping concentration levels disclosed
15 in Lamers?

16 A So Choi describes a front surface field,
17 does not provide an exact or a particular doping
18 density for that front surface field. Front surface
19 fields were known and practiced in the art.

20 So a POSITA would go looking to the
21 literature. I have provided, I think, five
22 references that a POSITA would have likely found

1 that indicated doping density around 1 times 10 to
2 the 18.

3 A POSITA would have -- or could have
4 encountered Lamers in that search for, hey, which
5 doping density should I choose in my implementation
6 of Choi.

7 Lamers teaches two different things.
8 One, how to design a front surface field if it has
9 to perform two functions. One is to reduce surface
10 recombination, and the other is to provide lateral
11 transport. That's the first thing that Lamers
12 teaches.

13 Lamers arrives at a doping density of, if
14 I remember correctly, around 3 times 10 to the 18th.

15 But Lamers teaches a second thing. He
16 says, if the lateral transport is not required, then
17 go see this other reference.

18 Those are the teachings of Lamers that
19 are relevant to Choi because Choi describes the
20 front surface field as needing to provide -- needing
21 to reduce surface recombination but not needing to
22 provide lateral transport.

1 And so a POSITA would look at Lamers and
2 look at this teaching and go to that reference that
3 Lamers cites. And the reference that Lamers cites
4 is Granek, which is the art that I use in my
5 combination.

6 So I think the answer to your question
7 is, yes, a POSITA could have been or would have been
8 motivated to combine the teachings of Choi and
9 Lamers. Lamers, however, teaches two things, and
10 the relevant part of Lamers' teaching is actually
11 Granek, which is what I used in my combination.

12 Q Would it have been obvious to use the
13 3 times 10 to the 18th that Lamers teaches in
14 implementing Choi?

15 A No, it would not have been obvious
16 because Lamers has a second teaching that is the
17 teaching that is relevant to Choi. So a POSITA
18 reading Lamers would have seen both of these
19 teachings and would have chosen the one that was
20 relevant to Choi to make the combination.

21 Q Do you still have the opinion that a
22 person of ordinary skill in the art would not have

1 had to have chosen the most optimal concentration?

2 MR. SELWYN: Objection, form.

3 A I think you're asking me if I've changed
4 my opinion from a few minutes ago, and no, I have
5 not changed my opinion. That is what was
6 communicated to me by counsel. I'm not an attorney,
7 but that is what I've been informed.

8 Q Okay. Why is it your opinion that Choi
9 would not benefit from improved lateral transport?

10 A Well, lateral transport, as I describe in
11 my reply declaration, is required -- and actually,
12 as Lamers described, is required if the substrate is
13 very insulating or if the -- yeah, if the diffusion
14 length is quite short in the wafer, and Choi doesn't
15 describe that.

16 Choi describes requiring one of the two
17 things that Lamers points to. It is the common one,
18 the one that front surface fields are usually
19 implemented for, namely, reducing surface
20 recombination.

21 So Choi doesn't -- Choi says, hey, use a
22 front surface field, it reduces surface

1 recombination. There's no teachings that say also
2 use -- also -- you also need lateral transport.

3 And that's important because adding
4 lateral transport, it's not just like a net benefit.
5 It means that you need higher doping density in your
6 front surface field. This is what Lamers teaches.
7 And that has other consequences. In particular, it
8 is worse in terms of recombination.

9 So, you know, adding lateral transport
10 functionality to the front surface field isn't just
11 like an extra benefit that you can put on. You do
12 it if you have to, but it comes with a cost.

13 Q Is it your opinion that every
14 implementation of Choi would not benefit from
15 lateral transport being increased?

16 MR. SELWYN: Objection, form.

17 A It's my opinion that Choi does not teach
18 a need for lateral transport. I wouldn't -- I can't
19 think of an instance of Choi that would benefit from
20 lateral transport -- additional lateral transport
21 from the front surface field based on the teachings
22 of Choi. Yeah, I can't think of an instance at the

1 moment where that would be necessary or helpful.

2 Q Lamers says that for moderate to low bulk
3 resistances and small pitches, the additional value
4 of the FSF for lateral transport is of less
5 importance. Under these circumstances, a lightly
6 doped and shallow FSF with a high resistance in
7 combination with good surface passivation will give
8 the highest cell output.

9 And that's where it references Granek, as
10 you mentioned earlier, right?

11 A Correct.

12 Q So do you know where in Granek the phrase
13 "lightly doped" appears?

14 A Yes, I do.

15 Q Where is that?

16 A You need to give me just a moment here.

17 Q Granek is Exhibit 1010. I'm going to
18 drop that in the chat.

19 A I just read this a day or two ago, but
20 it's a long reference. I'm having trouble finding
21 exactly what I'm looking for. Give me another
22 moment, please.

1 Q Let me try to help. I think that it
2 appears on page 46, in the first sentence of the
3 second paragraph.

4 A So that is one instance, but it's
5 actually not the one that I have in mind.

6 Q Okay. Well, let's focus on this one
7 first, then. It says, The front side is textured
8 with random pyramids and passivated with a lightly
9 doped (N peak equals 5 times 10^{18} per
10 cubic centimeter), and then it proceeds.

11 Do you see that?

12 A Yes.

13 Q Do you agree with that in that passage,
14 Granek is stating that a concentration of 5 times 10^{18}
15 to the 10^{18} per cubic centimeter is lightly doped?

16 MR. SELWYN: Objection, form.

17 A Granek is calling a -- this front surface
18 field, this is one of the ones he fabricated. He
19 fabricated solar cells with five different front
20 surface fields. This is the one that is most
21 lightly doped of the five that he made. It has a
22 surface doping density of 3.8 times 10^{18} .

1 It has a peak doping density of 5 times 10 to the
2 18th. It is the most lightly doped of the five that
3 he made, and he's calling it lightly doped here, but
4 also deeply diffused, yes.

5 Q So that's a yes to my question, right?

6 MR. SELWYN: Objection, form.

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

9 Q Looking at paragraph 2 of your
10 declaration, you're reproducing Granek's Figure 7-1.

11 A Before we move on, I actually found the
12 passage that I was interested in, in response to
13 your previous question.

14 Q You found another instance of "lightly
15 doped"?

16 A Yes. Yes, I did.

17 Q What page is that on?

18 A For example, page 123 of Granek. And I
19 suspect this is what Lamers is drawing from.

20 The top paragraph above the figure --
21 actually, the whole paragraph is relevant. But the
22 sentence that says, On the other hand, for the

1 well-passivated surfaces, an optimal diffusion
2 profile is lowly doped and shallow (see Figure 7-3)
3 bottom -- and that's one of the figures that I rely
4 on in my combination -- with the sheet resistance of
5 around 200 to 800 ohms per square.

6 And I believe that that text is very
7 similar to the text that Lamers uses. And it looks
8 like I do cite this part of Granek in paragraph 127
9 of my declaration.

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

13 A Page 120 at the bottom uses "lowly doped"
14 rather than "lightly doped" and says, A lowly doped
15 FSF results in high quantum efficiency. This is
16 because the Auger recombination inside the highly
17 doped region and the surface recombination velocity
18 are low. And therefore, a proper choice of a front
19 surface field is critical.

20 Q Is that a no?

21 MR. SELWYN: Objection, form.

22 A Oh, I'm sorry. Specifically the words

1 "lightly doped," is that what you're asking?

2 Q Yeah. The words that we see in Lamers.

3 MR. SELWYN: Objection, form.

4 Q And that we saw in 46 of Granek.

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

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

14 Q I'll stay away from that one.

15 In Granek, you are -- excuse me.

16 Paragraph 102 of your declaration, you
17 reproduce some figures from Granek, one of them
18 being the bottom of Figure 7-3.

19 Do you see that?

20 A Yes.

21 Q And that relies on this modeling of
22 Cuevas.

1 Is that right?

2 A Cuevas is an input into Granek's PC1D
3 simulation, and Cuevas is an empirical model based
4 on experimental results of silicon oxide passivated
5 silicon.

6 Q And according to the Cuevas model,
7 surface recombination is a function of one variable,
8 namely, doping concentration, correct?

9 A It is a function of doping concentration.
10 It can be a function of other things, too. But it
11 is a function of doping concentration. And that's
12 not just according to Cuevas's model. That is
13 universally recognized.

14 Q Per page 42 of Granek and the figures
15 that appear there, surface recombination velocity is
16 a function of one variable, namely, doping
17 concentration, correct?

18 A Do you mean to imply that it's a function
19 of only one variable? Because I don't agree with
20 that. I see that these plots show the dependence of
21 surface recombination velocity on doping density.
22 That doesn't mean that it's dependent only on doping

1 density. It isn't.

2 Q Where is the other dimension?

3 MR. SELWYN: Objection to form.

4 A Not everything is always shown in one
5 plot. You have to pick which information to -- that
6 you're investigating.

7 So for example, the built-in or fixed
8 charge in a passivation layer influences the surface
9 passivation as well. And actually, I have a part of
10 my declaration that shows that quite nicely for
11 aluminum oxide.

12 But these plots are for silicon dioxide
13 passivation, and for silicon dioxide passivation,
14 there's one value or near one value of fixed charge.
15 So it is not actively varying in this study that
16 Cuevas is doing.

17 Q So has Cuevas assumed the values of other
18 parameters that could influence surface
19 recombination in giving those charts that we see on
20 page 42?

21 MR. SELWYN: Objection to form.

22 A No, Cuevas has not assumed. Cuevas has

1 limited his study to silicon dioxide passivation,
2 which was the most common passivation layer in
3 silicon solar cells at the time. And he has made an
4 empirical model. An empirical model is one that is
5 a fit to experimental data.

6 And so what Cuevas has done is corrected
7 experimental data on silicon dioxide passivated
8 silicon and said, hey, look, you can describe this
9 experimental data by these curves. In particular,
10 you can describe how the passivation, the surface
11 recombination velocity, depends on the doping of the
12 silicon that is being passivated.

13 Q Paragraph 106 of your declaration, you
14 make the statement that Choi and Cousins have a
15 well-passivated front surface. Looking specifically
16 in your second sentence.

17 Do you agree with that characterization
18 of your opinion?

19 A Yes.

20 Q What is your basis to believe that Choi
21 and Cousins have a well-passivated front surface?

22 A Choi and Cousins describe passivation

1 layers on their front surface, and they give
2 examples of what materials may be used for
3 passivation. Those include, for example, silicon
4 dioxide, silicon nitride, and these materials are
5 known to achieve good passivation of silicon.

6 Q Is that it?

7 A Yeah.

8 Q In that same paragraph, you reference
9 Exhibit 1118. I'll drop that in the chat. This
10 will be in your Volume 3.

11 A Okay.

12 Q You reference this document, apparently
13 in support of the notion that front surface
14 recombination velocities were lower than
15 500 centimeters per second in 2014.

16 Is that right?

17 A Yes.

18 Q And you cite page 447, but I think you
19 intended to cite page 474.

20 Is that right?

21 A It does look like I must have made a
22 transcription error because there is no 447, huh.

1 Q On page 474, the authors have examined
2 the behavior -- or the efficiency of a solar cell at
3 recombination velocities of 10 centimeters per
4 second, 1,000 centimeters per second, and 100,000
5 centimeters per second, correct?

6 A Just one moment, because I don't think
7 that was actually what I meant to be citing to. I
8 was citing to another part of the paper.

9 Those PC1D simulations aren't relevant.
10 They're for the back of the solar cell where
11 something called an aluminum back surface field was
12 commonly used.

13 I believe it's supposed to be 477, not
14 447 as I typed in my declaration.

15 And so the first paragraph of 477
16 describes -- it's under a header, a section called,
17 Surface passivation methods for crystalline silicon,
18 and it describes the state of the art as of the time
19 that Aberle was writing in 2000.

20 And it says such things as thermal
21 silicon dioxide provides excellent surface
22 passivation and high resistivity in p- and n-type

1 wafers as demonstrated by S effective values below
2 10 centimeters per second.

3 And then it says, However, for low
4 substrate resistivities, the passivation quality
5 depends on the doping type, and you see that in
6 Cuevas's model, and goes on to talk about results
7 for n- and p-type silicon, and says such things as,
8 typically, the S effective values for such
9 substrates lie in the 50 to 500 centimeter per
10 second range.

11 Which I agree with. That was the state
12 of the art in 2000, and the state of the art had
13 advanced further by 2014. That is to say, to lower
14 values.

15 Q Going to paragraph 108 of your
16 declaration, Dr. Holman, it appears as though at a
17 concentration of 1 times 10 to the 18th, this Cuevas
18 model suggests a surface recombination velocity of
19 approximately 100 centimeters per second.

20 Is that right?

21 A That's correct. And that's consistent
22 with the range that I just read from Aberle, for

1 example.

2 Q And then looking at that same Figure 3-6
3 of Granek, and using the same concentration of
4 1 times 10 to the 18th, we get a different surface
5 recombination velocity for boron, correct?

6 A That is correct.

7 Q It appears as though it might be greater
8 than 2,000 centimeters per second, right?

9 A Yes. As of the time that Cuevas was
10 writing, the state of the art for both n-type and
11 p-type silicon was silicon dioxide passivation. But
12 it worked better on n-type silicon than on p-type
13 silicon. And in fact, the passage that I just read
14 from Aberle said the same thing, if you'll recall.

15 (Cross-talk.)

16 Q Go ahead.

17 A Importantly, there were dramatic
18 improvements in the passivation in p-type silicon
19 between about 2005 and 2015 with a new material,
20 aluminum oxide. It doesn't work on n-type silicon,
21 but it works on p-type silicon, and it brings the
22 surface recombination values down comparable to

1 silicon dioxide on n-type silicon. And I elaborate
2 on that in my declaration and include a figure from
3 the art showing those developments.

4 So yes, I agree with you that 1 times 10
5 to the 18 in p-type silicon does not result in -- or
6 low surface recombination velocities, that is to
7 say, below 500 if it's silicon dioxide passivating.
8 But the field had moved on for p-type silicon by
9 2014.

10 Q When you say your declaration, you mean
11 your reply declaration, Exhibit 1089, correct?

12 A I do. Sorry if that was confusing.

13 Q You don't talk about aluminum oxide in
14 Exhibit 1003, right?

15 MR. SELWYN: Objection, form.

16 A 1003 is my initial declaration? Is that
17 correct?

18 Q Right.

19 A Let me check. I might actually because
20 it's a common passivation material.

21 Q Let me withdraw that question because I
22 want to keep things moving. I'll ask a different

1 question.

2 A Okay.

3 Q You don't suggest in Exhibit 1003
4 modifying the references to include an aluminum
5 oxide passivation layer, do you?

6 MR. SELWYN: Objection, form.

7 A I don't believe that I -- well -- sorry,
8 I've got too many things open here.

9 I guess I would want to first check that
10 aluminum oxide is not mentioned by, for example,
11 Choi because Choi does mention quite a -- I think
12 multiple possibilities in the passivation layer, and
13 I believe he has language to the effect that the
14 materials he suggests are not limited to those, and
15 that stacks of them are possible as well.

16 And so I don't think that a modification
17 of Choi, for example, is required. I think that
18 it's already included within the scope of Choi's
19 teachings.

20 Q What about Cousins, do you think that you
21 recommended adopting an embodiment of Cousins or
22 modifying Cousins to have an aluminum oxide

1 passivation layer?

2 MR. SELWYN: Objection to form.

3 A I don't believe that --

4 (Cross-talk.)

5 A I don't believe that Cousins describes
6 aluminum oxide, because while Cousins doesn't limit
7 his teachings to n-type silicon, n-type silicon
8 wafer is the only type that he explicitly calls out
9 and describes. And as I mentioned, aluminum oxide
10 is not commonly used on n-type silicon.

11 I would need a little bit more time to
12 refresh myself on the exact words of Cousins. But
13 if I remember correctly, Cousins doesn't teach
14 aluminum oxide explicitly. I don't say in my
15 declaration that he teaches aluminum oxide
16 explicitly.

17 But he does describe passivation layers
18 really in passing, I think it's something like one
19 sentence, and does not limit those materials -- the
20 passivation layer to any subset of materials. I
21 think his intention is to bring in the wealth of
22 knowledge about passivation layers from the art in

1 limiting his description of something that was
2 well-known.

3 MR. SELWYN: Jacob, we've been going
4 about 80 minutes. Do you want to take another
5 five-minute break, or get to a stopping point if
6 you're not at one?

7 MR. SNODGRASS: I've stopped talking for
8 the moment, so...

9 MR. SELWYN: Exactly. I determined that
10 that's a stopping point. Let's take five minutes.

11 (Recess from 5:36 p.m. until 5:43 p.m.)

12 BY MR. SNODGRASS:

13 Q So Dr. Holman, I've had a chance to look
14 at Choi, and maybe I have found what you're
15 referring to. In paragraph 92, there is an
16 embodiment shown in Figure 5, and there's a
17 discussion about an aluminum oxide layer.

18 A Sorry, I wasn't quite able to keep up
19 with you. Which paragraph are you in?

20 Q 92 of Exhibit 1006.

21 So I guess my question is --

22 (Cross-talk.)

1 Q Sorry. I didn't mean to interrupt.

2 Were you recalling in your earlier
3 testimony the disclosure in paragraph 92?

4 A I wasn't. No, that's not what I was
5 thinking of. But you're right that aluminum oxide
6 is referenced here, and the fact that it has a fixed
7 charge, which is what I was telling you about during
8 our conversation of Cuevas as being another thing
9 that -- besides dopant density of silicon that
10 influences passivation.

11 This reference to aluminum oxide, Choi is
12 trying to explain how a different embodiment that
13 even has no front surface field might work.

14 But I was thinking of earlier paragraph
15 in which Choi is describing the passivation layer,
16 and I believe he lists a number of materials. And I
17 don't recall whether one of them was aluminum oxide.
18 I'm trying to look now.

19 Q Okay. So your obviousness opinions are
20 not based on the embodiment discussed in paragraph
21 92 of Choi?

22 A I'm not relying on paragraph 92 of Choi,

1 no.

2 Q Okay. Because obviously, that would be
3 problematic because there's no front surface field,
4 right, in that embodiment?

5 A Correct. Choi teaches multiple things,
6 including an embodiment without a front surface
7 field.

8 Q Okay.

9 A I believe I was thinking instead of
10 paragraph 31 and 32 in which Choi describes
11 antireflection coating, says that the antireflection
12 coating also passivates the -- passivates defects,
13 removes recombination sites, increases open circuit
14 voltage. This is at the bottom of paragraph 31, I'm
15 paraphrasing.

16 And then paragraph 32, Choi lists
17 materials that might be used, says there could be
18 multilayer film, combination of them, and the
19 present invention is not limited thereto. And the
20 antireflective film may include a variety of
21 materials.

22 That's what I was thinking of.

1 Q Returning to Granek, Figure 3-6 on
2 page 42, looking again at that right-hand side of
3 that figure.

4 A Right.

5 Q So in order to determine what the surface
6 recombination velocity is, one can look at the
7 graph, or one can use the equations that are
8 provided both in the graph and further on down on
9 that page, right?

10 A Correct.

11 Q Okay. So if one wanted to figure out
12 what the surface recombination velocity was at 10 to
13 the 18th per cubic centimeters for boron, they'd use
14 the equation at 3.10, right?

15 A That's correct. And again, this is for
16 silicon dioxide passivation layers. That's correct.

17 Q And they would take 500 centimeters per
18 second and multiply that by the cube root of 100?

19 A That looks right to me.

20 Q Okay. Paragraph 111 of your declaration,
21 you -- you also -- sorry. It's at the bottom of
22 paragraph 110, right above paragraph 111 on page 66

1 of your declaration, Exhibit 1089, you've reproduced
2 Granek's Figure 7-1.

3 Do you see that?

4 A Yes, I do.

5 Q All right. And there's a point at about,
6 I'd say, 500 centimeters per second where the curves
7 for 10 to the 18th and 10 to the 19th intersect.

8 Do you agree with that?

9 A I do. I've written about this in my
10 declaration, and I believe that it was -- yes, I
11 agree.

12 Q Okay. And everything to the right of
13 that point suggests 10 to the 19th is -- yields a
14 better efficiency than 10 to the 18th, right?

15 A Correct. So for poorly passivated
16 surfaces, surfaces that were not consistent with
17 what was practiced in the art in 2014, surfaces that
18 had high surface recombination velocity above 500,
19 require a higher doping density for the front
20 surface field.

21 But for the doping densities that were --
22 excuse me. For the surface passivation layers and

1 surface recombination velocities that were achieved
2 in 2014, the relevant data is between about surface
3 recombination velocity of 10, that appears as 10 to
4 the 1, and 500, for which 1 times 10 to the 18th is
5 the preferred doping density consistent with
6 Granek's more extensive model using Cuevas's
7 empirical input data in Figure 7-3 on the bottom.

8 Q I want to go to the next page, on
9 page 67, paragraph 112. In the second full
10 sentence, you state, FSFs in solar cells are added
11 to aid in reducing surface recombination, that is
12 their purpose.

13 Is that right?

14 A Yes. And this was stated by most authors
15 that describe front surface fields, that their
16 purpose is to reduce surface recombination.

17 Q And FSF is front surface field, right?

18 A Yes, it is.

19 Q Okay. Do the graphs at Figure 3-6 of
20 Granek reflect that FSFs reduce surface
21 recombination?

22 A No. The graph of Figure 7-1 and also

1 Figure 7-3 show that FSFs reduce surface
2 recombination.

3 Figure 3-6 of Granek doesn't specify a
4 front surface field or not front surface field. It
5 simply asks the question, what is the surface
6 recombination velocity, or SRV, of a silicon dioxide
7 passivated surface as a function of the doping
8 density of that silicon surface.

9 So Figure 3-6's input into a model that
10 produces Figure 7-1 and Figure 7-3 that show that
11 the front surface field reduces surface
12 recombination, J_{naught} values -- that's why
13 Figure 3 plots J_{naught} , for example -- and that
14 this increases efficiency, which is the y-axis on
15 Figure 7-1.

16 Q In the next paragraph, paragraph 113, my
17 question is pretty specific. In this paragraph, do
18 you dispute Dr. Schubert's opinion that it would
19 have been difficult to achieve low surface
20 recombination velocities in 2014?

21 A Yes. The first sentence says that,
22 Patent owner and Dr. Schubert are incorrect that it

1 would have been difficult to achieve a low surface
2 recombination velocity in 2014.

3 Q And then you proceed to suggest that it
4 would have been possible to achieve those
5 velocities, right?

6 MR. SELWYN: Objection, form.

7 A Yes. That's what my subsequent sentences
8 say, that it was well understood how to achieve a
9 low surface recombination velocity.

10 Q In the next paragraph, paragraph 114, you
11 provide recombination velocities for n-type dopants.

12 Is that right?

13 A Yes. I provide two examples from the
14 literature and specify that one of them is for a
15 phosphorous doping concentration of 1 times 10 to
16 the 18. Phosphorous is an n-type dopant. And for
17 the other one, I say n-type surfaces. So I think
18 I'm clear in both cases that those are for n-type
19 silicon.

20 Q Again, very specific question.

21 Do you know what low surface
22 recombination velocities would have been for p-type

1 dopants in 2014?

2 A Yes, I do.

3 Q What were the values of those velocities?

4 A Sure. So let us turn to paragraph 143 of
5 my reply declaration. And here I describe what the
6 state of the art was in passivating p-type silicon.
7 In particular, on page 86, I indicate values of
8 13 centimeters per second, 70 centimeters per
9 second, 20 centimeters per second, specifically for
10 a p-type silicon doping density of 1 times 10 to the
11 18.

12 And I present this plot from Bram Hoex
13 from 2007 in which he's showing that aluminum oxide
14 on p-type silicon achieves comparable surface
15 recombination velocities as silicon dioxide on
16 n-type silicon.

17 This graph here is really -- it is the
18 same as Figure 3-6, the Cuevas plots in Granek, but
19 combined into one. It's showing N and P together,
20 but updated to 2007 technology when aluminum oxide
21 was available.

22 So to answer your question, a value of

1 10 centimeters per second would have been like, oh,
2 that's good, you're doing great. That's a low
3 surface recombination velocity on n- or p-type
4 silicon. A value of 500 would be like, hmm, you're
5 far off the mark here.

6 Q In paragraph 115 of your declaration,
7 you've reproduced the top of Figure 7-3 at the very
8 bottom of the paragraph, page 70.

9 A Yes.

10 Q Okay. Does the top of Figure 7-3 of
11 Granek apply to poorly passivated surfaces?

12 A In fact, it is the extreme version of a
13 poorly passivated surface. It is for a metallized
14 surface. That is metal directly on silicon. And
15 this is the most recombination active surface that
16 we know how to make.

17 And so I bring this up in responding to
18 an argument made by Dr. Schubert simply to point out
19 that a POSITA would not have looked to this for
20 designing a front surface field as one does not
21 cover the front of a silicon solar cell, silicon
22 back-contact solar cell, with metal directly on the

1 silicon.

2 Q So that's a yes, right? Figure 7-3 --
3 the top of Figure 7-3 of Granek applies for a poorly
4 passivated surface?

5 A Yes. An extremely poorly passivated
6 surface. Or one would probably even say
7 unpassivated surface.

8 Q Okay. But Granek says "poorly passivated
9 surface," right?

10 A I know he says a metallized surface. Let
11 me remind myself.

12 Q Look at the top of page 123. From the
13 simulations, it is clear that for the poorly
14 passivated surfaces, highly doped and deep
15 diffusion, and then it goes on.

16 Do you see that?

17 A Yes, that's correct. And then in the
18 figure caption, he says that metallized diffusion
19 profiles -- he says on the top, the case of the
20 metallized diffusion profiles is presented.

21 Q So when Granek says from the simulations,
22 he's referring to the simulations on page 122 of his

1 thesis, right?

2 A Yes. In fact, in that sentence, he
3 refers the reader to Figure 7-3 top, making clear
4 that that's what he's referring to.

5 Q Right. So "poorly passivated surfaces"
6 refers to the top of Figure 7-3, right?

7 A Right. Those surfaces that are
8 metallized. That's what he has simulated. He's
9 characterizing these metallized surfaces as poorly
10 passivated here.

11 Q In paragraph 132 of your declaration, you
12 use the expression "high-low junction."

13 Do you see that?

14 A Yes.

15 Q What is a high-low junction?

16 A A high-low junction is one in which the
17 doping type, N or P, is the same on both sides of
18 the junction. And the difference between the two
19 sides is one of concentration rather than type.

20 So a front surface field is a high-low
21 junction. It is an n-plus layer on an n-type wafer
22 or a p-plus layer on a p-type wafer. A high-low

1 junction contrasts to a p-n junction in which it is
2 the doping type that varies across the junction.

3 Q I believe you have a criticism of the
4 Desa reference and perhaps a misuse or loose use of
5 the term "front surface field."

6 Is that accurate?

7 A My criticism, if you would call it one,
8 is simply that it doesn't apply to Choi or to Choi's
9 solar cell. They have different structures. Desa
10 has what we call a floating front junction, that's a
11 p-n junction, whereas Choi has a front surface field
12 there. They're different. They're designed
13 differently. They're optimized differently.

14 Desa does seem to not understand what the
15 word "front surface field" -- or the term "front
16 surface field" means, and so uses it incorrectly in
17 a confusing way. But the input parameters to his
18 simulations which are listed in the table make
19 explicit that what he has simulated is a floating
20 front junction.

21 Q But you agree with me that a person of
22 ordinary skill in the art would understand that you

1 could take Desa and replace the n-type dopant with a
2 p-type dopant and the optimal doping concentrations
3 would be the same, right?

4 A Only if you were to change the doping
5 type of the wafer as well. So Desa's findings in
6 which he has a p-n junction at the front of the
7 wafer. Whether it's P substrate and N emitter, as
8 he simulates, or the converse, those are different
9 from a P, p-plus front surface field or an N, n-plus
10 front surface field. The learnings are not the
11 same. The purpose is not the same.

12 Remember that the purpose of the front
13 surface field is to reduce front surface
14 recombination.

15 Q I want to shift to paragraph 136 of your
16 declaration. Here we have -- I'll tell you my
17 characterization, you can disagree if you want. But
18 I think what's going on here is, we have two Procel
19 references, the exhibit that patent owner introduced
20 as Exhibit 2005, and then we have another one,
21 Exhibit 1040, and I believe -- correct me if I'm
22 wrong, I believe you're suggesting that in 1040,

1 Procel is advocating for a doping concentration of
2 1 times 10 to the 18th, and that's different than
3 the one we see in Exhibit 2005 as being optimal.

4 Is that how you see the parties' disputes
5 as to Procel?

6 A I think you've characterized it
7 accurately. We have two different Procel
8 references. They came out close in time. The 1040
9 reference came out a little bit later.

10 The 2005 reference purportedly found an
11 optimum of about 3.5 times 10 to the 18, but then in
12 the subsequent paper, the same authors choose and
13 use a different value of 1 times 10 to the 18th.

14 They're close-ish together. They're not
15 the same. It's not clear why the second one doesn't
16 choose 3.5 or so times 10 to the 18th if that was
17 indeed optimum unless perhaps the authors found
18 additional things in their simulation that led them
19 to believe 1 times 10 to the 18th was optimal
20 instead. But they don't elaborate to explain in the
21 1040 reference.

22 And so a POSITA, I think, would conclude

1 from looking at these two references, well, I know
2 the optimum is somewhere in this range in the low
3 10 to the 18th, that's what Procel is teaching me,
4 but I'll keep looking in the literature to determine
5 precisely what value I should use.

6 Q We see another instance of your citation
7 to 1124 for the proposition that the design of the
8 front side (optical side) and the back side
9 (electrical side) can easily be optimized
10 separately.

11 Do you see that?

12 A Yes.

13 Q And you have a high degree of confidence
14 as to that statement, right?

15 A As I mentioned, this is from a book
16 chapter from Pierre Verlinden, who is about the most
17 accomplished solar cell scientist that you would
18 find in the field. And he's a smart guy that knows
19 what he's talking about. I do agree with what he's
20 written here, and I think that a POSITA would
21 understand this as well.

22 Q So let's assume that's true. If the

1 Procel Exhibit 10- -- if Procel 1040 would have used
2 3.47 times 10 to the 18th per cubic centimeter as
3 its front surface field doping concentration, would
4 the findings of Exhibit 1040 have been any
5 different?

6 MR. SELWYN: Objection, form.

7 A Presumably, the values calculated in
8 Figure 2, 3, or 4 of the paper, for example, the
9 efficiency values, the fill factor, the VOC, the
10 JSC, may have shifted somewhat in absolute value.

11 Q I'm circulating Exhibit 1040.

12 So you are saying the results would have
13 been different with a different front surface field.

14 Is that right?

15 A I'm saying that the absolute value of the
16 metrics plotted in Figures 2, 3, 4 may have been --
17 may have been slightly different. I wouldn't expect
18 a large change because 3.47 times 10 to the 18 and
19 1 times 10 to the 18 are not that different. And,
20 in fact, you can see that in any papers that we've
21 been talking about, that usually these are broad
22 maximums around 1 times 10 to the 18.

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

5 MR. SELWYN: Objection, form.

6 A When you say "the optimal values," do you
7 mean, for example, the x-axes on Figures 2, 3, and
8 4; that is to say, the emitter pitch ratio, the gap,
9 or the pitch?

10 Q I'm referring to, for example, what
11 bridges the two columns on page 16 of Exhibit 1040,
12 there's a reference to a optimum point around 0.84.

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

20 Q If the result was different, that would
21 cast doubt on Mr. Verlinden's proposition that the
22 designs of the front side and the back side can be

1 optimized separately, right?

2 A Well, that's not the reason I believe
3 that they would be the same. It's not that I
4 believe it because if I didn't it would cast doubt.

5 But indeed, my answer is consistent with
6 what Pierre Verlinden writes, yes.

7 Q And no disrespect. I'm sure he's a
8 doctor.

9 But you agree with me that if the optimum
10 were different, had a different front surface field
11 concentration been used, then it could not be the
12 case that the front side and back side would be
13 optimized separately?

14 MR. SELWYN: Objection, form.

15 A Yes, I agree with you. I think your
16 question was just another way of restating, is it
17 really true that the front side and back side can be
18 optimized separately.

19 Q Perhaps. You've answered my question.
20 I'll ask a different question.

21 Do you think it's possible that for
22 Exhibit 1040, Procel and his co-authors recognized

1 the statement that you've reproduced here from
2 Dr. Verlinden and recognized that whatever front
3 surface field they chose didn't matter for purposes
4 of their investigation?

5 MR. SELWYN: Objection, form.

6 A It's certainly possible. I don't -- I
7 don't know why they made the change between the two
8 papers. And that's kind of my point is that it's a
9 bit confusing. And fortunately, there's a ton of
10 other literature out there that can help me figure
11 out, as a POSITA, well, is 1 times 10 to the 18th
12 better than 3.47 times 10 to the 18th.

13 And those other references, whether it's
14 Granek, whether it's King, whether it's Marvin,
15 whether it's Chen, all point to values of around
16 1 times 10 to the 18th.

17 So I think that a POSITA would look at
18 these two Procel references and say, huh, these
19 numbers are similar-ish, but this is kind of odd,
20 let me continue to explore what others have to say.
21 I know that was my reaction.

22 Q Would you have expected Procel to modify

1 or retract his prior findings if he had subsequently
2 found out that they were wrong?

3 MR. SELWYN: Objection, form.

4 A It's possible. I don't know. I don't
5 think that -- I don't think that Procel is making a
6 very large change in going from 3.47 times 1. It's
7 not as if he said, this bacteria solves cancer,
8 cures cancer, and then found out otherwise.

9 So I don't know whether they would have
10 retracted the article if they had found that their
11 previous optimum wasn't indeed optimum.

12 Q Okay.

13 A I will note that in the Procel, I
14 believe, 2050 I think is what we're talking about --

15 Q 2005?

16 A 2005. Thank you.

17 Q You may not have a hard copy of --
18 actually, you do. It should be the last exhibit in
19 Volume 3.

20 A Okay. Thank you. I've got it here.

21 So the front surface field doping
22 analysis in this paper is in Figure 4, and you'll

1 note that the authors simulated the condition of
2 1×10^{18} , 3.47×10^{18} , and
3 it looks like a little bit more than 1×10^{19} . They simulated a couple others, but they
4 simulated those three.

6 And those three gave quite similar
7 efficiencies in Figure 4A and very similar total
8 recombinations -- recombination currents in
9 Figure 4B.

10 So this is what I meant by saying it's a
11 broad maximum in efficiency or minimum in doping
12 that these authors found.

13 And, you know, if they had simulated
14 2×10^{18} , they might have found that
15 that one was even slightly better than 3.47×10^{18}
16 to the 18. They don't simulate all values.

17 That's one nice thing about Granek is
18 Granek simulates all of these values, and so you can
19 get more granularity.

20 So my point is that the results that they
21 get for 3.47×10^{18} and 1×10^{18} in this
22 reference of 2005 appear to be very similar, and

1 perhaps that influenced or has something to do with
2 their subsequent decision to use 1×10^{18} to the
3 10^{18} in their next article.

4 Q So if I understand, your opinion,
5 Dr. Holman, is, you believe that it's possible
6 Procel found that 3.47×10^{18} was the
7 optimal doping concentration for the front surface
8 field, later determined that it was 1×10^{18} to
9 the 10^{18} , never made any changes to their original
10 publication, never wrote any other articles about
11 it, and that's why we see 1×10^{18} in
12 Exhibit 1040.

13 Is that right?

14 MR. SELWYN: Objection, form.

15 A No, that's not my opinion.

16 My opinion is that these two numbers are
17 different, and it's a bit confusing or confounding
18 as to why this change happened. And a POSITA would
19 go and look to the rest of the literature to narrow
20 in on a correct number.

21 After that, you asked me questions why,
22 and I hypothesized about why that might happen, but

1 I don't know. I'm coming up with guesses here
2 because you're asking.

3 Q I'm going to shift to paragraph 139 of
4 your declaration. And you cite Exhibit 1115.

5 A Okay. I believe I'm ready.

6 Q Okay. This exhibit has a title ITRPV.
7 Do you see that, top of page 1?

8 A Yeah. It stands for International
9 Technology Roadmap for Photovoltaics. This is a
10 publication that is compiled and shared with the
11 whole industry and academia every year. It's
12 inspired by a very similar publication for
13 semiconductors, and it provides a bit of a roadmap,
14 as it says, for where the industry thinks the
15 industry is going.

16 Q Do you have any knowledge regarding the
17 origin of Exhibit 1115? By that I mean the actual
18 document itself, not the generation of the document,
19 but the -- I'll withdraw that question and ask a
20 different question.

21 Did you retrieve this document?

22 A I did. As a matter of fact, I didn't

1 even have to go online because I commonly download
2 these documents every year and already had it
3 downloaded on my computer.

4 Q Do you know when you had downloaded it?

5 A No, not offhand.

6 Q I'm going to shift forward to
7 paragraph -- sorry, before I do that, you also cite
8 Exhibit 1116, maybe in the next paragraph.

9 A Yes.

10 Q Similar questions on this one.

11 It has a header, Bernreuter Research.

12 Is that right?

13 A Yes.

14 Q Did you retrieve this document?

15 A I did. I found this document myself. I
16 did so with a Google search. I believe my search
17 term was something like historical polysilicon
18 prices.

19 Q Had you ever heard of Bernreuter Research
20 before?

21 A No, I had not. But this was one of, you
22 know, any number of graphs all plotting the same

1 information about polysilicon prices. This is not
2 specialized knowledge. Could have given you a dozen
3 other reports that have the same information.

4 Q Do you know Mr. Bernreuter?

5 A I don't even know if Bernreuter is a
6 person's last name.

7 Q Okay. Shifting to paragraph 143, you
8 state in the third to the last line on page 85, by
9 the earliest possible. So the full statement is, by
10 the earliest possible priority date of the '315
11 patent, it was known that significantly lower
12 surface recombination velocities could be achieved
13 for p-type silicon using aluminum oxide (Al_2O_3)
14 passivation layers.

15 Do you see that?

16 A Yes, I do.

17 Q Is your opinion for -- I guess maybe I
18 should back up here.

19 This is under the heading for claims 13
20 to 14. I'm looking at page 81.

21 Is that right?

22 A Yes.

1 Q So is your opinion for claims 13 and 14
2 based on a combination of references in which an
3 aluminum oxide passivation layer is employed?

4 A My opinion for claims 13 and 14 is based
5 on Choi and Granek or Marvin, and always the
6 knowledge that a POSITA had, as I was instructed
7 when considering obviousness to consider not only
8 the intrinsic evidence in the patents, but also the
9 extrinsic evidence that a POSITA would commonly
10 know.

11 And aluminum oxide passivation,
12 polysilicon was as hot as gettering in the kind of
13 2005 to 2012, '14 time frame. I went to solar
14 conferences at the time, and these two topics were
15 the most prominent.

16 As a matter of fact, I was cleaning my
17 office last week and throwing away old copies of the
18 Journal of Photovoltaics, which is kind of a
19 prominent journal in PV, from that time period, from
20 2011, I think it was. And I looked in the entire
21 contents of the journal, that is to say, all of the
22 papers were about aluminum oxide. It was probably

1 12 papers in this one journal about aluminum oxide.

2 So this was in your face important
3 developments over the years prior to the 2014
4 priority date of the '315 patent.

5 Q So are your opinions for claims 13 and 14
6 premised on a combination of disclosures that
7 employs an aluminum oxide passivation layer?

8 MR. SELWYN: Objection, form.

9 A I think the way that you stated the
10 question, the correct answer is, no. They are -- my
11 opinions are based on combinations that include a
12 passivation layer and allow that passivation layer
13 to be whatever was known in the state of the art.

14 Choi doesn't focus on the passivation
15 layer because Choi isn't doing anything necessarily
16 innovative with the passivation layer. Choi wants
17 those practicing his invention to go and use the
18 best passivation layer. And for p-type silicon,
19 that was aluminum oxide and well-known to be so as
20 of 2014.

21 MR. SNODGRASS: I may have some follow-up
22 questions if your counsel has any questions for you.

1 Otherwise, I'm done for now.

2 MR. SELWYN: Why don't we go off the
3 record for a few minutes so I can confer with my
4 colleague, and then we will resume.

5 MR. SNODGRASS: Okay. Sounds good.

6 (Recess from 6:26 p.m. until 6:30 p.m.)

7 EXAMINATION

8 BY MR. SELWYN:

9 Q Dr. Holman, do you recall being asked
10 some questions about the file history of a related
11 patent to the '315 patent which is cited in your
12 reply declaration at paragraph 36?

13 A Yes, I do remember being asked.

14 Q In paragraph 36, you cited to page 42 in
15 addition to page 76 of that file history.

16 Is that right?

17 A Yes. I cite to both page 42 and 76.

18 Q Would you put in front of you
19 Exhibit 1036, which is the file history referred to
20 in paragraph 36 of your reply declaration.

21 A Okay. I have the file history in front
22 of me.

1 Q Would you please turn to page 42 of
2 Exhibit 1036.

3 A Okay. I'm looking at page 42.

4 Q Does claim 1 recite, a first emitter
5 region having metal impurities formed over the
6 dielectric region?

7 A Yes, it does. That's one of the
8 limitations of the claim. I believe I brought that
9 up without specifically reading from this page when
10 I was discussing the other part of the file history
11 on page 76 previously.

12 Q Do you believe, based on the file
13 history, that it was clear the examiner was
14 examining a claim reciting the metal impurities
15 limitation?

16 A Yes, I believe so. There's this
17 unfortunate missing text in that part of the file
18 history, but it's clear that the examiner is
19 commenting on claim 1, and the examiner starts by
20 talking, a first emitter region having me, and those
21 are the words of this limitation of claim 1. So I
22 believe that that's what the examiner was referring

1 to, even though it was cut off.

2 Q Could you now please put in front of you
3 Exhibit 2002, the Lamers reference.

4 MR. SNODGRASS: There may not be a hard
5 copy of that unless you guys have it from the first
6 one. I can circulate it.

7 MR. SELWYN: Would you, please?

8 MR. SNODGRASS: Yes.

9 THE WITNESS: Thank you. Appreciated.

10 A Okay. I have Lamers open on my computer.

11 Q Would you please turn to page 2 of
12 Lamers.

13 A Yes.

14 Q Do you recall being asked about Lamers
15 teaching about a, quote, lightly doped and shallow
16 FSF in the middle of the second paragraph?

17 A Yes. In particular, the sentence that
18 refers to Granek.

19 Q Can you please now turn to Granek.

20 A Okay.

21 Q And let me direct your attention, please,
22 to page 46, the first sentence of the first full

1 paragraph.

2 A I'm looking at it now.

3 Q Do you recall being asked about the
4 teaching in Granek on that page of a, quote, lightly
5 doped (N peak equals 5 times 10 to the 18th cubic
6 centimeters) and a deeply diffused (1.4 micrometer)
7 phosphorous front surface field?

8 A Yes.

9 Q Is that teaching of Granek a lightly
10 doped and shallow FSF that Lamers references on
11 page 2?

12 A No. This is a lightly doped but deeply
13 diffused front surface field, as described here on
14 page 46 of Granek.

15 Q Can you now please turn to page 123 of
16 Granek.

17 A Okay. I'm looking at it.

18 Q Do you see Granek's disclosure of the
19 lowly doped and shallow FSF (see Figure 7-3 bottom)?

20 A Yes. An optimal diffusion profile is
21 lowly doped and shallow (see Figure 7-3 bottom).
22 That's correct.

1 Q Is Granek's disclosure of the, quote,
2 lowly doped and shallow FSF, a, quote, lightly doped
3 and shallow FSF that Lamers references on page 2?

4 A Yes. The lowly doped and shallow FSF of
5 Granek is a lightly doped and shallow; that is to
6 say, "lowly" and "shallow" both mean that the doping
7 density is not large.

8 Q Last few questions, Dr. Holman.

9 Do you remember being asked about whether
10 the cleaning and etching steps are also techniques
11 in addition to gettering that are used to reduce
12 metal impurities?

13 A Yes.

14 Q As of 2014, was gettering needed during
15 solar cell fabrication processes?

16 A Yes. As I've described in my reply
17 declaration and referred to many references, those
18 solar wafers that were used in the solar industry
19 had metal impurities in them that could cause
20 recombination that resulted in reduced solar cell
21 efficiency. And even if they didn't have such
22 impurities when they arrived at the solar cell

1 fabrication plant, they could pick up additional
2 impurities during solar cell fabrication itself.

3 And conveniently, one of the last steps
4 in solar cell fabrication is typically a high
5 temperature step used for diffusion, which can also
6 perform the act of gettering, cleaning up the
7 wafers.

8 Q Would gettering still be used in a solar
9 cell fabrication process that also used etching or
10 cleaning steps?

11 A Yes. Both of these were entirely
12 standard processes. They were both used in standard
13 silicon solar cell fabrication. It wasn't one or
14 the other. In fact, both steps also had additional
15 purposes.

16 So the etching step of -- that could
17 remove metal impurities from the surface and near
18 surface region also played the role of texturing and
19 removing saw damage, mechanical damage.

20 And the gettering step frequently also
21 played the role of diffusing in dopants, as I
22 mentioned a moment ago. So these weren't optional

1 steps, you don't leave out one or the other. They
2 were both used in solar cell fabrication.

3 MR. SELWYN: I have no further questions.

4 MR. SNODGRASS: I have no follow-up.

5 COURT REPORTER: Anything else for the
6 record?

7 MR. SELWYN: Nothing else for the record
8 except I thank Dr. Holman, Mr. Snodgrass. Thank
9 you, Lisa, for your help today.

10 MR. SNODGRASS: Nothing from us. Thank
11 you.

12 (Transcript orders discussed.)

13 COURT REPORTER: Thank you. That's all I
14 need.

15 (Off the record at 4:39 p.m.)

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1 CERTIFICATE OF SHORTHAND REPORTER - NOTARY PUBLIC

2
3 I, Lisa V. Feissner, RDR, CRR and Notary
4 Public in and for the District of Columbia, do
5 hereby certify:

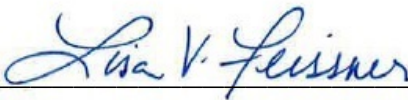
6
7 That ZACHARY HOLMAN, Ph.D., the witness
8 whose deposition is hereinbefore set forth, was duly
9 sworn by me before the commencement of such
10 deposition, and that such deposition was taken
11 before me and is a true record of the testimony
12 given by such witness.

13
14 I further certify that the adverse party,
15 HANWHA SOLUTIONS CORPORATION, was represented by
16 counsel at the deposition.

17
18 I further certify that the deposition of
19 ZACHARY HOLMAN, Ph.D., occurred REMOTELY on FRIDAY,
20 SEPTEMBER 12, 2025, commencing at 12:02 and
21 concluding at 4:39.

1 I further certify that I am not related
2 to any of the parties to this action by blood or
3 marriage, I am not employed by or an attorney to any
4 of the parties to this action, and that I am in no
5 way interested, financially or otherwise, in the
6 outcome of this matter.

7
8 IN WITNESS WHEREOF, I have hereunto set
9 my hand this 17TH day of SEPTEMBER, 2025.

10
11
12 

13 NOTARY PUBLIC IN AND FOR

14 THE DISTRICT OF COLUMBIA

15 MY COMMISSION EXPIRES JUNE 15, 2028
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Transcript of Zachary Holman, Ph.D.
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I, **ZACHARY HOLMAN, PH.D**, have read the transcript of my deposition testimony taken on **September 12, 2025**, and hereby make the following changes in form and/or substance.

I further state that the foregoing is true and correct, except as noted herein.

PAGE	LINE(S)	CHANGE	REASON FOR CHANGE
13	14	Change “articular” to “a particular”	Transcription Error.
13	22	Change “in” to “and”	Transcription Error.
14	1	Change “Cousins” to “cousins”	Disambiguation. Does not refer to the reference called “Cousins.”
22	13	Change “Specialist” to “Specialists”	Transcription Error.
42	21	Change “objections” to “rejections”	Transcription Error.
47	8	Change “why” to “where”	Transcription Error.
47	13	Delete “was”	Transcription Error.
56	5	Insert “for” between “And” and “the”	Transcription Error.
84	21	Change “of the” to “after”	Transcription Error.
90	15	Insert “of” between “model” and “recombination”	Transcription Error.
108	4	Change “by” to “but”	Transcription Error.
109	19	Delete “of”	Transcription Error.

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PAGE	LINE(S)	CHANGE	REASON FOR CHANGE
111	5	Insert “in” between “emitter” and “p-type”	Transcription Error.
119	2	Insert “the” between “says” and “silicon”	Transcription Error.
119	14	Change the speaker from “Mr. Selwyn” to “Mr. Snodgrass”	Attribution Error.
123	6	Change the speaker from “Mr. Selwyn” to “Mr. Snodgrass”	Attribution Error.
129	10	Change “Oak” to “OK”	Transcription Error.
132	5	Change “was” (first instance) to “of”	Transcription Error.
140	9	Change “phrasing” to “rephrasing”	Transcription Error.
165	22	Change “if” to “in”	Transcription Error.
167	1	Change “pure” to “p- or”	Transcription Error.
168	5	Change “and” to “in”	Transcription Error.
178	14	Change “and do” to “into”	Transcription Error.
195	6	Change “corrected” to “collected”	Transcription Error.
197	22	Change “and” (first instance) to “on”	Transcription Error.
197	22	Delete “in”	Transcription Error.
202	7	Insert “an” between “silicon,” and “n-type” to read “his teachings to n-type silicon, an n-type silicon”	Transcription Error.

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PAGE	LINE(S)	CHANGE	REASON FOR CHANGE
204	14	Insert “an” between “of” and “earlier”	Transcription Error.
205	10	Add “an” after “describes”	Transcription Error.
209	9	Change “3-6’s” to “3-6 is”	Transcription Error.
228	2	Insert “I” before “Could” to read “I could”	Transcription Error.
229	11-12	Change “passivation, polysilicon” to “passivation of silicon”	Transcription Error.
229	20	Change “in” to “and”	Transcription Error.
235	5	Delete “a”	Transcription Error.
235	6	Change “shallow” to “lightly”	Clarity.



Zachary Holman, Ph.D.

09.23.2025

Date