

1 UNITED STATES PATENT AND TRADEMARK OFFICE

2
3 BEFORE THE PATENT TRIAL AND APPEAL BOARD

4
5 HANWHA SOLUTIONS CORPORATION,

6 Petitioner

7 v.

8 MAXEON SOLAR PTE. LTD.

9 Patent Owner

10
11 Case IPR2024-01198

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

13
14
15 Videoconference Deposition of

16 ZACHARY HOLMAN, Ph.D.

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1 Pursuant to Notice, before Dawn M. Hart,
2 RPR/RMR/CRR and Notary Public.

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(Exhibits were attached to the transcript.)

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

2 ZACHARY HOLMAN, Ph.D.

3 being first duly sworn or affirmed to
4 testify to the truth, the whole truth, and nothing
5 but the truth, was examined and testified as
6 follows:

7 MR. SNODGRASS: I'd like to introduce
8 counsel if that works.

9 This is Jacob Snodgrass with PV Law on
10 behalf of Patent Owner, Maxeon. I have my
11 colleague Jing Zhao as well.

12 MR. SELWYN: Yes, and for Petitioner,
13 Hanwha Solutions Corporation, and for the witness.
14 My name is Mark Selwyn. With me in the conference
15 room is my partner John Hobgood, and on the Zoom
16 is Nora Xu, also from the (indiscernible).

17 (Court Reporter clarification.)

18 EXAMINATION BY COUNSEL FOR THE PATENT OWNER

19 BY MR. SNODGRASS:

20 Q Good morning, Dr. Holman.

21 A Good morning.

22 Q Have you had your deposition taken

1 before?

2 A No, this is my first time.

3 Q Okay. So I'll ask a series of questions
4 today. Your counsel may object to certain of my
5 questions from time to time. Unless your counsel
6 instructs you not to answer, I would ask that you
7 answer each question truthfully, is that okay?

8 A Yes.

9 Q And if you need to take any breaks,
10 please let me know, okay?

11 A Okay.

12 Q And I believe, Dr. Holman, you have a
13 binder accessible to you with certain documents
14 that have been filed in this proceeding.

15 A Yes, that was just handed to me.

16 Q Okay. And you also, I suspect, have
17 access to a laptop; is that right?

18 A I have a laptop in front of me that's
19 running Zoom for this meeting.

20 Q Okay. When we discuss certain Exhibits,
21 I'll distribute them via Chat as well, so feel
22 free to refer to either the hard copy or the

1 electronic version that I circulate via Chat,
2 whichever is more convenient for you, okay?

3 A Great. Thank you.

4 Q And if we're talking about a document or
5 talking about anything and you want to see a
6 document, please let me know and I'll try to
7 facilitate that. Is that okay?

8 A Okay.

9 Q So, Dr. Holman, I'm going to distribute
10 what has been submitted in this proceeding -- by
11 this proceeding I mean IPR 2024-01198 -- as
12 Exhibit 1003. So I'll distribute that via Chat,
13 and you also should have a copy as well.

14 Do you see Exhibit 1003?

15 A Yes, I have it in front of me.

16 Q And that's a Declaration that you
17 prepared; is that correct?

18 A That's correct.

19 Q And on page 222, and I'm referring to
20 the pagination in the hard copy, the PDF pages are
21 probably going to be a few pages after that, but
22 on page 222 is a signature. Do you see that?

1 A Yes.

2 Q And that's your signature?

3 A It is.

4 Q And in Exhibit 1003 you render certain
5 opinions regarding the patentability of claims in
6 U.S. Patent 11,251,315; is that right?

7 A That's correct.

8 Q And I just distributed via Chat Exhibit
9 1001 in this proceeding, which is U.S. Patent
10 11,251,315. Do you have a copy of that patent,
11 Dr. Holman?

12 A I do.

13 Q And if today I refer to Exhibit 1001 as
14 the '315 patent, will you understand?

15 A Yes.

16 Q And also if I refer to Exhibit 1003 as
17 your Declaration, will you understand that I'm
18 referring to your Declaration in this IPR
19 proceeding?

20 A Yes, I will.

21 Q Did you notice any errors in your
22 Declaration before you signed it?

1 And I'm referring to the final version
2 that we have, not a draft.

3 A No.

4 Q Have you, since you've signed your
5 Declaration, discovered any errors in it?

6 A No, I have not.

7 Q And, Dr. Holman, I believe you've
8 submitted Declarations in other IPR proceedings
9 with Hanwha and Maxeon as the parties. I want to
10 put those to the side for the moment. I want to
11 just talk about your work on this proceeding, the
12 1198 proceeding.

13 How much time have you spent working on
14 this proceeding?

15 A You mean going back to, and inclusive
16 of, the preparation of the Declaration?

17 Q Yes, please.

18 A Okay. I haven't kept track of my hours
19 separately for the '315 patent, or the '053 and
20 '516. Together I have spent just under 150 hours
21 to date, and I would estimate that approximately
22 half of that was directed to the '315.

1 Q Okay. So about 75 hours, approximately,
2 for the '315?

3 A Approximately, yes.

4 Q Okay. And that would include time --
5 you mentioned "to date." So that would include
6 time subsequent to the preparation of your
7 Declaration, right?

8 A Correct.

9 Q Do you have a ballpark of how much time
10 you spent on your Declaration for the '315 patent?

11 A I would estimate 50 of the 75 hours were
12 spent in the preparation of the Declaration.

13 Q Is it fair to say the Declaration was a
14 collaborative effort between you and counsel for
15 Hanwha?

16 MR. SELWYN: Objection. Form.

17 A The Declaration is my work and my words.

18 Q As far as actually literally typing the
19 words into the document, that may have been done
20 by you and counsel; is that right?

21 A I didn't type all of the words into the
22 word processing software myself, but they are my

1 words. I have reviewed every word, and the
2 signature at the end of the document represents
3 that these are my opinions and my opinions solely.

4 Q Understood. Certain sections, such as
5 the Legal Background section and stuff, that would
6 have been prepared by counsel, correct?

7 A Yeah, in certain sections I clarify that
8 I understand certain things and that certain
9 things were provided to me, mostly legal
10 principles since I'm not an attorney. I tried to
11 be clear many in my writing of the Declaration
12 when I was provided with such guidance.

13 Q Okay. And that prompts me, if I
14 accidentally ask a subsequent question before you
15 finish answering your question, please let me know
16 and I'll give you an opportunity to finish your
17 answer.

18 A Thank you.

19 Q In paragraph 2 of your Declaration you
20 mention that you've prepared it at the request of
21 Hanwha Solutions Corporation. Do you see that?

22 A I do.

1 Q Without getting into the particulars of
2 any discussions you had with Hanwha's counsel, can
3 you describe at a general level what that request
4 was?

5 A Sure. Let me see if I can answer your
6 question.

7 I initially received email contact from
8 an attorney whose counsel to Hanwha Solutions
9 Corporation inquiring as to whether or not I was
10 available or interested. We had subsequent
11 conversations. I reviewed the patents, and I
12 agreed to provide my opinions in the matter.

13 Q Can you, at a high level, describe the
14 approach you took in analyzing the patentability
15 of the claims of the '315 patent?

16 MR. SELWYN: Objection. Form.

17 A Yes. I was asked to evaluate the
18 obviousness of the claims. And I understand that
19 obviousness has to do with the combination of one
20 or more previous pieces of art by a person of
21 ordinary skill in the art, or a POSITA, at the
22 time.

1 And so I took a path similar to what I
2 believe a POSITA would have taken, which included
3 studying the material, including patents and
4 papers that were available, prior to the earliest
5 priority date of the '315 patent and assessed
6 whether or not a combination of those would have
7 been obvious; that is to say, a person of ordinary
8 skill in the art would have had motivation to
9 combine and a reasonable expectation of success in
10 doing so.

11 Q Okay. So you reviewed the entirety of
12 the '315 patent; is that right?

13 A I have, yes.

14 Q Did you understand the '315 patent?

15 A I did.

16 Q Were there any aspects at all of the
17 '315 patent that you felt were unclear or
18 ambiguous?

19 A And I describe this a little bit in the
20 claim construction part of my Declaration, that
21 there are certain aspects that I can't say for
22 sure what the meaning is. For example,

1 "approximately" in, I think it's claim 10,
2 "approximately or less than." But in general I
3 understood the '315 patent and I understood the
4 scope of the '315.

5 Q You understand the scope of each of the
6 claims of the '315 patent for which you've offered
7 opinions; is that right?

8 A Correct. I have interpreted them,
9 understood them, the meanings of the words, the
10 plain and ordinary meanings of the words and taken
11 into account the context provided in the
12 specification.

13 (Court Reporter clarification.)

14 Q I believe, Dr. Holman, you said that you
15 understood the scope of -- strike that. Let me
16 ask a different question.

17 You offered opinions on claims 10
18 through 20 of the '315 patent, correct?

19 A Yes, I did.

20 Q Okay. So if I refer to claims 10
21 through 20 of the '315 patent as the challenged
22 claims or the claims at issue, will that be okay?

1 A Yes, I will understand.

2 Q I believe you said that you understood
3 the scope of the challenged claims; is that right?

4 A That's correct.

5 Q Do you believe a person of ordinary
6 skill in the art would have understood the scope
7 of the challenged claims?

8 A Yes, I do. Per my previous note, there
9 would likely be some question about the
10 definiteness of certain things, for example, the
11 "approximately" statement, but I believe a POSITA
12 would understand the scope of the challenged
13 claims.

14 Q Okay. Dr. Holman, can you direct me to
15 where in your Declaration you discussed that issue
16 regarding the "approximately" or "about"?

17 A On page 66 of the written Declaration,
18 paper copy -- I guess it's page 67. That would be
19 paragraph 124. I describe, for example, my
20 reading of and interpretation of "approximately
21 less than or equal to two times 10 to the 18 per
22 cubic centimeter" and what that means.

1 Q All right. Thank you.

2 At the end of that section, in paragraph
3 127 you say: I have applied these instructions in
4 this Declaration.

5 Do you see that?

6 A I do.

7 Q I'm assuming that you're referring to
8 the instructions as set forth in the prior
9 paragraphs, 123 through 126; is that right?

10 A That is correct, 123 through 126.

11 Q Can you describe in what way you applied
12 those instructions?

13 A Yes. As written, for example in 123,
14 that the claims -- the words in the claims should
15 be understood in the context of the patent, and
16 that a patent prosecution history may be
17 important, and that the claims should be
18 interpreted within the patent's prosecution
19 history.

20 And that extrinsic evidence of things
21 that a POSITA might know is also important, and
22 that the claim terms should be understood within

1 that.

2 So practically what that means is that I
3 read and understood the entirety of the '315
4 patent, that I reviewed the patent's prosecution
5 history, and that I understood and applied the
6 understanding of a POSITA who may be aware of
7 extrinsic evidence (indiscernible).

8 Q Was there anything in particular in the
9 prosecution history that informed your
10 understanding of the claims, of the challenged
11 claims?

12 A So in the prosecution history, which I
13 describe in paragraphs 117 through 122, I noted
14 that the Examiner who examined this patent
15 application, and several others, I believe it's
16 five others from the same family, did not consider
17 the references that I have used in the grounds in
18 my Declaration, with the exception of Cousins.
19 Cousins is mentioned in the Examiner's search
20 history, but there's no content indicating what
21 the Examiner read or understood of Cousins, so I
22 noted that from the prosecution history.

1 Q And is it your understanding that the
2 application that issued as the '315 patent claims
3 priority through four prior filed applications?

4 A Yes. I understand that the priority
5 date from prior applications of the '315 patent is
6 December of 2014. I believe it's December 22nd.

7 Q Did you review the prosecution histories
8 for the applications to which the application at
9 issue, the '315 patent, claimed priority?

10 A Yes, I did.

11 Q Was there anything in the prosecution of
12 any of those applications or in the application of
13 the '315 patent that you believe important in
14 understanding the meaning of any term used in a
15 challenged claim?

16 A Important in understanding the meaning
17 of any term.

18 No, I don't, I don't recall from my
19 review of those prosecution histories any specific
20 discussion that was important to understand the
21 meaning of the claim terms. And we're referring,
22 just for clarity here, to the prosecution history

1 for the '315 patent and the prosecution history of
2 the other patents within the same family, correct?

3 Q That was the intent of my question. So
4 yes, thank you.

5 A Yes.

6 Q Did you -- and I'm speaking here in
7 reference to paragraph 126. Did you believe that
8 any scientific or technical reference or
9 dictionary was relevant to understanding any term
10 in a challenged claim?

11 A I felt that there was extrinsic
12 evidence. I've pointed to many papers, but not,
13 for example, a dictionary, was important in
14 understanding some of the terms in the challenged
15 claims. One example would be the word "emitter".

16 Q Do you know where in your Declaration
17 that you included that discussion?

18 A Yes. Give me one moment.

19 Okay. So beginning on page 30, that's
20 paragraph 56, which is the Background section of
21 my Declaration, I'm introducing appropriate
22 background for solar cells and how they're

1 designed and how they work. And beginning in
2 paragraph 56 I talk about P-N junctions.

3 And then turning to paragraph 58, the
4 second sentence from the bottom is where I
5 introduce the common understanding in the solar
6 field of the term emitter. And I note that in
7 this field, the word emitter, which comes to us
8 from the semiconductor field and transistors, is
9 understood to, is typically understood to have the
10 opposite doping of the absorber, which for the
11 types of solar cells that we're discussing here is
12 a silicon wafer, also referred to sometimes as the
13 "substrate" as I've done in this paragraph, too.

14 Q I believe you used the word "typically"
15 in your answer. Is it sometimes -- let me ask a
16 new question.

17 I believe you used "typically" in your
18 prior answer. Is the word "emitter" sometimes
19 used to refer to a region that has the same
20 polarity as the substrate?

21 MR. SELWYN: Objection. Form.

22 A That is not normal usage of the word

1 "emitter". I was surprised, and noted, and
2 required to reread in the '315 patent in order to
3 to understand how it was being used. It is not
4 the, not the way that solar cell scientists,
5 engineers use the word "emitter". Has anyone ever
6 used it in that way? I'm sure, but it's not the
7 common usage in our field.

8 Q Is it your opinion that, at least with
9 respect to '315 patent, "emitter" is not
10 restricted to a region having a polarity opposite
11 that of a substrate?

12 MR. SELWYN: Objection. Form.

13 A I interpreted the '315 patent with the
14 usual meanings of the words, and the usual meaning
15 of the word "emitter" is a region having the
16 opposite doping polarity of the substrate. And
17 that definition, that common usage of "emitter" is
18 how I've understood the claims of the '315 patent
19 until I encountered a claim in which that usual
20 usage can't be applied, and in particular, I
21 believe it's claim 20. We can talk about that if
22 you would like. And in that case, one must refer

1 to the context within the patent in which the
2 specification introduces this unusual, atypical
3 usage of "emitter" in which it may have the same
4 doping polarity of the wafer.

5 Q Is it possible that it's actually
6 claim 16 when you first encounter the opportunity
7 to apply the '315 patent's understanding of
8 "emitter"?

9 A No, it's not. You might think that
10 because claim 16 introduces a second emitter, but
11 I read that, it says "a second emitter region,"
12 and it is not clear at that point in time that the
13 "second emitter region" is not a second region
14 also having the opposite doping polarity of the
15 wafer.

16 So I'm able to read claim 16 with the
17 usual interpretation, the common definition of
18 "emitter", and it's only when I get to claim 20
19 that specifies "first emitter region p-type, the
20 second emitter region n-type," that I have to use
21 this unusual interpretation, and that's found at
22 some places of the specification.

1 Q Okay. So if I understand correctly, all
2 the way until claim 16, correct me if I'm wrong,
3 you're viewing the claims as reciting "a first
4 emitter region," which could be an area that has
5 opposite doping polarity relative to the
6 substrate, and "a second emitter region," which
7 could be next to the first emitter region and just
8 being another area that has an opposite dopant
9 polarity relative to the substrate; is that right?

10 MR. SELWYN: Objection to form.

11 A The question was a bit long so let me
12 see if I can clarify.

13 I don't quite agree with the precise
14 wording. So I think you started by saying "all
15 the way up to claim 16," but prior to the claim
16 16, starting at claim 10, there isn't "a second
17 emitter region," so I'm only understanding one at
18 that time.

19 And I'm understanding that that emitter
20 region has the opposite doping polarity of the
21 wafer because that is the common understanding of
22 "emitter" and the solar cell would not function

1 without having an emitter, a region that's
2 oppositely doped the wafer.

3 And then beginning in claim 16, we have
4 "a second emitter region," and I understand at
5 that point in time that that second emitter region
6 as an emitter would have opposite doping polarity
7 as the wafer.

8 And when I get to claim 20, then there's
9 this clarification that "the first emitter region
10 comprises a p-type layer," and "the second emitter
11 region comprises an n-type layer," so one of those
12 is using an unusual use of the word "emitter".

13 Is that clear?

14 Q Thank you.

15 Do you agree that the specification of
16 the '315 patent suggests that "emitter" is not
17 limited to having an opposite dopant polarity
18 relative to the substrate?

19 MR. SELWYN: Objection. Form.

20 A As I said before, the '315 patent uses
21 the word "emitter" in an unusual way. Much of the
22 '315 patent is consistent with the conventional

1 use of the word "emitter" to mean opposite doping
2 polarity of the wafer, or of the substrate, but
3 there are, there are instances in the '315 patent
4 in which the word "emitter" is used to mean other
5 things, in particular the same doping polarity,
6 and as I mentioned that was an unusual usage.

7 Q If I understand correctly you applied
8 the unusual meaning of "emitter" only with respect
9 to claim 20; is that right?

10 MR. SELWYN: Objection. Form.

11 A Yeah, I understood the claims within the
12 typical usage of the plain meanings in our field
13 of the words as a POSITA would understand, except
14 for when I arrived at a point when that wasn't
15 possible and then I considered the context of the
16 specification to understand, and in particular
17 that is what is required for claim 20, that is
18 correct.

19 Q Was there any other instance in which
20 you applied an unusual or non-customary meaning to
21 a claim term?

22 MR. SELWYN: Objection. Form.

1 A Give me just one moment, please.

2 No. The other claim terms in claims 10
3 through 20 can be understood in their, to have
4 their usual meaning without relying on
5 understanding from the specification that is
6 different from their customary meaning.

7 Q So, Dr. Holman, I'm going to distribute
8 via Chat, we have copies of these as well, certain
9 Exhibits; in particular Exhibits 1006, 1007, 1008,
10 1110, 1011, and 1012.

11 Just a minute, please.

12 I'm seeing some large file sizes so if
13 something doesn't come through, we'll figure out a
14 way of getting it to where it needs to go. Again
15 I am not sure if you need these electronic copies
16 anyway, but, Dr. Holman, were you able to see if
17 those went through?

18 A Yeah, they are coming through, and I
19 have the paper copies in front of me.

20 Q Okay. And I believe, in your opinion,
21 claims 10 through 20 of the '315 patent are
22 unpatentable in view of a combination of two or

1 more of the prior art references that I
2 distributed; is that right?

3 A That is correct.

4 Q And in particular that would be Exhibit
5 1006, or the Choi reference; is that one of the
6 references you relied on?

7 A That is correct.

8 Q And just for purposes of ease today can
9 we refer to Exhibit 1006 as Choi?

10 A Yes.

11 Q And can we refer to Exhibit 1007 as
12 Cousins?

13 A Yes.

14 Q And Exhibit 1008 as Marvin?

15 A Yes.

16 Q And Exhibit 1010 as Granek?

17 A Yes.

18 Q And Exhibit 1011 as Smith?

19 A Yes.

20 Q And Exhibit 1012 as Istratov?

21 A Yes.

22 Q Okay, Dr. Holman, I'd like to ask a

1 question about paragraph 73 of your Declaration.
2 I believe in this section you're describing a
3 background of surface passivation; is that right?

4 A I'm going there now.

5 Paragraph 73?

6 Q Yes.

7 A Yes, that is correct.

8 Q And you describe creating a field by
9 introducing dopants; is that right?

10 A Yes.

11 Q Does surface passivation also include
12 applying a passivating surface on a layer?

13 MR. SELWYN: Objection. Form.

14 A We don't use those words. We call it a
15 "passivating layer," not a passivating surface.
16 And I talk about that in, beginning in -- I will
17 continue to look for it when I go into more
18 detail.

19 But the answer to your question is we,
20 depositing a layer on top of, for example, a
21 silicon wafer surface is an additional method in
22 providing surface passivation.

1 Q Yeah, I appreciate that. Thank you. I
2 swapped "surface" and "layer" in my question, but
3 it sounds like we're on the same page.

4 A Okay.

5 Q And I didn't see that discussion, and
6 maybe you're having trouble seeing it as well, but
7 to the extent you do not discuss depositing a
8 passivating layer on a surface within this section
9 that begins at paragraph 73, that would have been
10 just an inadvertent omission; is that right?

11 MR. SELWYN: Objection. Form.

12 A I know that I do talk about it, so if
13 it's important I can take the time to find my
14 discussion of deposited layers. You know what? I
15 think it may be actually a bit earlier than this.

16 I talk briefly about depositing layers
17 in paragraph 61, but that's primarily to form the
18 junction.

19 (Reviewing.)

20 Yeah, in paragraphs 97 and 98, as I'm
21 talking about the evolution of silicon solar cell
22 structures, I describe the passivated emitter and

1 passivated emitter -- locally diffused cells --

2 University of New South Wales --

3 (Court Reporter clarification.)

4 THE WITNESS: Thanks for the reminder.

5 A I describe in paragraphs 97 and 98, I
6 refer briefly to passivation layers and I show
7 them in associated figures, but I do not have a
8 detailed discussion in the section that we were
9 looking at previously --

10 Q Okay.

11 A -- that starts on paragraph 73.

12 Q Okay. I want to ask about paragraph 79.

13 You state in the second sentence:

14 Researchers understood that FSF dopant
15 concentration above one times 10 to the 18 per
16 cubic centimeter induced auger recombination,
17 which in turn reduced solar cell efficiency. Do
18 you see that?

19 A Yes, I do.

20 Q At what point is auger recombination
21 induced?

22 MR. SELWYN: Objection. Form.

1 A There isn't a precise number. It
2 depends on particular conditions. But as I
3 described before this, the higher the doping
4 concentration, the more likely, the more probable
5 auger recombination becomes. I need more
6 information about the solar cell structure and the
7 conditions in order to give you a number.

8 Q Is it true that a certain amount of
9 auger recombination is, on net, beneficial in that
10 the added dopants above a certain level will
11 improve efficiency to an extent greater than any
12 decreased efficiency as a result of the auger
13 recombination?

14 MR. SELWYN: Objection. Form.

15 A No one in the solar cell field would say
16 that auger recombination is beneficial, but I
17 believe your question, perhaps you can rephrase
18 it, is meant to talk about a balance between auger
19 recombination and other losses.

20 Q Yeah, that's exactly it. Okay, so let
21 me ask a different question, then.

22 Do you believe that as of the priority

1 date for the '315 patent, it was understood that
2 dopant concentrations above one times 10 to the
3 18th may be on net beneficial because the benefits
4 of the dopants outweighed any auger recombination
5 that attended that concentration?

6 MR. SELWYN: Objection. Form.

7 A So I do describe in the section that
8 choosing an optimal front surface field doping
9 concentration is a balance between reducing
10 surface recombination. One does a better job of
11 that with higher doping concentrations and
12 reducing, or not incurring, extra recombination
13 induced by the presence of the dopant impurities
14 themselves, for example, auger recombination.

15 And what I'm talking about in paragraph
16 79 is that several references, and I think I
17 include at least four, describe that optimum
18 point, balancing those two, as around one times 10
19 to the 18, because at higher dopant
20 concentrations, the drawbacks of the auger
21 recombination outweigh the benefits of the reduced
22 surface recombination.

1 Q You agree that the particular point at
2 which the drawbacks outweigh the benefits depends
3 on design parameters?

4 A It does. And yet for many solar cells,
5 researchers were finding that that value was
6 around one times 10 to the 18.

7 Q I believe you cite Marvin for that
8 proposition; is that right?

9 A I do.

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

14 A No, I do not.

15 Q So if you can turn to page 25 of Marvin,
16 Exhibit 1008, looking at the, what I believe to be
17 the fourth sentence, it provides the FSF should be
18 an approximately 0.5 micron step with doping
19 concentration of 5×10^{18} per cubic centimeter.

20 You see that?

21 A Yes, I do.

22 Q And can you explain how that's not

1 disclosing that the dopant concentration should be
2 five times 10 to the 18 th?

3 A Yes.

4 So this needs to be read within the
5 context of the conditions under which the solar
6 cell is being measured for Marvin. And Marvin
7 describes four different conditions in this paper;
8 two illumination intensities, one sun and 100
9 suns, and two states of the solar cells, the
10 beginning of life solar cell, also referred to as
11 BOL. This is how the solar cell performs when
12 it's first made, measured. And end of life
13 condition that corresponds to the state of the
14 solar cell after it has been irradiated, as it
15 would be during its entire life in a mission in
16 space. That's also called an EOL solar cell.

17 So the conditions that I refer to in my
18 Declaration and that are similar to, for example,
19 terrestrial solar cells would be the one sun
20 illumination intensity and the beginning of life,
21 or BOL conditions. And for those conditions
22 Marvin finds that one times 10 to the 17 to one

1 times 10 to the 18 optimum that I described in my
2 Declaration.

3 Q I see that range also on page 25, in the
4 second paragraph. Is that what you're referring
5 to?

6 A Yeah. You can also find it elsewhere in
7 the paper. So page 5 is the conclusions, but the
8 detailed description which Marvin evaluates and
9 the, evaluates different front surface field
10 doping is described, for example, on page 15.

11 The second paragraph --

12 Go ahead.

13 Q Sorry, go ahead.

14 A The second paragraph of 15 Marvin
15 summarizes his findings on the thickness and
16 doping level of the front surface field or
17 beginning of life conditions and one sun
18 illumination.

19 Q So we may turn to that in a second, but
20 sticking with page 25, the instance in which "one
21 times 10 to the 17" to "one times 10 to the 18" is
22 mentioned is in a paragraph that begins, "in a

1 high radiation environment," do you agree?

2 A That is -- yes, I see on page 25 a
3 sentence that mentions one times 10 to 17 to one
4 times 10 to 18 in a paragraph that begins "a high
5 radiation environment."

6 Q Do you understand "high radiation
7 environment" to be a space environment?

8 A A space environment is one example of a
9 high radiation environment, and in particular
10 certain atmos -- certain elevations in space.
11 Close to the sun, not close to Pluto, for example.

12 Q Do you believe that Marvin was meaning
13 something in addition to a space environment by
14 the phrase "high radiation environment"?

15 A I think that Marvin's studies is --
16 Marvin is interested in space solar cells. Marvin
17 says as much. I don't think that Marvin's
18 teachings are limited to space solar cells.

19 I think that a person who, a POSITA who
20 was interested in solar cells for other high
21 radiation environments would also take from the
22 learning in this paragraph. But I don't rely on

1 this paragraph, and this is not the instance of
2 one times 10 to the 17th to one times 10 to the
3 18th that I use in my Declaration.

4 Q Do you agree that the instance of five
5 times 10 to 18th in Marvin on page 25 is
6 immediately after a sentence that begins "in the
7 low radiation environment"?

8 A Yes, I do agree with that, but that is
9 right before a sentence that talks about 100 sun
10 concentrations for arrays, and it also, the next
11 sentence says "these parameters are much more
12 critical for 100 sun operation."

13 So as I was mentioning, Marvin considers
14 four different scenarios to illumination
15 intensities and two solar cell states, and the
16 learnings that I used in my Declaration are those
17 associated with one sun illumination and beginning
18 of life, so that combination. Because that was
19 the combination that was, for example,
20 representative of terrestrial solar cells in
21 normal use.

22 (Court Reporter clarification.)

1 Q Do you believe that Marvin used the
2 phrase "low radiation environment" to refer to a
3 terrestrial environment?

4 A Not necessarily. I don't know all that
5 Marvin was thinking, but Marvin's teachings for a
6 low radiation environment could be applied to a
7 terrestrial environment, could be applied to a
8 space environment in which there is not a lot of
9 radiation; for example, perhaps low earth orbit or
10 perhaps very far away from the sun, like out to
11 Pluto.

12 So I think that Marvin is probably
13 purposeful in saying a low radiation environment
14 and that those teachings can be applied to the
15 various instances in which there's not a lot of
16 radiation.

17 Q Are you aware of any instances in which
18 an object that's as far as away from the sun as
19 Pluto is being powered by the sun?

20 A Yes. The spacecraft that go into space
21 are historically powered by solar cells, and we
22 have flown spacecraft quite far from the sun.

1 Q Such as Voyager 1, Voyager 2?

2 A I don't know the details of how they
3 were built, but I believe that is the case.

4 Q And when they reach Pluto, they're being
5 powered by the sun; is that your opinion?

6 A I believe that is the case.

7 Q Do you believe that was the subject of
8 Marvin's study?

9 MR. SELWYN: Objection. Form.

10 A No, I think that Marvin doesn't get so
11 specific. I think that Marvin -- I mean we can
12 look to the beginning of Marvin to understand his
13 purpose and I think that he's studying the
14 performance of solar cells. He says that he's
15 interested -- he talks about satellites. He says
16 that he's interested in understanding how IBC,
17 that stands interdigitated back contact solar
18 cells, will perform in space. He doesn't talk
19 about particular space missions or things of that
20 nature.

21 MR. SELWYN: When you get to a
22 breaking --

1 MR. SNODGRASS: Now is as good a time as
2 any. I'm happy to break.

3 MR. SELWYN: Five minutes or so?

4 (A recess was taken at 12:55 p.m.)

5 (Back on the record at 1:13 p.m.)

6 BY MR. SNODGRASS:

7 Q Dr. Holman, is there any testimony
8 you've provided today that you want to clarify or
9 withdraw or amend in any way?

10 A No.

11 Q Okay. We were talking before the break
12 about page 25 of Marvin. Do you agree that Marvin
13 teaches that at least under one set of
14 circumstances, five times 10 to the 18 per cubic
15 centimeter is the preferred doping concentration?

16 MR. SELWYN: Objection. Form.

17 A I'm turning to page 25 just for a
18 moment.

19 I'd probably like to spend a little bit
20 more time with Marvin. I see the sentence that
21 you're referring to on page 25 that says the FSF
22 should be, and gives that number, and these are

1 for conditions different from the conditions that
2 I relied on in my combination. I use conditions
3 that are representative more of terrestrial solar
4 cells.

5 But I also notice, and on page 17 for
6 example, Marvin says the previous design used a
7 half-micron-thick front surface field uniformly
8 doped at 5 times 10^{18} . And then it was
9 found that by replacing this with a Gaussian
10 doping profile with a characteristic with the 15
11 microns and a peak concentration of one times 10^{18}
12 to the 18th, the end of life efficiency was
13 11.49 percent and that that feature restored most
14 of the lost performance.

15 So the short answer to your question is
16 I would probably like to read all of Marvin with a
17 perspective of looking at these conditions that
18 are not the conditions that we relied upon, that I
19 relied upon in my combination in order to give a
20 yes/no answer to your question.

21 I'm happy to do that if we'd like to sit
22 here. I just noticed this discrepancy with the

1 sentence you pointed out in this paragraph on page
2 17, middle of the second paragraph.

3 Q Had you seen that passage of Marvin
4 before today?

5 A I've read all of Marvin, yes, multiple
6 times.

7 Q Before you signed your Declaration, you
8 had an opportunity to consider any what you call,
9 I believe, inconsistency in Marvin; is that right?

10 A I didn't call it inconsistency. Marvin,
11 as I mentioned before, considers four different
12 scenarios; two radiation intensities and two
13 states of a solar cell, a beginning of life and
14 end of life.

15 And my testimony, my Declaration relies
16 on the one sun illumination intensity and
17 beginning of life conditions, as those are
18 representative of terrestrial solar cells, for
19 example.

20 So Marvin finds other optimums for other
21 things, like end of life solar cells. But it's
22 not an inconsistency, it's a different optimum for

1 these, for example, a solar cell after it's been
2 banged up in space.

3 Q It's correct that Marvin examines both a
4 one sun environment and a concentrator
5 environment; is that right?

6 A One sun and 100 suns, that is correct.

7 Q Is 100 sun also known as a concentrator
8 or concentration?

9 A It is under concentration, that's
10 correct. When we say concentrator, that usually
11 implies at least some optics that are taking
12 diffused -- not diffused, but less intense
13 sunlight and focusing it to create concentration.
14 But in a space environment, one might also get to
15 100 suns just by flying to Mercury.

16 So I'm comfortable with saying it's
17 under concentration, yes.

18 Q Are there any particular considerations
19 that a designer would need to take into account in
20 designing a solar cell for a concentrator -- or
21 excuse me, for an environment?

22 A For concentration?

1 Q For a concentration environment?

2 MR. SELWYN: Objection. Form.

3 A Yeah, a POSITA would need to take the
4 intended use of a solar cell into consideration in
5 its design for all environments. But that being
6 said, many features of solar cells will stay the
7 same, or largely the same, regardless of their
8 illumination intensity. But design choices of
9 particular layers, particular materials,
10 particular things may change under high
11 concentration relative to one sun, for example.

12 So the teachings are often, went across
13 those interested in solar cells under
14 concentration and those in one sun, but some of
15 the details, some of the design choices might
16 vary.

17 Q Does carrier concentration increase in a
18 concentration environment relative to a one sun
19 environment?

20 MR. SELWYN: Objection. Form.

21 A It usually does. So in particular what
22 we call the excess carrier density or excited

1 carrier density, those are the electron hole pairs
2 that are generated by absorbing sunlight. But if
3 the doping density of a layer is higher than the
4 excited carrier density, then there wouldn't be a
5 substantial change in the total carrier density.

6 So this is a qualified yes to your
7 question.

8 Q Does auger recombination get induced at
9 lower dopant concentrations in a concentrator
10 environment relative to a one sun environment?

11 A I need more information. It can under
12 some circumstances. It doesn't under most.

13 Q Okay. And so we're talking about a one
14 sun environment and a hundred sun environment.
15 All other things being equal, my question is would
16 auger recombination be induced at a lower doping
17 concentration in the 100 sun environment, and is
18 it your answer it depends?

19 MR. SELWYN: Objection. Form.

20 A Correct. I understand the question, but
21 I can't answer it without knowing, for example,
22 what the dopant concentration is and -- yes.

1 Q I think what I'm envisioning is the
2 dopant concentration is kind of what we're varying
3 as we're trying to induce auger recombination.

4 A I understand that, but if, for example,
5 and now we're out on hypotheticals here, the
6 doping concentration started at one times 10 to
7 the 15, reducing it to one times 10 to the 14
8 isn't going to affect auger recombination. If it
9 started at one times 10 to 20 and it was reduced,
10 this is why I say I need more information.

11 Q Is auger recombination induced at any
12 dopant concentration?

13 MR. SELWYN: Objection. Form.

14 A I describe auger recombination in my
15 Background. It's a three-bodied process. It
16 takes two electrons and one hole, or two holes and
17 one electron. It becomes more likely as there's
18 higher concentrations of electrons or higher
19 concentrations of holes.

20 There's two different ways at least to
21 achieve that. One is through doping, which is why
22 auger recombination increases with heavier doping.

1 And the other is by exciting electron hole pairs,
2 which is why auger recombination also increases
3 with a higher generation rate or higher sunlight
4 intensity.

5 Q So in paragraph 79 of your
6 Declaration -- I'll let you get there -- when you
7 said researchers understood that FSF dopant
8 concentrations above one times 10 to the 18 per
9 cubic centimeter induced auger recombination, you
10 just as easily could have said any amount of
11 concentration will induce auger recombination,
12 correct?

13 MR. SELWYN: Objection. Form.

14 A No, I think you may be getting confused
15 by the fact that in the industry we use the word
16 "concentration" to refer to the number of dopant
17 atoms per cubic centimeter and we also, rather
18 unfortunately, use the word to refer to the number
19 of suns incident.

20 So this paragraph here, 79, isn't
21 talking about the number of suns on a solar cell
22 at all. It's talking about the concentration of

1 dopant atoms per cubic centimeter of silicon. We
2 also use the word "dopant density, "density" and
3 "concentration" interchangeably, but I've used
4 "concentration" in my Declaration.

5 Q I understand that. But is it valid to
6 say researchers understood that FSF dopant
7 concentrations above one times 10 to the 6 per
8 cubic centimeter induced auger recombination?

9 A No, that's not valid. Those doping
10 concentrations are not inducing auger
11 recombination.

12 Q Those dopants would not contribute to an
13 extra electron or an extra hole?

14 A Yes, those dopants -- well, actually at
15 those concentrations, no, it turns out in silicon
16 the intrinsic concentration, that is if there are
17 no dopants whatsoever, in silicon there's already
18 10 to the 11th per cubic centimeter electrons and
19 holes. But I think I understand your point.
20 Perhaps you want to rephrase that.

21 Q Okay, I'll try again.

22 Do you believe it to be true that

1 researchers understood that FSF dopant
2 concentrations above one times 10 to the 15 per
3 cubic centimeter induced auger recombination?

4 A No, I don't believe that researchers
5 understood that because those low dopant
6 concentrations don't induce auger recombination in
7 any meaningful way, and that's why I've given
8 instances from the literature. I think I refer to
9 three or four of them here, but include at least
10 five in my Declaration that find that 10 to the 18
11 is where auger recombination begins to turn on.

12 Q You mean begins to turn on, or actually
13 outweighs the perceived benefits of the dopants?

14 A Yeah. Your phrasing may be better than
15 mine here. As I described previously, what we're
16 looking for on the front surface field is this
17 balance between reducing surface recombination and
18 inhibiting auger, and it's around one times 10 to
19 the 18 where this optimal is found. Above that,
20 as Marvin says, the effect of this will
21 increase -- sorry, the effectiveness of the front
22 surface field will decrease due to increased auger

1 recombination.

2 Q So if we were interested in actually
3 when the auger recombination actually turns on, it
4 would be at a concentration less than one times 10
5 to the 18th per cubic centimeter, correct?

6 A All the recombination mechanisms are not
7 like a switch with an on/off. They increase with
8 increasing carrier density as I've described in my
9 Declaration.

10 Q I'll try a different way. Do you agree
11 that there would be auger recombination in a
12 meaningful way, or a non-meaningful way at
13 concentrations less than one times 10 to the 18th
14 per cubic centimeter?

15 A I believe that there would be auger
16 recombination in a non-meaningful way. That's why
17 these references in the literature have found that
18 from the position of designing a solar cell as a
19 POSITA would be doing, that at a doping
20 concentration of around one times 10 to the 18 is
21 an optimum, beyond which the contributions from
22 auger recombination outweigh the benefits of any

1 increased doping.

2 Q Are you aware of any reference that
3 teaches the use of a doping concentration greater
4 than one times 10 to the 18th?

5 A Yes, I am.

6 Q And are you aware of any references that
7 postdate Marvin and nevertheless recommend a
8 doping concentration greater than one times 10 to
9 the 18?

10 A Yes, I'm aware of references, for
11 example, that were introduced in Maxeon's
12 Preliminary Response.

13 Q Do you believe that the authors of those
14 references were misguided?

15 A I do.

16 Q Do you believe that a person of ordinary
17 skill in the art would have understood that those
18 authors were misguided?

19 A I believe a person of ordinary skill in
20 the art would have looked at the literature that
21 was out there, including the literature that I've
22 referenced, and understood that there were design

1 choices that one times 10 to 18, or in that range,
2 was identified by many authors as being an optimal
3 value, and I think a person of ordinary skill in
4 the art would have identified some of the
5 shortcomings of other studies which we can look at
6 in detail if you'd like.

7 Q Do you believe a person of ordinary
8 skill in the art would have understood Marvin to
9 be a well-guided author?

10 MR. SELWYN: Objection. Form.

11 A Yeah, I think that a person of ordinary
12 skill in the art would have taken away that Marvin
13 considered these four conditions that I've talked
14 about and had teachings for a condition at one sun
15 and beginning of life that was useful and could be
16 implemented in other solar cells having a front
17 surface field.

18 Q I want to shift gears for second, Dr.
19 Holman. Can you please turn to paragraph 147?

20 A Of my Declaration?

21 Q Yes.

22 A Yes, I'm there.

1 Q Okay. You've reproduced an annotated a
2 figure from Granek in that paragraph, correct?

3 A Yes, figure 7-1 as it appears in
4 Granek's thesis.

5 Q And you've highlighted one of the curves
6 in yellow, right?

7 A Yes, the curve that corresponds to a
8 front surface field peak doping density of one
9 times to 10 to the 18.

10 Q And at least at the higher recombination
11 velocities, that doping concentration does not
12 yield the best efficiency among the doping
13 concentrations that they modeled; is that right?

14 A That's correct. At approximately three
15 times 10 to the second, so that is 300 centimeters
16 per second, there is a crossover. And for higher
17 surface recombination velocities, one times 10 to
18 the 18th is not optimal. Below about 300
19 centimeters per second, one times 10 to the 18th
20 is optimal.

21 This might not be immediately apparent,
22 but a POSITA would understand that the range shown

1 here is enormous. So on the left side of the
2 graph, 10 to the zero centimeters per second is a
3 very low surface recombination velocity. This is
4 a very well-passivated surface. And on the right
5 side 10 to the fifth is like no passivation, a
6 very poorly passivated surface. So 300 is a
7 relatively poorly passivated surface. Not the
8 worst, but quite poor.

9 Q What factors impact surface
10 recombination velocities?

11 A I talk about this in my Declaration when
12 I talk about surface recombination. But, for
13 example, the number of dangling bonds at a silicon
14 surface, that increases surface recombination
15 velocity. And so correspondingly the layers, the
16 surface passivation layers added to the surface
17 and the extent that they remove dangling bonds
18 impact surface recombination velocity.

19 Q Do you agree that surface recombination
20 velocity is strongly dependent on technological
21 factors, some of which are difficult to control?

22 MR. SELWYN: Objection. Form.

1 A I wouldn't say that. For decades, solar
2 researchers, learning from semiconductor device
3 researchers, knew how to passivate surfaces and
4 how to achieve well-passivated surfaces and the
5 materials that could be used to do so. This was
6 well-practiced art.

7 But I believe I referred you previously
8 to my Background section showing evolutions of
9 solar cells from the 50s to more modern times and
10 how adding surface passivation layers was some of
11 the important developments in, 40 years ago for
12 example.

13 Q Does surface recombination velocity vary
14 with surface roughness?

15 MR. SELWYN: Objection. Form.

16 A It can, depending on the nature of that
17 surface roughness.

18 Q Does it depend on surface contamination?

19 A It can. Contamination can be lots of
20 different things, so we'd have to get into detail.
21 But there could be contaminants on the surface of
22 the wafer maybe prior to depositing a surface

1 passivation layer that increase surface
2 recombination velocity. Although similar to the
3 passivation layers themselves, there have been
4 decades of research and understanding from the
5 micro-electronics industry and in the solar
6 industry about how to clean wafer surfaces.

7 Q Does surface recombination velocity vary
8 with respect to oxidation temperature?

9 A It can, but there isn't a one-to-one
10 correspondence. So when you say oxidation
11 temperature, I'm assuming that what you mean is we
12 are depositing or growing a silicon oxide layer on
13 the silicon surface, and there are multiple
14 techniques to grow or deposit such an oxide layer,
15 and a temperature that's found to be optimal with
16 one technique isn't necessarily the optimal
17 temperature with another technique. Or the
18 temperature found to be optimal with one piece of
19 equipment is not necessarily the optimal
20 temperature for another piece of equipment even if
21 they're within the same technique or technique
22 family.

1 Q Does surface recombination velocity vary
2 with respect to ambient gases during oxidation?

3 A It can. Oxidation, as one example, can
4 be done with or without the addition of water
5 vapor, and the resulting passivation can depend on
6 that. Maybe as another example, it's always
7 possible to add unwanted gas to have poor surface
8 passivation.

9 But once again, oxidation was a
10 technique that goes back, I believe 80 years at
11 this point in time in the micro-electronics
12 industry, and then in the solar industry for the
13 last at least 60 years, and so this is a technique
14 that's well-understood and the best ways to
15 perform it. A POSITA would not be surprised or be
16 unable to figure out how to perform a good quality
17 oxidation.

18 Q Does surface recombination velocity vary
19 with respect to post-oxidation annealing?

20 A Similar to my other questions, it can.

21 Q Are you finished?

22 A One second.

1 I want to think about your question a
2 little bit more.

3 Yes. So as an example, it's always,
4 it's always possible to, I'll say -- I'll stick
5 with my answer that yes, it can.

6 Q Is surface recombination velocity
7 dependent on whether n-type or p-type dopants are
8 used?

9 A Used in what?

10 Q Used in the solar cell.

11 A I have multiple regions of a solar cell
12 that have dopants. Do you mean the wafer?

13 Q The dopants that are used to create a
14 front surface field.

15 A Oh.

16 MR. SELWYN: Objection. Form.

17 A So your question is can surface
18 recombination velocity depend on whether the
19 dopants in the front surface field are n-type or
20 p-type; is that your question?

21 Q Yes.

22 A Yes, it can. But the solar industry

1 knew how to make high-quality passivation layers
2 for both n-type and p-type wafer surfaces. It was
3 well-known which materials to choose, what
4 properties they might have in order to achieve low
5 surface recombination, well below 100 centimeters
6 per second, regardless of whether the surface was
7 n-type or p-type.

8 Q What costs would a POSITA have to endure
9 to achieve those low surface recombination
10 velocities?

11 MR. SELWYN: Objection. Form.

12 A I think that's a very open-ended
13 question that I couldn't answer with additional
14 detail [sic] about which process was being used,
15 how many process steps, with which equipment, with
16 which materials, et cetera. Costs can vary widely
17 with process.

18 Q And I'll ask another question. I didn't
19 mean to be asking for a specific dollar amount,
20 but I'll ask a new question.

21 Do you agree that to achieve lower
22 surface recombination velocities more costs would

1 be incurred?

2 A Not necessarily. You know, with the
3 same equipment and same process it's possible to
4 achieve high or low depending on how you, how you
5 set the knobs, just like it's possible to bake a
6 great cake or a terrible cake with the same oven
7 and ingredients. And so there's not a one-to-one
8 correlation to those.

9 Q So you agree with me that in figure 7-1
10 Granek thought it relevant to provide data for
11 surface recombination velocities greater than
12 2,000 --

13 MR. SELWYN: Objection. Form.

14 Q -- centimeters per second?

15 A Yes. Granek's Ph.D. thesis, and this
16 chapter in particular, explores, as a good Ph.D.
17 student would do, a wide range of conditions to
18 understand behavior. You know, a natural thing,
19 if my student brought me back this graph and it
20 was cut off with a maximum value of 10 to the 2,
21 for example, and the line was flat all the way
22 across the top, I would also ask, hey, what

1 happens if you go further out.

2 So Granek's thesis is exploratory, as a
3 thesis should be, and takes into account the
4 entire practical range of surface recombination
5 velocities from very good to absolutely horrible.

6 Q Any reason why a POSITA would design a
7 solar cell with high surface recombination
8 velocities if it were equally costly to implement
9 lower surface recombination velocities?

10 A No. The goal is always lower surface
11 recombination velocity, and that has been the
12 trend of the solar industry, and that's why the
13 devices have become increasingly more
14 sophisticated with better surface passivation
15 layers as I pointed out in that Background section
16 that I referenced before showing the evolution of
17 devices.

18 So it's been a constant march towards
19 higher efficiency, and reducing surface
20 recombination velocity has been one important
21 component of that march.

22 Q Do smoother surfaces generally yield

1 lower recombination velocities?

2 A They can. Not in all instances, but
3 they can.

4 Q Dr. Holman, I believe you've answered my
5 question. I don't mean to cut you off. If you
6 want to continue, you can.

7 A No, what I said is accurate and
8 complete.

9 Q Generally, if you know, are smoother
10 surfaces more costly to achieve?

11 MR. SELWYN: Objection. Form.

12 A In the solar industry -- yeah, the
13 answer is it depends on how much smoother. So in
14 the solar industry wafers typically come what we
15 call "as cut," which means that they were sawed
16 out of an ingot, which is a big cylinder of
17 silicon, and the surfaces are naturally rough.

18 The wafers then undergo processes to
19 remove any residual damage caused by sawing. We
20 call that a saw damage removal step. And the
21 wafer surfaces end up smoother afterwards.

22 In many instances, but not all, the

1 wafers then go into a texturing bath which
2 purposefully makes them rougher. It's also
3 possible, however, to put them into other baths
4 which would purposefully make them smoother.

5 So if we were to track the roughness of
6 a wafer through its processing, it would start
7 very rough, it would become smoother, it might
8 then be made rougher or it might then be made
9 smoother.

10 So depending on the level of smoothness
11 you would like to achieve, it could be already
12 happening in a solar cell fabrication line, and it
13 could be simpler, it could be less expensive, or
14 it might be more expensive.

15 If you wanted to achieve the smoothness
16 used in the semiconductor industry, those wafers
17 are atomically smooth, and that's done by a
18 process called chemical-mechanical polishing.
19 That's quite expensive.

20 So depending on the smoothness
21 desirable, it may or may not be cheaper or more
22 expensive.

1 Q Is it cheaper, or more expensive to have
2 lower surface contaminants?

3 MR. SELWYN: Objection. Form.

4 A I guess lower than what?

5 Q I guess we can just envision two
6 scenarios. One has fewer contaminants relative to
7 the other, so we can call that one lower, and the
8 other one higher.

9 A And the surface contaminants were
10 introduced how in the processing? What might I be
11 doing to -- surface contaminants from what
12 chemical cleaning? Contaminants that are
13 throughout the wafers that are impurities that
14 were introduced during the ingot pulling process?
15 What do you have in mind?

16 Q Do the holes in electrons on the surface
17 of a wafer know where the contaminants came from?

18 A Holes in electrons don't know anything,
19 I'm afraid.

20 No, the holes in electrons -- no, the
21 holes in electrons don't know.

22 Q So the source of the contaminants

1 doesn't really matter, does it?

2 A Well, I believe your previous question
3 was about a cost, and so the cost to remove
4 contaminants may very well depend on their source
5 because presumably you would be altering processes
6 to either not introduce them from that source in
7 the first place or maybe remove them subsequently.

8 Q Either way it seems like it's more
9 costly to have fewer contaminants, correct?

10 MR. SELWYN: Objection. Form.

11 A I don't know how to answer because I
12 don't know the source of the contaminants. So for
13 example, you know, I can add contaminants to
14 something and it could cost me more to do so.

15 Yeah, I don't know, I don't know how to
16 answer with the limited information.

17 Q Returning to the figure in paragraph 147
18 of your Declaration, there are five options,
19 correct? No FSF and then four different
20 concentrations; is that right?

21 A Yes, correct.

22 Q Okay. This is just a simulation, right?

1 A This is a simulation, result of a
2 simulation.

3 Q And I believe you said it's maybe
4 reading between the lines, you think Granek may be
5 just trying to show trends, right?

6 MR. SELWYN: Objection. Form.

7 A I think that Granek is trying to do more
8 than show trends. But I think Granek is trying to
9 explore the full parameter space.

10 Q And so you agree that a person of
11 ordinary skill in the art would not read Granek
12 and believe that he or she were limited to these
13 five options, right?

14 A Yes, I agree with that. I think that a
15 person of ordinary skill in the art would take
16 from this paper, or others, the teachings of it,
17 but wouldn't necessarily limit themselves to the
18 specific conditions used if a limited number of
19 conditions were used.

20 Q A person of ordinary skill in the art
21 might look at figure 7-1, and maybe other passages
22 of Granek, and decide that a doping concentration

1 between one times 10 to the 18th and one times 10
2 to the 19th is preferred. Do you agree with that?

3 A No, I think a person of ordinary skill
4 in the art would look at Granek and probably
5 determine that a doping concentration between one
6 times 10 to the 17 and one times 10 to 18 is
7 optimal.

8 So if you'll turn one page in my
9 Declaration, to paragraph 149, which is Granek
10 figure 7-3, here Granek simulations aren't limited
11 to five specific conditions, but now the peak
12 doping density is varied for many conditions.
13 It's the left axis of the plot. The color bar is
14 the J not value. Low J not values are good. So
15 closer to dark blue is good. And the optimum that
16 Granek identifies is a little bit below one times
17 10 to the 18.

18 Q You put a cite there of Granek figure
19 7-3, right?

20 A Yes, that's correct.

21 Q But that's not Granek figure 7-3, is it?

22 A Did I use the wrong number? Let's look.

1 Q I believe you used part of figure 7-3.

2 A Ah. I know what you're saying.

3 Yes. Shall we look at Granek?

4 Q Do you agree that the cite probably
5 should have been 7-3 partial or something to
6 indicate you're not using the entirety of the
7 figure, that's there part of the figure that you
8 don't like, part that you do like, right?

9 MR. SELWYN: Objection. Form.

10 A Well, it's not that I dislike or like
11 part of the figure. But to your point, I think it
12 would not have hurt to put figure 7-3(b).

13 Q Well, it may have hurt, though, because
14 it actually shows that higher doping
15 concentrations are preferred, right?

16 MR. SELWYN: Objection. Form.

17 A No. The other portion of the figure,
18 perhaps we can look at it, is not relevant to
19 solar cells with any reasonable passivation,
20 surface passivation for the discussion that we
21 were just having. It corresponds to the rightmost
22 extreme surface recombination velocity in figure

1 7-1, which is a surface that is unpassivated or
2 has metal deposited directly on it without a
3 surface passivation layer.

4 Q And how much -- strike that. I'll ask a
5 new question.

6 What is the surface recombination
7 velocity in the lower part of figure 7-3?

8 A The lowest -- the lower part of 7-3.

9 Ah. It is, it's a model introduced by
10 an author named Cuevas that shows surface
11 recombination velocity that would be expected by a
12 front surface field having the doping
13 concentration on the y axis. We call that that
14 passivation varies with the front surface field
15 doping. This model takes that into account. So
16 it's a value for surface recombination that is
17 representative of passivated solar cells.

18 Q There are different degrees of
19 passivation, correct?

20 A There are.

21 Q So is it a perfectly passivated cell,
22 something less than perfect?

1 MR. SELWYN: Objection. Form.

2 A It is not a perfectly passivated cell.
3 The model is meant to be -- let's take a moment
4 and look at Granek's description of the model.

5 So in the figure caption, Granek says,
6 the top case of the metallized diffusion profiles
7 with the surface recombination velocity of one
8 times 10 to sixth, so actually it's even one order
9 of magnitude off the scale to the right of figure
10 7-1. Then it says on the bottom graph the case of
11 the passivated diffusion profiles is shown. For
12 the passivated emitter, the surface recombination
13 velocity was calculated using the model of Cuevas
14 which was presented in 3.23.

15 And it's figure 3-6 of Granek that shows
16 you those surface recombination values. You can
17 see, for example, for phosphorus concentration --
18 sorry, for phosphorous doping of the front surface
19 field. And you'll note that figure 7-3 is
20 phosphorus, so we'll look at that one. So that's
21 the left side of figure 3-6. The surface
22 recombination velocity looks to be about 70, up to

1 doping densities, front surface field peak doping
2 densities of 10^{18} , and then it starts
3 increasing thereafter.

4 Q Up to 10^{15} ?

5 A 10^{15} when you have extremely high
6 phosphorus.

7 As a note, the rightmost axis on this
8 graph, 10^{21} , to put that in context,
9 silicon, pure silicon has five times 10^{22}
10 silicon atoms per cubic centimeter. So 10^{21}
11 phosphorus atoms would be two percent. We
12 normally don't call that doping anymore, we would
13 call that an alloy. That's bad news.

14 So once again, Granek is taking a very
15 wide range in his simulation exploration as we
16 talked about.

17 Q Does the image in the lower part of
18 figure 7-3 correspond to any particular surface
19 recombination velocity as represented in figure
20 7-1?

21 A It does correspond to specific values,
22 and in particular, as you move up the y axis in

1 figure 7-3, you move along the x axis in figure
2 3-6. So the surface recombination velocity is
3 constant at 70 centimeters per second up to about
4 10 to the 18th, and then it begins increasing per
5 Cuevas's model thereafter.

6 And the reason that it increases is
7 because those higher densities of surface -- of
8 phosphorus at the surface, those impurities induce
9 more recombination consistent, for example, with
10 what Marvin was teaching.

11 Q If I understood you correctly, the y
12 axis in the lower part of the figure 7-3 is doping
13 concentrations?

14 A That's correct. It's the surface
15 phosphorus concentration. That's how the y axis
16 is labeled on figure 7-3.

17 Would you like me to explain again, or
18 do you understand?

19 Q Oh, no. Thank you, no.

20 I believe you mentioned that this was
21 specific to a phosphorus doping; is that right?

22 A That the results of 7-3 are for the

1 particular instance of phosphorus doping. You can
2 see for figure 3-6 on the right side that Granek
3 also has access to a surface recombination
4 velocity model for boron doping, but doesn't
5 include, maybe doesn't do those simulations in
6 Chapter 7.

7 Q Do you believe those simulations would
8 have yielded different results?

9 MR. SELWYN: Objection. Form.

10 A (Reviewing.)

11 I believe looking at figure 3-6 that the
12 results would be similar, but I haven't done those
13 simulations and so I'm hypothesizing at this
14 point.

15 Q Figure 7-1 is also specific to a
16 phosphorant -- let me start over.

17 Do you agree that figure 7-1 also
18 reflects the results when phosphorus is used as
19 the dopant?

20 A Yes, Granek's simulations were for
21 phosphorus diffusion profiles. But I would note
22 that the teachings here, the trends of them are

1 going to be the same for different dopant atoms.
2 And in particular the open question here is -- let
3 me say that differently.

4 The trends would be the same for
5 different dopant atoms. Granek has chosen
6 phosphorus in order to show these trends as
7 opposed to including a simulation for every dopant
8 atom on the periodic table.

9 Q But Granek doesn't include any
10 simulations for any p-type dopant, right? At
11 least something similar to figure 7-3 or 7-1.

12 A Yeah, those simulations are shown for
13 n-type dopants, and phosphorus in particular. As
14 I mentioned, I believe the results would be
15 similar for other dopant atoms, but they're not
16 included.

17 Q Questions on this. Figure 7 -- excuse
18 me. Start over.

19 Figure 3-6 gives us multiple surface
20 recombination velocities on the y axis, right?

21 A Yes.

22 Q And is there any one of those values in

1 particular that is used for the bottom part of
2 figure 7-3?

3 A I was trying to explain this before.
4 They all are, depending on where within figure 7-3
5 you are. So the input parameter of the surface
6 recombination velocity value -- varies across that
7 figure according to a model. That model gives the
8 results shown in figure 3-6.

9 So when you calculate, let's start maybe
10 at the bottom of the figure. One times 10 to the
11 17 -- excuse me, the bottom of figure 7-3. We
12 have a surface doping density of one times 10 to
13 the 17th. We would turn to figure 3-6, look on
14 the x axis for 10 to the 17. Go up to y where it
15 intercepts the line, see a value of 70. The value
16 of 70 was used in the model for all points on the
17 horizontal line of figure 7-3 that has a value of
18 one times 10 to the 17.

19 If we then move up to one times 10 to
20 the 18 and we look at that line on figure 7-3, we
21 come back to figure 3-6, we go 10 to the 18 on the
22 x axis. We travel vertically. We run into the

1 line at a value of 70 centimeters per second. We
2 put that value into our model and we get the data
3 along the horizontal line at one times 10 to the
4 18th in figure 7-3, et cetera.

5 And it is useful, I think, you say like
6 where did these come from, why these values. If
7 you look at the sentence before figure 3-6 in
8 Granek, for these diffusion profiles with surfaces
9 passivated with thermally-grown silicon oxide, the
10 parameterization of Cuevas was taken. That's what
11 shown in figure 3-6.

12 Q The x axis of the two images in figure
13 7-3 is the phrase "junction depth".

14 Do you see that?

15 A Yes.

16 Q Do you have an understanding as to what
17 junction depth is?

18 A I do.

19 Q What is that understanding?

20 A So Granek here is talking about the
21 characteristic, the depth, of the front surface
22 field that is being simulated. So the front

1 surface field has the peak doping density shown on
2 the y axis and it extends into the wafer, the
3 value given on the x axis.

4 Now -- pardon me. I'm done. Go ahead.

5 Q So is it the case that the doping
6 concentration decreases as one proceeds from the
7 surface of the device into the device?

8 MR. SELWYN: Objection. Form.

9 A For Granek's simulations, Granek says
10 that he uses a Gaussian profile, which is a shape
11 of -- which is a function that describes the
12 doping density as a function of depth from the
13 surface. And yes, it decreases. It has its peak
14 value at the surface, and decreases as it goes
15 into the wafer.

16 Q Another question about Granek. Can you
17 please turn to page 48 of Granek, Exhibit 1010?

18 A Granek page 48 did you say?

19 Q Yes.

20 A Okay, I'm there.

21 Q And before we get there, Granek is a
22 long reference, do you agree?

1 A It's a Ph.D. thesis. It's maybe not
2 long for a Ph.D. thesis, but it's longer than a
3 common patent application or published paper.

4 Q Did you read the entirety of Granek?

5 A I did read Granek, yes.

6 Q Did you find anything that you disagreed
7 with in your review of it?

8 MR. SELWYN: Objection. Form.

9 A Not that I recall at this time.

10 Q One of the things that Granek says on
11 page 48, the second -- sorry, the first full
12 paragraph, phosphorous-doped n-type silicon has
13 received increased interest in the PV research
14 community in recent years due to shortage of the
15 p-type silicon feedstock and due to its high
16 minority carrier lifetime.

17 Do you see that?

18 A I do.

19 Q Does PV stand for photovoltaic?

20 A Yes, it does.

21 Q Do you agree with that statement?

22 A 2009.

1 Yes, there was a lot of interest in this
2 period in finding new and better silicon materials
3 for the wafers in solar cells. At the time, the
4 wafer was the most expensive part of the solar
5 cell and so there was a lot of work to improve the
6 quality of silicon while still keeping it cheap.
7 And there was a lot of interest in a lot of
8 different types of silicon at the time. P-type
9 silicon was the dominant one in the industry, but
10 many things were being explored, including n-type
11 silicon.

12 Q When it says "its high minority carrier
13 lifetime," do you understand "its" to be referring
14 to n-type silicon?

15 A In this sentence that is my
16 understanding, yeah. If -- so silicon has this
17 property -- "due to its high minority carrier
18 lifetime."

19 Yeah, if there are not, you know, if you
20 had very high-purity wafers without a lot of
21 impurities causing recombination, then the
22 lifetime in n-type silicon would be higher than

1 the lifetime in p-type silicon, for example.

2 Q Generally speaking, is high minority
3 carrier lifetime desired in a solar cell?

4 MR. SELWYN: Objection. Form.

5 A Yes, in general high minority carrier
6 lifetime is good for a solar cell.

7 Q In the section joining, or bridging
8 pages 48 and 49, there is a bolded list, three
9 items?

10 A Uh-huh.

11 Q They're introduced by the statement "the
12 advantages of n-type Si when compared to p-type Si
13 are as follows."

14 Do you see that?

15 A Yep.

16 Q "Si" refers to silicon, right?

17 A It does.

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

20 A (Reviewing.)

21 Yes, these are correct. So the first
22 one is about recombination caused by association

1 of oxygen with boron. Boron being a p-type
2 dopant.

3 The second one indicates that there can
4 be less sensitivity to impurities in the n-type
5 silicon than in p-type silicon.

6 And the third one is essentially a
7 summary of the effects of those.

8 Q Dr. Holman, I'd like to discuss
9 paragraph 161 of your Declaration.

10 MR. SELWYN: If you are somewhat
11 changing topics, is now a good time for a break?

12 THE WITNESS: Works for me.

13 MR. SNODGRASS: We can go off the
14 record?

15 MR. SELWYN: Yep, let's do that.

16 (A recess was taken at 2:13 p.m.)

17 (Back on the record at 2:24 p.m.)

18 BY MR. SNODGRASS:

19 Q Dr. Holman, is there any testimony
20 you've provided today that you want to change?

21 A No. Thank you for asking.

22 Q Okay. I wanted to talk about paragraph

1 161 of your Declaration. You mention the
2 reference Istratov, and you also mention the
3 notion of gettering; is that right?

4 A Yes.

5 Q And do you agree that Istratov is
6 interested in gettering impurities from a device
7 layer to a substrate?

8 A No. Istratov is an experimental study
9 to understand the diffusion of, that is the
10 gettering, of two metallic impurities, iron and
11 copper, from a silicon wafer, which is a
12 substrate, through an oxide layer into a
13 polysilicon layer.

14 Istratov doesn't have a particular
15 device in the study. Istratov is understanding
16 gettering behavior using that test structure.

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

20 MR. SELWYN: Objection. Form.

21 A No, I do not. The polysilicon layer is
22 a deposited layer and would not be called a

1 substrate.

2 Q Right. But Istratov talks about
3 gettering from the polysilicon to the silicon
4 substrate.

5 A Do you want to show me where you're
6 looking at?

7 Q The Introduction.

8 MR. SELWYN: Objection. Form.

9 A Can you direct me to the sentence that
10 you have in mind, or sentences?

11 Q The first sentence in the second
12 paragraph. The BOX, or B-O-X, layer not only
13 provides electrical isolation between the top
14 silicon layer and the substrate, but also
15 introduces a barrier for diffusion of metal
16 impurities from the device layer to the gettering
17 sites in the substrate. And then it continues,
18 this barrier may render inefficient the
19 traditional gettering techniques.

20 Did you consider that disclosure in
21 connection with forming your opinions?

22 A (Reviewing.)

1 I'm just reading. Please give me one
2 moment.

3 (Reviewing.)

4 Yes, I did consider it. I have read
5 Istratov in its entirety. In this paragraph here,
6 Istratov is talking about previous work in the
7 state of the field as understood -- as is typical
8 in Introduction sections.

9 And as you pointed out in the second
10 sentence, traditional gettering techniques are
11 inefficient in this structure. And Istratov
12 examines a structure through two experiments in
13 which metal impurities are introduced at the
14 backside of a wafer, that is the side without the
15 oxide in polysilicon, the wafer is the substrate,
16 and studies the movement, the diffusion, of those
17 metals through the substrate through a buried
18 oxide layer into the polysilicon layer.

19 So not from a device layer into a
20 substrate, but through a substrate -- from a
21 substrate, through a substrate, into the
22 polysilicon layer. That's what Istratov does in

1 this paper.

2 Q Istratov states: In this study -- I'm
3 continuing in that same paragraph I'd referenced
4 earlier.

5 In this study, computer modeling was
6 used to evaluate the feasibility of traditional,
7 in parentheses, substrate gettering techniques for
8 iron and copper in SOI wafers.

9 Do you understand that to be a technique
10 of gettering impurities into a substrate, not from
11 a substrate?

12 A (Reviewing.)

13 I understand that Istratov simulations,
14 which begin in Section 4, include movement of
15 impurities into the substrate. In my Declaration,
16 I rely on Istratov's experimental results in which
17 iron and copper are moved from the wafer, through
18 the wafer, through the oxide, into polysilicon.

19 Q That movement is achieved by subjecting
20 the sample to a temperature of 1020 degrees C for
21 eight hours; is that right? At least in the case
22 of iron.

1 A For the case of iron those were the
2 conditions investigated by Istratov, yes.

3 Q Do you believe it would have been
4 obvious to a person of ordinary skill in the art
5 to subject a solar cell to those temperatures for
6 that time?

7 A As I discussed in the Background section
8 of my Declaration, a wide range of temperatures
9 are used in processing solar cells, including
10 temperatures as high as the temperature used here.
11 However, a POSITA would have taken the learnings
12 from Istratov, rather than the recipes from
13 Istratov, to implement in a solar cell.

14 In particular a POSITA would have noted,
15 as I did in my Declaration, that Istratov uses the
16 same structure as the solar cells of interest
17 here, but a thicker oxide layer, and that a
18 thicker oxide layer would require higher
19 temperatures or longer times.

20 And so a POSITA would take the learnings
21 and likely apply either a lower temperature or
22 shorter time rather than copying the particular

1 settings from Istratov. A POSITA learns from
2 Istratov that iron can be gettered at temperatures
3 that are compatible with solar cell fabrication
4 through an oxide layer and accumulate in
5 polycrystalline silicon.

6 Q But if a person of ordinary skill in the
7 art wanted to do that, take impurities from a
8 substrate, through an oxide, into a poly layer,
9 they could consult Istratov to provide guidance as
10 to how to do that; is that your opinion?

11 A Yes. Istratov's teachings show that
12 iron, and also copper, can be gettered from a
13 crystalline silicon substrate, through an oxide
14 layer, into polycrystalline silicon. And Istratov
15 shows conditions which that's true, conditions
16 that are compatible with silicon solar cell
17 processing.

18 But a POSITA would also use his or her
19 normal ingenuity to observe the difference of
20 thickness in Istratov's oxide layer compared to,
21 for example, Choi's or Cousins' and so may make
22 design choices accordingly.

1 Q And specifically with respect to the
2 eight hours, a person of ordinary skill in the art
3 would not employ a temperature of 1020 degrees for
4 eight hours to Cousins or Choi, right?

5 A A person of ordinary skill would, yeah,
6 would make design choices based on the structure
7 that he or she had. And so for Choi, with a
8 thinner oxide, that person would know to use a
9 shorter time or lower temperature.

10 Q How would that heat temperature -- let
11 me start over.

12 Do you agree that's a heat treatment
13 process?

14 A I do.

15 Q How would that heat treatment process
16 impact Choi?

17 Actually, I'll withdraw that question.

18 Do you discuss in your Declaration how
19 that heat treatment process would impact Choi?

20 A I describe in the Motivation To Combine
21 section of my Declaration that Choi has a heat
22 treatment process as well; in particular, a

1 diffusion process, and that a person of ordinary
2 skill in the art would have understood that Choi's
3 heat treatment process could be used to provide
4 gettering per Istratov's teachings with perhaps
5 design choices made by that POSITA.

6 Q In order to getter impurities from
7 substrate in Choi to a poly layer in Choi, there
8 needs to be impurities in the substrate of Choi,
9 correct?

10 MR. SELWYN: Objection. Form.

11 A There has to be impurities in order to
12 getter impurities, that is true.

13 Q Do you agree with me that Choi does not
14 disclose that its substrate has impurities?

15 A No, I do not agree with you.

16 Q Choi discloses that its substrate has
17 impurities; is that your opinion?

18 A It does, yes.

19 Q And can you direct me to where in Choi
20 that disclosure is?

21 A Yes, I can.

22 If you look at paragraph 230 of my

1 Declaration -- pardon me, that's not the right
2 paragraph. Give me just one moment. I want to
3 direct you elsewhere.

4 Paragraph 131, please. Starting with
5 the second sentence, Choi solar cell (100)
6 comprises of semiconductor substrate (10), that
7 may be formed of a crystalline semiconductor,
8 parentheses, for example, crystalline silicon, end
9 parenthesis, containing a first conductive type
10 dopant.

11 Choi explains that the first conductive
12 type dopant can be either n-type, in which case
13 the substrate is doped with a Group 5 element,
14 also called an impurity in Choi, such as
15 phosphorous, arsenic, bismuth, or antimony, or a
16 p-type dopant, also called an impurity in Choi,
17 such as boron, aluminum, gallium and indium.

18 So of those eight examples, six I
19 recognize as metal impurities within the substrate
20 of Choi.

21 Q And Istratov deals with iron, correct?

22 A Iron and copper are the two examples

1 that Istratov gives.

2 Q Right. And Choi doesn't disclose that
3 its substrate has iron or copper, correct?

4 A Choi does not disclose that, no. Choi
5 does disclose that the semiconductor substrate
6 silicon could be n-type or p-type. And as I
7 discuss in the Background section of my
8 Declaration, and as we talked about earlier, it
9 was a common problem facing the semiconductor --
10 the solar industry at the time, perhaps the most
11 important problem, to get the highest quality
12 wafers for the lowest price.

13 And as a result of that, much of the
14 industry was using wafers that had impurities
15 within them. And those could include iron, for
16 example, and copper were some of the more common
17 impurities introduced into -- during wafer or
18 ingot fabrication, which is why I suspect Choi
19 chose those two to investigate -- sorry, not Choi,
20 Istratov chose those two to investigate.

21 Q You didn't include that discussion in
22 your Declaration, did you, that you just gave

1 about Choi perhaps including iron or copper?

2 A I didn't say that Choi -- I may have
3 misspoke at the end. I meant to say, and I
4 believe I corrected myself, that Istratov chooses
5 iron and copper because they're representative of
6 common impurities in wafers.

7 I do have a discussion in my Declaration
8 in the Background section that low-quality wafers
9 were common in the solar industry at the time, and
10 that those included impurities, and that gettering
11 was a standard and known process frequently used
12 in the solar industry at the time. All of that
13 information is in my Declaration.

14 Q You don't contend that Choi discloses
15 that the substrate has iron or copper; is that
16 correct?

17 A I do not. I simply note that metallic
18 impurities were a common problem, perhaps the most
19 important problem, in the semiconductor industry
20 at the time of Choi.

21 Q And you don't argue in your Declaration
22 that the substrate of Choi would necessarily have

1 had iron or copper, do you?

2 MR. SELWYN: Objection. Form.

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

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

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

11 Q I want to talk about paragraph 182 of
12 your Declaration.

13 You used the expression "Istratov's
14 gettering" in paragraph 182.

15 Do you see that?

16 A Yes.

17 Q Do you have anything in particular that
18 you have -- let me start over.

19 Is there anything in particular you have
20 in mind when you use that expression?

21 A That teachings from Istratov that metal
22 impurities can be gettered from a silicon wafer

1 through an oxide layer and accumulate in a
2 polycrystalline layer where they'll be rendered
3 less detrimental from a recombination perspective.

4 And Istratov, in teaching copper and
5 iron, really gives us two nice bookends of
6 processes. Iron diffuses relatively slowly in
7 silicon. Copper diffuses relatively quickly. And
8 so a person of ordinary skill would have
9 recognized that and understood that gettering
10 other metals would likely lie between the bookend
11 processes explored by Istratov, taught by
12 Istratov.

13 Q Do you believe that the effectiveness of
14 gettering is impacted by whether a poly layer has
15 p-type or n-type dopants?

16 A I believe it can be, yes.

17 Q So in paragraph 182 you don't have a
18 particular time and temperature in mind, right?
19 You're, if I'm understanding you correctly, you're
20 just referring to the general notion of gettering
21 from one place to the other.

22 MR. SELWYN: Objection. Form.

1 Q Is that fair?

2 A It's my understanding that in making an
3 obvious, making a combination for obviousness, as
4 I've suggested here, one doesn't need to take
5 particular steps or recipes and mechanistically
6 swap is them or apply them, but one is able to
7 take the teachings from the studies.

8 And in this case, Istratov provides
9 specific times and temperatures, what I would call
10 existence proofs, things that we know work, for
11 copper and for iron for a thicker oxide layer.

12 And so a POSITA would likely make an
13 adjustment in time or temperature, as we've
14 discussed, accordingly. And the teachings of
15 Istratov more generally are, as I have said, that
16 metal impurities, including fast diffusers and
17 slow diffusers, can be gettered from a wafer,
18 through an oxide, into polycrystalline silicon.
19 So those are the teachings that I think a POSITA
20 would take from Istratov.

21 Q Would implementing Istratov's gettering
22 in Choi be attended by any drawbacks?

1 A Choi discloses a thermal treatment step
2 similar to Istratov. I believe that, depending,
3 for example, on the specific metals being
4 gettered, that there could be implementation
5 without drawbacks.

6 Q Can you envision an implementation where
7 there were drawbacks?

8 MR. SELWYN: Objection. Form.

9 A Sure, I can always imagine ways of
10 putting two things together that don't work. And
11 that's why a POSITA with their ordinary ingenuity
12 would make design choices for a combination that
13 did work.

14 Q Are you contending that Choi's disclosed
15 thermal processes would result in gettering?

16 A They could. Gettering was known, as I
17 describe in my Background section, to take place
18 in the dope regions and in the polysilicon
19 regions. It could. Choi doesn't say otherwise.
20 Choi doesn't say it does happen.

21 Q I apologize. I don't think I was
22 specific enough in my question.

1 In your Declaration, do you contend that
2 Choi's thermal processes will necessarily result
3 in gettering?

4 A Necessarily result in gettering, no, I
5 do not contend that. Choi does not, does not say
6 that one way or the other.

7 I contend that, per paragraph 82, an
8 implementation of Istratov's teachings in Choi
9 could successfully getter impurity, metal
10 impurities from Choi's substrate into Choi's
11 polysilicon layer.

12 Q And that may necessitate a longer
13 thermal process, correct?

14 A I didn't say that. I think that there's
15 a time-temperature trade-off, and a POSITA would
16 make a design choice for a time/temperature
17 combination that worked.

18 Q Would that analysis also entail
19 considering the drawbacks to the time and
20 temperature required to getter?

21 A Yes, absolutely. A POSITA would use his
22 or her normal ingenuity to make design choices,

1 and that means considering how is the teachings,
2 you know, going to work together in making design
3 choices accordingly.

4 Q You don't discuss any of those drawbacks
5 in your Declaration, do you?

6 MR. SELWYN: Objection. Form.

7 A I do not. I think that Choi and Granek
8 are analogous art. I've provided motivation to
9 combine. I think there's a reasonable expectation
10 of success. There is thermal treatments described
11 in both, and that a POSITA, you know, isn't
12 mechanistically exchanging one thing for another
13 and so would make design choices as I've
14 described.

15 Q And your opinion -- I'll start over.
16 You have that opinion notwithstanding
17 you don't know what the drawbacks are; is that
18 right?

19 MR. SELWYN: Objection. Form.

20 A You know, I wouldn't have said that -- I
21 wouldn't have put it like that. I can find the
22 sentence where I explain this clearly in my

1 Declaration, but, you know, I have said that a
2 POSITA would have understood what metal impurities
3 were present in the wafer and would have designed
4 a process accordingly.

5 I believe you asked previously if there
6 could be drawbacks, and you mentioned, for
7 example, long times. That could be a drawback. I
8 agree with you that that could be a drawback, and
9 I offered that an appropriate time and temperature
10 combination would be selected. So, for example, a
11 shorter time could be achieved by a slightly
12 higher temperature or vice versa.

13 What I'm trying to say is in every
14 design choice there are trade-offs, and a POSITA
15 would have been sensitive to those trade-offs in
16 implementing the teachings of Istratov as a
17 particular recipe. That's what I mean to say.

18 Q Do you agree that Cousins does not
19 disclose that its substrate has either iron or
20 copper?

21 A I do agree, Cousins does not explicitly
22 describe iron or copper in the substrate. In

1 2014 -- excuse me, 2010, when Cousins was writing,
2 there were common challenges in the solar industry
3 as I've described with these and other impurities,
4 but they're not mentioned explicitly in Cousins.

5 Q In your Declaration you do not contend
6 that the substrate of Cousins necessarily would
7 have included copper or iron, correct?

8 A That is correct.

9 Q And if one of skill in the art were
10 contemplating incorporating the teachings of
11 Istratov into Cousins, would that person evaluate
12 whether the net benefits of doing so would
13 outweigh the net drawbacks of doing so?

14 MR. SELWYN: Objection. Form.

15 A I believe another way of saying what you
16 said is would that person consider any trade-offs
17 that would be present, and the answer to that is
18 yes, as a POSITA would know how to do. And so,
19 you know, if the POSITA determined that the
20 temperature needed to be slightly higher than was
21 necessary to diffuse the dopants, perhaps the
22 POSITA would have reduced the time or vice versa

1 as we discussed previously for the Choi/Istratov
2 combination.

3 Q Could the POSITA also have determined
4 that there is no time/temperature combination
5 which provides a benefit? In other words, no
6 matter what combination I use to try to implement
7 Istratov, all these drawbacks that attend that
8 modification aren't worth it?

9 Do you think that's possible?

10 A I think that -- I can't think of a
11 scenario off the top of my head in which that
12 would occur. I don't want to say that it's
13 impossible; perhaps you can present me with a
14 scenario.

15 But as I noted, Istratov has done this
16 nice job of choosing iron and copper as exemplary
17 or model system impurities to investigate. And
18 the reason it's nice, as I mentioned, is because
19 those are the examples of a slow diffuser and a
20 fast diffuser, and so most other impurities would
21 fit between those two. And the temperatures that
22 Istratov finds work, and Istratov doesn't say

1 these are the lowest temperatures that work or
2 these are the lowest times that work, Istratov
3 chose certain things to investigate, and that's
4 why I says these are nice existence proofs.

5 The temperatures that Istratov shows are
6 compatible with solar cell processing, in
7 particular 1020 degrees for iron, for example, and
8 690 degrees for copper. And a POSITA would have
9 understood that given a thin oxide layer in Choi
10 or Cousins' device, those temperatures would
11 likely be even lower still, the optimum
12 temperatures would be even lower still.

13 So that to me shows that there's a wide
14 range of processes, a wide range of metal
15 impurities that a POSITA would have a reasonable
16 expectation of success when implementing with Choi
17 or with Cousins. But to your question, is it
18 possible that there are impurities or instances in
19 which implementing Choi's teachings would not
20 provide a net benefit, certainly there is a
21 possibility.

22 Q Would the implementation of Istratov's

1 teachings into Choi or Cousins result in the
2 dopants that are present in the substrate
3 gettering to another location?

4 (Technical interruption.)

5 (The record was read as follows:

6 "QUESTION: Would the implementation of
7 Istratov's teachings into Choi or cousins result
8 in the dopants that are present in the substrate
9 gettering to another location?")

10 A No, I think that is unlikely. And the
11 reason is that the substrate has relatively low
12 doping density. Cousins gives us a -- excuse me,
13 Choi gives us -- we can determine from Choi, as
14 I've done in my Declaration, the approximate
15 doping density of the wafer. It's around one
16 times 10 to the 16 per cubic centimeter. And the
17 layers, for example in Choi or Cousin that are
18 added on either side, the polysilicon layers, et
19 cetera, tend to be heavier doped. And diffusion,
20 which is the underlying physical process that
21 causes gettering, moves atoms from places of high
22 concentration to lower concentration.

1 And so in general, because the dopant
2 concentration is higher in the substrate -- excuse
3 me, in the layers on either side of the wafer than
4 in the substrate, I don't think that diffusion of
5 the dopants out of the substrate into the other
6 layers is likely.

7 That being said, I can imagine certain
8 scenarios in which the layers added to each
9 surface, you know, don't have the same dopant atom
10 or are undoped. So there is always that
11 possibility, but I don't think that that's a
12 likely concern.

13 Q Dr. Holman, I want to direct your
14 attention to paragraph 178 of your Declaration.

15 A Yes.

16 Q In particular, the second sentence. It
17 states: Choi, Granek, Marvin and Istratov each
18 describe techniques to reduce recombination.

19 You see that?

20 A Yes.

21 Q Then there's a cite to Istratov at 569
22 to 70. You see that?

1 A I do.

2 Q Can you point me to anything more
3 specific in Istratov that you believe supports the
4 statement that Istratov describes techniques to
5 reduce recombination?

6 A Give me just a moment, please.

7 (Reviewing.)

8 Okay. What I'm referring to is in the
9 middle of the paragraph on page 569, second
10 column, the paragraph begins "the available
11 experimental reports." And here the author,
12 Istratov, is discussing iron gettering and its
13 effects. And speaking of Yoshimi, et al., this is
14 the third sentence of the paragraph, they did not
15 observe any increase in the minority carrier
16 lifetime after this procedure, which would be
17 expected if iron were gettered by the oxide. And
18 the next sentence: In contrast, graph stated just
19 the opposite, the several consecutive oxidations
20 improved the lifetime through the process of
21 gettering of iron by silicon dioxide.

22 Now lifetime increases when there is

1 reduced recombination. It is recombination that
2 determines lifetime. And so here we have
3 instances of gettering being linked to
4 improvements in lifetime. And it's understood by
5 a POSITA that what Istratov is interested in with
6 this gettering is reducing recombination and
7 improving lifetime. That's the purpose here. So
8 these are the sentences that I'm referring to in
9 my citation.

10 Q Can you please review Paragraph 199 of
11 your paragraph -- or please turn to paragraph 199.

12 A (Complying.)

13 Q I want to ask you about the second
14 sentence that states: To the extent that Choi's
15 solar cell is not already fabricated, the front
16 surface field having the disclosed dopant
17 concentrations of Granek or Marvin, and then it
18 proceeds.

19 A I see that.

20 Q Okay. So my first question, by the
21 phrase "to the extent that," do you mean "if"?

22 A Yes. What I mean is that Choi doesn't

1 disclose a particular dopant density, and so one
2 making, perhaps the solar cell that Choi made in
3 describing, already had doping density in its
4 front surface field that meets the limitation of
5 the claim. And if that were not the case, an
6 adjustment, only a small adjustment would be
7 required to implement Granek or Marvin's
8 teachings. That's what I mean.

9 Q Two paragraphs down, paragraph 201, you
10 state, first sentence: Finally, it is my opinion
11 that the front surface field dopant concentration
12 in Marvin is not dependent on the environment,
13 space or terrestrial, in which the solar cell is
14 used.

15 Do you see that?

16 A I do.

17 Q And you agree with that?

18 A Yeah. I go on to elaborate in the next
19 sentence that the teachings that I'm using are
20 those of solar cells under one set of conditions
21 in beginning of life, consistent with our
22 discussion previously. And so what I mean is,

1 well, what the sentence, what the first sentence
2 says, yes.

3 Q Okay. And later in that paragraph, at
4 the bottom of the page: Thus teachings for one
5 environment were commonly implemented in the
6 other.

7 Do you see that?

8 A Yes.

9 Q You have two cites there; one to Green,
10 one to Marvin. Is that right?

11 A Yes.

12 Q Are you aware of any other authorities
13 that support that proposition?

14 A I have encountered numerous other papers
15 that show crossover of learnings between solar
16 cells that went to space and solar cells that were
17 used on earth. I've cited two here. I'd be happy
18 to get back to you with additional references if
19 you desire.

20 Q No, I'm not requesting that, just so
21 it's clear.

22 Are you aware of references that discuss

1 unique challenge that is present in the space
2 environment?

3 A Yes. I think even Marvin does so when
4 Marvin examines end of life, so the degradation
5 that solar cells might experience in space. Those
6 are aren't the teachings that I rely on from
7 Marvin, but there are additional, or -- yes, is
8 the unqualified answer to your question.

9 Q Are there any particular considerations
10 that a designer of a solar cell for a space
11 application must take into account?

12 A Sure. We talked about the, we just
13 spoke about a high radiation environment that
14 might be the case for some solar cell missions to
15 space. A solar cell in space may experience wider
16 temperature swings than on earth.

17 So, yes, there are unique things. But
18 these are not -- the teachings that I have used
19 from Marvin in my combination are applicable on
20 earth as well as in space as I describe in this
21 paragraph, and I believe a POSITA would understand
22 that in reading Marvin.

1 Q Have you designed a solar cell for a
2 space application?

3 A I have designed solar modules for space
4 applications. I have not designed solar cells for
5 space applications.

6 Q I want to turn to paragraph 207.

7 A Okay, I'm there.

8 Q Give me just a second.

9 A Uh-humh.

10 Q I want to shift forward just a bit.

11 Let's go to 268, paragraph 268.

12 MR. SELWYN: Just for planning purposes,
13 I know you're on Eastern time, we're on western
14 time. If we could take a brief lunch break in 10
15 or 15 minutes, we'd be grateful.

16 MR. SNODGRASS: Okay. Just let me know
17 when you want to break, we'll break.

18 A I am on paragraph 268. Go ahead.

19 Q Yeah. The second sentence: Thus, to
20 the extent that the Patent Owner argues that the
21 claimed invention includes any metal or any source
22 of metal, and it proceeds.

1 Do you see that?

2 A I do, yes.

3 Q Does the expression "to the extent that"
4 mean "if" here as well?

5 A Yes. I think it means what it says, but
6 I think that "if" is, at least in the way that I
7 understand the word, I don't know if lawyers have
8 alternative understandings of the word "if", but
9 in the way I understand the word "if", yes, that's
10 also satisfactory.

11 Q So I believe this discussion relates to
12 the claim limitation of claim 10 of the '315
13 patent, a first emitter region having metal
14 impurities.

15 A Correct.

16 Q And so do you believe that "metal
17 impurities" is amenable to multiple
18 interpretations?

19 A I mean, I applied the ordinary plain
20 meaning of "metal impurities" within the
21 semiconductor or solar fields. And "impurity" is
22 a term of art. Anyone who works in this field

1 knows what it means. It's an element other than
2 the host element; for example, the crystal
3 structure. So for a silicon wafer, an impurity is
4 any non-silicon atom. And a metal is, it's a
5 metal. It's an element on the periodic table that
6 typically appears in nature as metallic.

7 So when I apply the plain and ordinary
8 meaning, "metal impurity" is any non-silicon atom
9 that is, is a metal.

10 Q Okay. So is it fair to say that in
11 paragraph 268 you equally effectively could have
12 argued everything after the comma -- excuse me,
13 the second comma -- I'll strike that. Let me
14 start over.

15 You have a statement: A person of
16 ordinary skill in the art would have understood
17 that Choi's first and second conductive areas,
18 (32), (34), have metal impurities.

19 Do you see that?

20 A I do.

21 Q And you qualify that at the beginning
22 with the condition that if Patent Owner argues

1 that the claimed invention includes any metal or
2 any source of metal. Do you agree with that, that
3 your statement is conditioned on the contingency
4 as to what Patent Owner argues?

5 MR. SELWYN: Objection. Form.

6 A I think I see your question and that
7 therefore why your question about "if" previously.

8 I believe that Choi, and I believe a
9 person of ordinary skill in the art would have
10 understood that Choi meets the claim limitations
11 of "metal impurities". Choi calls them impurities
12 when talking about (32) and (34), and Choi gives
13 examples of those impurities being metal. That is
14 plain.

15 However, I don't know exactly what the
16 Patent Owner envisioned as being -- as meeting the
17 claim limitation or not. And I don't know that
18 because in the patent it gives examples of metal
19 impurities, and then, I don't have the language in
20 front of me, says among others or something like
21 that. And I don't know everything that is within
22 "among others".

1 So when I understand the claim within
2 the context of the patent specification, it's not
3 clear to me whether or not the Patent Owner was
4 intending for all metals to meet the limitation or
5 not. And so that is the basis for a justification
6 of the statement.

7 Q Putting aside what argument Patent Owner
8 may make, do you believe that Choi discloses --
9 strike that.

10 Putting aside any argument the Patent
11 Owner may make, do you believe that Choi's first
12 and second conductive type areas, (32, (34), have
13 metal impurities?

14 A I know they do. Choi discloses that
15 they have impurities and he lists impurity atoms,
16 and several of them, including the ones I've
17 listed in this paragraph, are metals.

18 Q Is it your testimony that the plain and
19 ordinary meaning of "impurity" is any material
20 that is foreign to a host material?

21 A Any element that is foreign to a host
22 element, that is correct. We teach that in

1 Introductory Semiconductor courses. Dopants are
2 regularly referred to as impurities. That is the
3 plain meaning of the word "impurity". I'm quite
4 sure Google will come up with the same.

5 Q Is a dopant a contaminant?

6 A I don't know. Contaminant is not a term
7 of art in the same way that impurity is.
8 Typically contaminant sounds like it has a
9 negative connotation.

10 Q Would an understanding of impurity as a
11 contaminant be not a plain and ordinary meaning of
12 the word "impurity"?

13 MR. SELWYN: Objection. Form.

14 A I think I understood your question.

15 As I mentioned, "impurity" has a
16 particular meaning in the field, and it is not, it
17 is not contaminant. They are -- it is what I
18 said, which is an atom that's different than its
19 host. And that's why that you find in much of the
20 art, including Choi, that, you know, dopant is
21 introduced as an impurity. That's regular usage.

22 Q Do you believe "impurity" has only one

1 plain and ordinary meaning?

2 A I believe that "impurity" has one plain
3 and ordinary meaning within the silicon -- excuse
4 me, within the semiconductor or solar fields. I
5 believe a POSITA would understand the plain and
6 ordinary meaning to be as I've described.

7 MR. SNODGRASS: I've lost track of time
8 relative to our prior discussion. Now is a decent
9 breaking point if that will work.

10 We can go off the record.

11 (A recess was taken at 3:21 p.m.)

12 (Back on the record at 3:56 p.m.)

13 BY MR. SNODGRASS:

14 Q Dr. Holman, before we broke I believe we
15 were discussing impurities and how that term
16 should be interpreted in the context of the
17 challenged claims. Is that consistent with your
18 recollection?

19 A Yes.

20 Q Okay. Do you have -- sorry, I'll ask a
21 different question.

22 Focusing again on paragraph 268, if in

1 fact Choi does disclose that its first and second
2 conductive type areas, (32), (34), have metal
3 impurities, you don't need Istratov, correct?

4 A That's correct. So the, you know, as
5 the sentence says, you know, if the -- I don't
6 know precisely what the Patent Owner was intending
7 to be included within the limitation of the claim
8 when it says "metal impurity". I know that, I
9 believe it's iron, nickel and chromium are
10 explicitly named within the patent, and so those
11 must meet the limitation. I don't know what other
12 metals do. But to the extent that any metal
13 impurities are intended as those words are
14 commonly understood, then Choi alone meets the
15 limitation and Istratov is not required, that's
16 correct.

17 Q If I understand correctly, you have an
18 opinion that "metal impurities" as used in the
19 claims of the '315 patent may be different than
20 the plain and ordinary meaning of "metal
21 impurities"; is that your opinion?

22 MR. SELWYN: Objection. Form.

1 A No. I understand that I'm supposed to
2 interpret the claims with the plain and ordinary
3 meanings, and also within the context of the
4 patents. And I am certain about what the plain
5 and ordinary meaning of "metal impurity" is. And
6 we've discussed that.

7 But as I mentioned, the examples given
8 within the specification, there are three explicit
9 examples given and not beyond that. And so when
10 I'm interpreting within the context of the
11 specification, I know that those meet the
12 limitation. I don't know everything that the
13 Patent Owner might have intended to be within the,
14 I think the words are like "and others."

15 Q Do you believe that the plain and
16 ordinary meaning of "impurities" applies, or do
17 you believe the Patent Owner's understanding of
18 "impurities" applies?

19 A You know, I think I answered the
20 question to the best of my ability in the previous
21 response. I haven't proposed a claim
22 construction. I'm not aware of the claims being

1 construed by the Patent Owner. And so I
2 understand what "metal impurities" mean, and to
3 the extent that the Patent Owner means something
4 else, you know, I will -- I can interpret within
5 that meaning.

6 Q And I apologize, I don't mean to be
7 repeating myself, it just seems -- I just want to
8 get a firm grasp of what's going on here.

9 So you believe, correct me if I'm wrong,
10 you believe that the meaning of "impurities" in
11 claim 10 of the '315 patent is the plain and
12 ordinary meaning of "impurities"; is that right?

13 A I believe that I am to interpret the
14 claim using plain and ordinary meanings, but also
15 taking into account content of the specification.

16 And I know what the plain and ordinary
17 meaning is, and the content within the
18 specification gives particular examples, but also
19 has an open-ended and others such that it isn't
20 clear all that Patent Owner intended to meet the
21 limitation or not.

22 Q Okay. If Patent Owner only intended a

1 handful of other elements and that's what they
2 meant by "et cetera, "and others", whatever
3 verbiage is used, do you believe that the claims
4 are limited to nickel, iron, chromium, and the few
5 others that the Patent Owner had in mind?

6 MR. SELWYN: Objection. Form.

7 A I believe that -- you know, I don't have
8 that case to consider, but I would imagine that
9 the Patent Owner may, in that case, you know, list
10 such elements in the claim.

11 Perhaps you can ask the question again.
12 I'd like to think about that a little bit more.

13 Q I'll try. I might come at it from a
14 slightly different angle.

15 If I understand your understanding, you
16 believe "metal impurities" as recited in the claim
17 includes nickel, iron, chromium, and any other
18 metallic element that is foreign to the host
19 element, whatever constitutes the first emitter
20 region; is that your opinion?

21 A I know that "metal impurities", the
22 plain and ordinary meaning of it includes anything

1 in a sentence that's not silicon, because that's
2 the definition of impurity, and anything that's
3 metallic, because that's the definition of metal.

4 I know that that's the plain and
5 ordinary meaning, and "metal impurities" are the
6 words that appear in claim 10.

7 But I understand that I'm supposed to
8 interpret the claims as well within the context of
9 the specification for which I have some, but not
10 complete, clarity.

11 Q Okay. I believe you said that you did
12 not construe any claims in connection with your
13 analysis; is that right? Any claim terms.

14 A That's correct.

15 Q Okay. So did you apply the plain and
16 ordinary meaning of "metal impurities" in arriving
17 at your opinions?

18 A Yes, I have applied the plain and
19 ordinary meaning, and that's why, for example, you
20 find paragraph 268.

21 I understand, however, that the metals
22 that, you know, are demonstrated within Choi do

1 not overlap with those explicitly named, of which
2 there are just three, in the '315 patent. And
3 Istratov, however, does consider at least one of
4 those.

5 So I applied the plain and ordinary
6 meaning, but in any interpretation, Istratov has
7 overlap with those explicitly mentioned if, for
8 example, the Patent Owner suggests a claim
9 construction that has a meaning for "metal
10 impurities" that is not plain and ordinary.

11 Q And I apologize if I've asked this
12 already. Do you have an understanding as to what
13 a contaminant is?

14 A So as I mentioned, a contaminant is not
15 a term of art in our field in the way that an
16 impurity is. It does not have a strict
17 definition. And so I have to understand
18 "contaminant" really based upon the context given
19 in the specification without extrinsic evidence or
20 knowledge by a person of ordinary skill of a
21 precise definition.

22 Q I believe you testified that you believe

1 "contaminant" may have a negative connotation
2 associated with it; is that right?

3 MR. SELWYN: Objection. Form.

4 A I did say earlier that it sounded like
5 it may be negative. I do, however, also see that
6 in the, I believe the '315 patent uses
7 "contaminant" interchangeably with "impurity", so
8 I have a precise definition for one of those, a
9 less precise definition for the other, and my
10 reading of the '315 patent to go on to understand
11 "contaminant".

12 Q I believe you may be referring to column
13 5, lines 8 through 9 of the '315 patent?

14 A Yes, that's correct.

15 Q So it provides: As referred throughout,
16 "contaminants" and/or "impurities" can be used
17 interchangeably. You see that?

18 A I do.

19 Q Do you understand "throughout" to be
20 throughout the entirety of the patent?

21 A That's what I understand it to mean.

22 Q Including the claims?

1 A Yes.

2 Q Do you believe a contaminant is
3 something that is deemed detrimental?

4 MR. SELWYN: Objection. Form.

5 A As I mentioned, we don't have a precise
6 definition in our field and so I have to read
7 within the context of the specification. As you
8 pointed out and reminded me, column 5 says that
9 that "contaminants" and "impurities" can be used
10 interchangeably. And I know what impurities
11 means. So if I -- to follow that, then I used the
12 same definition of "contaminants" as I do
13 "impurities". That's what I'm instructed to do by
14 this sentence.

15 Q If I understand correctly, you believe
16 "contaminants" as used in the '315 patent refers
17 to any element that is foreign to a host element;
18 is that correct?

19 A That is, that is how I -- that's what
20 I'm instructed to do by column 5: As referred
21 throughout, "contaminants" or "impurities" can be
22 used interchangeably. So I know what "impurities"

1 means. It is a term of art in the field; we have
2 a very solid definition for that. I don't have
3 that certainty with "contaminants". So my best
4 reading of this sentence is to assign the same
5 definition to "contaminants".

6 Q Do you believe that a dopant is a
7 contaminant?

8 A I believe -- I know that a dopant is an
9 impurity. And based on this sentence, I'm to use
10 those words interchangeably. Dopant, as a
11 contaminant, is -- I mean, as I mentioned before,
12 "contaminant" isn't a common word used in our
13 field. That is my reading of what's provided to
14 me.

15 Q Okay. So I'm sorry if I missed it. In
16 other words, yes, you believe that "a contaminant"
17 as used in the '315 patent is any element that is
18 foreign to a host element?

19 A I believe that, I know that of an
20 impurity, and I'm instructed to use "contaminant"
21 interchangeably with "impurity". So to do so,
22 then I arrived at what you said.

1 I don't have a plain and ordinary
2 meaning to suggest otherwise because it's not a
3 term of art in our field.

4 Q Is iron in a silicon substrate in a
5 solar cell desirable?

6 A In general it is not.

7 Q Are dopants in a substrate of a
8 silicon -- start over. Let me start over.

9 Are dopants in a substrate of a solar
10 cell desirable?

11 A They can be, if used in the right
12 concentration. As we discussed previously,
13 dopants are a double-edged sword. They can
14 provide good functionality. For example, we
15 require them to form p-n regions, to form p-n
16 junctions which separate charge carriers. We can
17 use them to reduce surface recombination, but they
18 themselves also induce recombination.

19 So they can be desirable. They are
20 often desirable, they're not always desirable, and
21 it depends on at what amount.

22 Q Are dopants purposefully introduced?

1 MR. SELWYN: Objection. Form.

2 A They can be. They aren't always. And
3 so we talked about in the field non-intentional
4 doping, and that's when an impurity is
5 incorporated that happens to act as a dopant.

6 So, yes, they're purposefully
7 introduced. They are also found unintentionally
8 within semiconductors.

9 Q If a dopant is not purposefully
10 introduced, is it beneficial, or detrimental, or
11 perhaps either depending on the circumstances?

12 MR. SELWYN: Objection. Form.

13 A It could be either depending on the
14 circumstances. Sometimes unintentional doping
15 ends up being desirable doping. In other cases,
16 that's not true. And once again, it would depend
17 on the concentration at which it's present.

18 Q I believe at least in one instance in
19 which the '315 patent discusses the possible
20 impurities or contaminants is at the bottom of
21 column 4, line 66 to column 5, line 5. There it
22 states: In an embodiment, the silicon substrate

1 (202) can have contaminants and/or impurities
2 (220), for example, metal contaminants and/or
3 metal impurities, such as iron, nickel, and/or
4 chromium among others.

5 Do you see that?

6 A I do.

7 Q Is the presence of iron, nickel and/or
8 chromium in a silicon substrate detrimental to a
9 solar cell?

10 A Yes, in sufficient quantities each of
11 these, each of these elements could induce
12 recombination, unwanted recombination in a solar
13 cell.

14 Q In Choi, there is disclosure of first
15 and second conductive type areas, (32, (34), that
16 have certain metals, correct?

17 A That is correct.

18 Q And those metals act as dopants in Choi,
19 right?

20 A Choi describes that those metal
21 impurities act as dopants, that's correct.

22 Q Do you believe that the presence of

1 those metals in Choi's first and second conductive
2 layers -- excuse me, I'll start over.

3 Do you believe that the presence of
4 those metals in Choi's first and second conductive
5 type areas, (32), (34), are desirable, beneficial?

6 A I think that they -- Choi is intending
7 for them to serve as dopants, and so to the extent
8 that they're incorporated in appropriate
9 concentrations, they are playing that role, and
10 that is what Choi intends.

11 Q They're serving a purpose, correct?

12 A Choi intends for them to serve a
13 purpose.

14 Q Otherwise Choi would not introduce them
15 as dopants, right?

16 A Presumably, yes.

17 Q I want to jump forward just a few
18 paragraphs to paragraph 276.

19 A Okay, I'm there.

20 Q On the beginning of the latter half of
21 that paragraph, this is on page 147, maybe three
22 lines down, it's a long sentence, I don't know

1 where to begin, but I want to direct your
2 attention to what's in the parenthetical. So
3 please review that to the extent you need to to
4 kind of get your bearings.

5 A Okay.

6 (Reviewing.)

7 Okay, I'm ready.

8 Q And here again we see "to the extent,"
9 and I just want to confirm that this again means
10 "if"; is that right?

11 A Yes, that's correct. Relocating metal
12 impurities in the wafer, if they were present, as
13 was common in solar wafers at the time, to the
14 second conductive type area of Choi.

15 Q I want to jump forward a few pages to
16 paragraph 289.

17 A Okay.

18 Q And in particular, I want to speak to
19 paragraphs 289 through 294. Here, correct me if
20 I'm wrong, I believe you're suggesting that
21 instead of an n-type dopant as has been discussed
22 previously in the Declaration, a p-type dopant

1 could be used; is that right?

2 A Yes. So claims 11 and 13 are symmetric,
3 or similar, but they consider the two cases, in 11
4 that the silicon substrate is dope n-type, and in
5 13, that it's doped p-type. And further in claim
6 14 that the p-type dopant is, or at least "a
7 p-type dopant" in the substrate is boron.

8 Q Have you designed a solar cell where
9 you've been responsible for determining doping
10 concentrations?

11 A Yes, I have.

12 Q And do you recall if that instance, or
13 those instances, you employed a p- or n-type
14 dopant?

15 A I have designed and made silicon solar
16 cells in both n- and p-type wafers.

17 Q Okay. Did you consider, in determining
18 the doping concentration, whether the dopant was a
19 p-type or an n-type?

20 A Do you mean the doping concentration of
21 the wafer?

22 Q If you're referring to the what for lack

1 of a better word I'll call the background doping
2 or the base doping. Does that make sense to you?

3 (Simultaneous speaking.)

4 A -- understand you.

5 Q Okay, I'm not talking about that. I'm
6 talking about like an FSF-type doping. Is that
7 okay?

8 A Okay. So I have made silicon, designed
9 and made silicon solar cells with n- and p-type
10 wafers, or in this case I was selecting background
11 or "base", as you called it, doping densities, and
12 I have determined the doping densities of
13 deposited layers on both sides, both n- and
14 p-type; not diffused, but deposited layers on both
15 sides. So to the extent that that meets your
16 question, that's what I have done.

17 Q Okay. So you've not designed a solar
18 cell and chosen a doping profile similar to what's
19 going on in Choi or Cousins; is that right?

20 A I have not designed a silicon solar cell
21 with a diffused -- with a diffusion, such as an
22 emitter or a front surface field.

1 I have designed and made them with
2 deposited ones. I've also worked on teams where
3 the same solar cell that I was designing or making
4 part of, somebody else was designing and making a
5 diffusion.

6 So I have papers that you would find,
7 for example, in which there are diffusions, but I
8 myself was not the key person in determining that
9 diffusion.

10 Q Do you know if the team member that did
11 determine what the doping profile should be
12 considered whether the dopant was a p-type or
13 n-type?

14 A Yes, in general the person, a POSITA,
15 for example, would consider not only the polarity
16 of the dopant, n-type or p-type, but also what the
17 atom was. Whether it was boron or aluminum, for
18 example.

19 Q Okay. So correct me if I'm wrong, but
20 it may be that for boron as the dopant, one
21 particular doping profile is optimal. And all
22 other things being equal, using aluminum as the

1 dopant, a different doping profile would be
2 optimal; is that right?

3 MR. SELWYN: Objection. Form.

4 A Yes, there could be variations in the
5 optimal as you switch dopant types, and these are
6 common design parameters that a POSITA would know
7 about. There aren't wild differences. It's not
8 going to be that it's doping density ten times
9 higher for one element than another. But there
10 could be small differences, and there could be
11 differences in the process used in order to
12 achieve even the same doping profile.

13 Maybe boron diffuses through silicon
14 differently than aluminum, for example. And so in
15 the same furnace you might change the process a
16 little bit in order to achieve the same doping
17 profile with different elements.

18 Is that clear?

19 Q I think so, yes. Thank you.

20 Can we jump forward to paragraph 365 of
21 your Declaration. And I actually want to talk
22 about the figure in there, so it's going to be on

1 page 188.

2 All right. And you've reproduced figure
3 7-4 from Granek there; is that right?

4 A Yes.

5 Q And we see the label junction depth
6 again on the x axis, right?

7 A Uh-humh.

8 Q Okay.

9 MR. SELWYN: Yes.

10 A Yes. Excuse me, yes.

11 Q Okay. And that has the same meaning as
12 it has in the other figures of Granek that we
13 discussed?

14 A Yeah. If you look to this section of
15 Granek, Granek simulating a back junction solar
16 cell says so repeatedly that this is the front
17 surface field that is being simulated here with
18 two aspects of the front surface field being
19 varied; one its depth, and two, the p-
20 concentration, which is the same as the surface
21 concentration, of doping of that front surface
22 field.

1 Q Does junction depth means the extent to
2 which the diffused dopant diffuses?

3 A It has a particular meaning. It is a
4 characteristic depth. It is not the same as the
5 farthest that one atom diffuses. It is a depth at
6 which the doping concentration falls off from its
7 peak value by a fixed amount. So it's a
8 characteristic depth of the front surface field.

9 Q So if I understand the boxes that you've
10 added to this figure in paragraph 365 of your
11 Declaration, anything in the red box would yield a
12 sheet resistance in the range specified by
13 Cousins; is that right?

14 A That's correct. The red box -- within
15 the interior of the red box are front surface
16 fields having sheet resistances that are
17 consistent with Cousins' claimed range -- or I
18 shouldn't say "claimed", described, taught range.

19 Q So you agree that you can achieve that
20 sheet resistance with doping concentrations
21 greater than two times 10 to the 18th, right?

22 A Yes. You can see that there are, there

1 is a region where the purple and red boxes do not
2 overlap. There's also a substantial region where
3 they do overlap.

4 One thing to note is that as we
5 described previously, Granek frequently simulated
6 the extremes. And so for example, the left side
7 of this plot, that's a junction -- excuse me, a
8 front surface field depth of just 100 nanometers,
9 which is very shallow and challenging to achieve
10 in practice. You would see, for example, in my
11 Declaration when I talk about diffused emitters
12 that typical depths are maybe 300 nanometers to
13 300 -- sorry, 300 nanometers to three microns.
14 And so that puts you in the middle of this plot in
15 terms of x to y for which the overlap between the
16 red box, the teachings of Cousins, and the purple
17 box meeting the claim specification -- meeting the
18 claim limitation is near complete.

19 Does that make sense?

20 Q Well, I'm not going to say it doesn't
21 make sense. Now whether I follow is a different
22 question, but that's not your problem.

1 Let's talk about some actual specifics
2 that Granek analyzed. In particular I want to
3 look at table 7-1.

4 So if you can pull up Granek, which is
5 Exhibit 1010, and it's on page 126.

6 A Okay.

7 Q All right. So I want to focus on FSF 4
8 and FSF 5. And the reason I want to do that is
9 because if I'm looking at figure 7-6 on the page
10 prior, that seems to have sheet resistances within
11 the range of Cousins; is that right?

12 A Yes, those two, FSF 4 and FSF 5, have
13 sheet resistance within the range of Cousins,
14 that's correct.

15 Q And then for FSF 4 we have a doping
16 concentration 4.5 times 10 to the 19th, right?

17 A Yes.

18 Q And then for FSF 5 we have 3.8 times 10
19 to the 18th, right?

20 A Correct.

21 Q And for FSF 5, we have a junction depth
22 of 1.44 microns?

1 A Correct.

2 Q So is that table a little inconsistent
3 with figure 7-4 of Granek in that we have a sheet
4 resistance within the range of Cousins at a
5 junction depth of 1.44 microns, but we've achieved
6 that with 3.8×10^{18} in our
7 concentration?

8 MR. SELWYN: Objection.

9 A (Reviewing.)

10 I want to make sure I understand your
11 question here. So one moment, please.

12 (Reviewing.)

13 Okay. So here's what's going on in this
14 case. Figure 7-4, which I've annotated, assumes a
15 Gaussian doping profile. You can see that on a
16 note of the y axis. That means the doping profile
17 has a particular shape. Many real diffusions
18 follow that shape. It is the most common model
19 for experimental doping profiles.

20 But not all doping profiles in practice
21 are going to follow that shape. And if you look
22 at figure 7-6, which has a doping profile, you can

1 see that FSF 5 in particular looks a fair amount
2 different in its shape than the others. And so it
3 falls on figure 7-4, which I've annotated, if you
4 map out the depth of the diffusion and the peak
5 doping density, it falls just outside of Cousins'
6 red box, despite the fact that the measure sheet
7 resistance is just inside Cousins' range; 138
8 being close to the 100 lower limit that Cousins
9 gives because I believe the experimental doping
10 profile is not perfectly Gaussian.

11 So it's not far outside of what you
12 would predict from a Gaussian profile, but if you
13 used a Gaussian profile with the peak density and
14 diffusion depth given, then you would predict a
15 sheet resistance more like 70 instead of 138.

16 That was rather detailed there. I can
17 review any of that if you would like.

18 Q The other types of profiles are, at
19 least indicated in table 7-1, as ERFC. I say
20 other, I mean other than FSF 5. And I assume
21 that's different than Gaussian?

22 MR. SELWYN: Objection.

1 A Yeah. That stands for error, error
2 function.

3 Q Is that a profile that is easily
4 achieved in practice?

5 MR. SELWYN: Objection. Form.

6 A One can achieve an approximation of it
7 as shown in figure 7-6 for the other experimental
8 diffusions.

9 Q If one is employing an error function
10 profile and not Gaussian, figure 7-4 of Granek is
11 kind of not relevant, right?

12 A The teachings are still relevant. And
13 the reason why this is important, and you can see
14 it, is because figure 7-4, both the x axis and the
15 y axis are logarithmic scales, which means that
16 small movements on either axis correspond to large
17 changes in value.

18 And so if you were to switch from one
19 doping profile to another with the same peak and
20 same depth, you're not going to make large
21 excursions on this plot. So the edges of the
22 boxes get fuzzy, but it's not as if it's

1 irrelevant or that they move all over.

2 Q All right. So taking the data from
3 table 7-1 and trying to place it within the figure
4 7-4, and with particular focus on FSF 4, if I want
5 to look at the doping concentration and junction
6 depth, I would go to 4.5 times 10 to the 19th in
7 the concentration and then .38 microns in the
8 depth, and it appears as though I would expect a
9 sheet resistance of around 21; is that consistent
10 with your understanding?

11 A (Reviewing.)

12 Yes, that's correct.

13 Q In fact, the sheet resistance is
14 actually at 353, right?

15 A That is what Granek reports for the
16 measured sheet resistance, that's correct.

17 Q Let's shift forward to paragraph 370 in
18 your Declaration. Actually 370 and 371. Both of
19 these paragraphs are under a heading Motivation To
20 Combine.

21 A Sure.

22 Q And I believe the proposed combination

1 is Cousins and Granek; is that right?

2 A Yes.

3 Q And is this the extent of the reasons
4 you believe it would have been obvious to combine
5 Cousins and Granek?

6 A Yes. I've argued in here about their
7 similar structure and the fact that Cousins does
8 not give -- Cousins reports a front surface field,
9 does not give a peak doping density for that front
10 surface field, but does give a range of sheet
11 resistances that are acceptable.

12 And that Granek, you know, so a POSITA
13 would be inclined to go find in other references a
14 compatible peak doping density of the front
15 surface field.

16 And that Marvin has a compatible
17 structure, and in fact, reports combinations and
18 gives teachings that overlap with Cousins' range,
19 sheet resistance range.

20 Q I think we talked earlier about some
21 references that disclose doping concentrations
22 greater than two times 10^{-18} . Do you

1 recall that discussion?

2 A Yes.

3 Q I believe you said that, or you agreed
4 when I suggested that perhaps those authors were
5 misguided; is that right?

6 A Correct.

7 Q Can you explain why you believe those
8 authors were misguided?

9 A Sure. Would you like to take one in
10 particular?

11 Q I'm happy to, if that's helpful. I mean
12 I don't know what you have, but I'm suspecting
13 you're referring to one of the three references
14 that were included in the IPR. I'm happy to
15 provide all of those.

16 Is that what you have in mind? I
17 believe one might be Procel --

18 A Lamers and Desa.

19 Q Okay. I'm going to distribute what's
20 previously been submitted in this case as Exhibit
21 2002, 2003 and 2005. These are Lamers, Desa and
22 Procel respectively.

1 So, Dr. Holman, I'm happy to take them
2 in whatever order you want to discuss.

3 A I'll follow your lead here. You get to
4 ask the questions.

5 Q Okay. So let's go with 2002 first. I
6 believe that's Lamers.

7 A Okay, I have it open.

8 MR. SELWYN: Do you have the question in
9 mind, or do you want Mr. Snodgrass to --

10 A Is there a particular question?

11 Q Not yet, but there's going to be real
12 soon. I'm just trying to direct you to the right
13 portion of Lamers.

14 A Perhaps Section 3.1. That one seems to
15 be titled Front Surface Field Optimization.

16 Q Yes. And towards the beginning of that,
17 recombination -- second sentence, recombination in
18 the FSF should be minimal, and the optimal doping
19 level was found to be 3.10×10^{18} atoms per, it
20 says square centimeter there.

21 A That's a typo, and it should be three
22 times 10^{18} per cubic centimeter.

1 Q Do you believe a person skilled in the
2 art would have appreciated that typo?

3 A Yeah. There are other instances in
4 which the units are used correctly in the paper.

5 Q Okay. Do you believe that Lamers was
6 misguided in concluding the optimal doping level
7 here?

8 A I believe Lamers has concluded the
9 optimal doping level in the sentence for
10 conditions that a POSITA would not look to when
11 modifying Choi.

12 So if you look at the first sentence of
13 this section of Lamers, Lamers explains the
14 function of the front surface field is to reduce
15 the recombination at the front side.

16 Okay, I understand that. That was
17 Choi's goal as well.

18 And improve lateral transport.

19 There's no mention of, in Choi of
20 lateral transport as a function. That means
21 moving charge carriers sideways.

22 And after that sentence, then Lamers

1 concludes this optimum value.

2 But if you scroll down a few sentences,
3 Lamers then says: For moderate to low bulk
4 resistances and small pitches -- pitches, he's
5 talking about the distance between fingers on the
6 rear side -- the additional value of the FSF for
7 lateral transport is of less importance. That is
8 to say these are conditions under which the
9 secondary function of lateral transport isn't
10 needed.

11 If you look back at Choi, these
12 conditions of moderate to low bulk resistances and
13 small pitches are met, which is probably why Choi
14 doesn't describe lateral transport as a required
15 function for the front surface field.

16 Lamers goes on to say: Under these
17 circumstances, a lightly doped and shallow front
18 surface field with a high resistance in
19 combination with good surface passivation will
20 give the highest cell output. And Lamers cites
21 reference 5.

22 And if I go and look at reference 5 of

1 that paper it's the Granek thesis that I've
2 included in my combination. So I believe Lamers
3 teaches that under the conditions relevant to
4 Choi, Granek shows you the way.

5 Q And then the next one is Exhibit 2003,
6 that's Desa.

7 A Okay, I have that one open.

8 Q I believe it's figure 5-C of Desa,
9 that -- it's on page 8. It shows highest
10 efficiencies at doping concentrations in excess of
11 one times 10 to the 19th. Is that a fair
12 interpretation of figure 5-C?

13 A Yes, it is.

14 Q And you believe this was --

15 A Both misguided and not applicable.

16 Q Why is it misguided?

17 A Maybe I'll start with why it's not
18 applicable if that's okay with you.

19 Q Sure.

20 A So if you look -- we'll come back to
21 figure 5, but if you look for a moment at figure
22 2, Desa shows the structure being simulated. Desa

1 shows a p-type silicon wafer and what's called a
2 floating junction that is n-plus. That is to say
3 it has the opposite doping polarity of the wafer.

4 This is reinforced in the description of
5 the simulations on page 70, second column, second
6 full paragraph. Desa describes that the layer at
7 the front was created by phosphorus implantation.
8 So again, n-type describes it as a floating
9 junction. Also uses the word "front surface
10 field", but in the solar field these have two
11 different meanings. "Front surface field", as we
12 know, has the same doping polarity of the wafer.
13 "Float junction" has the opposite polarity of the
14 wafer. "Floating junction" or "floating emitter";
15 those two words are used interchangeably.

16 The only one that Desa simulates is the
17 floating junction, not the front surface field,
18 and that's shown in figure 2. Desa is being loose
19 with language in that paragraph. And I'm sure
20 that that's the only one simulated because it's
21 reinforced in figure -- excuse me, table 1 at the
22 end of the paper where Desa lists simulation

1 conditions, showing that the wafer is p-type and
2 the front surface field, parentheses, floating
3 junction -- again being loose with words -- the
4 dopant is phosphorous. It is properly a floating
5 junction or floating emitter.

6 So Desa is simulating something that
7 isn't the same as Choi. Choi indicates that the
8 diffused region at the front has the same doping
9 polarity of the wafer. It is a front surface
10 field. Desa is simulating something different
11 that has the opposite doping polarity. So one
12 would not combine these.

13 But to come back to your original
14 question, the reason I also find it misguided
15 because in figure 5, the efficiency flatlines at a
16 maximum value whether you dope the front surface
17 field, which is properly a floating emitter or
18 floating junction, the emitter or the base
19 anywhere between 10 to the 19 and 10 to the 21.

20 But as we've discussed earlier, 10 to
21 the 21 is a very high doping density, and any
22 POSITA would look at that and know these modeling

1 results were garbage. That there's no way that
2 you would get to those high doping densities and
3 not see efficiency dropping.

4 So I have multiple problems with Desa
5 and reasons why a POSITA would not look to
6 implement these learnings.

7 Q You don't question the accuracy of the
8 efficiency numbers at one times 10 to the 19th, do
9 you?

10 A I don't know whether they're correct.
11 I'm skeptical because I can see the trends at
12 higher values. Typically when a model is wrong at
13 some values, you don't necessarily look to it for
14 guidance at other values.

15 Q So let's talk about the last one,
16 Procel. This is Exhibit 2005.

17 Figure 4-A appears to show highest
18 efficiency at doping concentrations in the
19 neighborhood of -- let me strike that. I'm going
20 to start over.

21 Just above figure 4-A Procel states:
22 According to our simulations, the inflection point

1 of the FSF doping is 3.47 times 10 to the 18th per
2 cubic centimeter.

3 Do you see that?

4 A I do.

5 Q And that's consistent with the figure
6 4-A, right?

7 A It is. As you began to say, 4-A shows
8 the highest efficiency in the neighborhood between
9 10 to the 18th and maybe up to 10 to the 19th
10 with, it looks like, three points simulated maybe
11 at 10 to the 18th, 10 to the 19th, and the claimed
12 value of 3.47 times 10 to the 18th. So we do have
13 a broad maximum there in that range, I agree.

14 Q You believe that Procel was misguided?

15 A I don't know, and the reason I don't
16 know is I see this result, but I've also
17 identified other work by Procel. In fact, I
18 included it in my Declaration. It's Exhibit 1040
19 in my Declaration. I don't have it in front of
20 me, but I talk about it in, briefly on paragraph
21 82 of my Declaration if you want to go there.

22 Q Paragraph 82 you said?

1 A Correct.

2 Q And this is the same Procel that was
3 also submitted as Exhibit 2005?

4 A That's correct. In fact, most, if not
5 all, of the authors on the two papers are the
6 same.

7 Q When you say "two papers," which ones
8 are you referring to?

9 A I mean most, if not all, of the authors
10 on Exhibit 2005, which we've just looked at, and
11 Exhibit 1040, which I'm referring to, are the
12 same.

13 Q I see. So the papers are different,
14 then, 1040 and 2005 are different?

15 A They're different papers submitted by
16 the same research group, same primary author. I
17 don't have both of them in front of me so I don't
18 know if all of the authors are the same.

19 Q Okay. Fair enough.

20 A The reason I bring this up, in 82 of my
21 Declaration, I refer to this, and these authors
22 describe the doping profiles in the back surface

1 field, front surface field and emitter are
2 Gaussian functions -- we were just having a
3 conversation about Gaussian functions and error
4 functions -- of the spatial coordinate
5 featuring the peak location --

6 THE WITNESS: I'm sorry, Dawn. Let me
7 do it again, but I will read it slower.

8 A The doping profiles in back surface
9 fields featuring the peak located at the edge of
10 the interface and junction depth of 0.5 microns
11 for FSF region, peak concentration doping is one
12 times 10 to the 18 per cubic centimeter for FSF.

13 So this paper comes just after, it's in
14 the same year, but it's submitted and comes just
15 after Exhibit 2005. So Exhibit 1040 comes
16 subsequently to Exhibit 2005. And in it, Procel
17 and coauthors identify one times 10 to the 18 th as
18 their front surface field peak concentration.

19 So I don't know with these two different
20 numbers what their final conclusion was, but I can
21 say that these authors also identified one times
22 10 to the 18 th as a desirable doping density.

1 Q Do you believe that a person of ordinary
2 skill in the art having both 2005 and 1040 before
3 them would see 1040 later in time, and because of
4 that, would cause them to, would dissuade [sic]
5 them from adopting the doping concentrations in
6 2005?

7 A I can't say. I don't know. What I do
8 know is that both references existed ahead of the
9 priority date and, of the '315 patent. A POSITA
10 could have had access to them, and would have many
11 references, I think I've given at least five, that
12 point to a preferred doping density around one
13 times 10 to the 18th for the front surface field.

14 MR. SELWYN: We've been going an hour or
15 so. When you get to a good stopping juncture.

16 MR. SNODGRASS: We can break, or go off
17 the record.

18 (A recess was taken at 4:57 p.m.)

19 (Back on the record at 5:06 p.m.)

20 BY MR. SNODGRASS:

21 Q Dr. Holman, I want to direct your
22 attention to paragraph 427 of your Declaration.

1 MR. SELWYN: What paragraph did you say?

2 MR. SNODGRASS: 427.

3 A I'm there.

4 Q I'm sorry?

5 A I'm there.

6 Q Okay. In the second sentence it states:
7 Silicon wafers can be either n-type or p-type, and
8 as of the earliest possible priority date of the
9 '315 patent, p-type silicon wafers were more
10 common and less expensive than n-type silicon
11 wafers.

12 Do you see that?

13 A Yes.

14 Q What's the basis for that opinion?

15 A It was common knowledge at the time that
16 the history and how we got there, was that
17 somewhat unexpectedly, or the history is somewhat
18 unexpected. It turns out that p-type wafers were
19 used more in the space industry than they were in
20 the terrestrial industry -- excuse me, used more
21 in the space industry than n-type wafers; this was
22 like in the 1980s and 90s. And as a result, more

1 of them were made. And as a result, they became
2 more cheaper. And as a result, more of them were
3 made.

4 And so when the terrestrial solar
5 industry started ramping up, there was already
6 these economies of scale. Similar to how all
7 barns are red because red paint is the cheapest
8 because all barns are red.

9 So as a result of this, the silicon
10 solar industry used primarily p-type wafers all
11 the way up until probably about 2022 in fact, and
12 they've always been cheaper than n-type wafers.

13 Q Is that consistent with the passage from
14 Granek that we discussed earlier; in particular,
15 the passage on page 48?

16 A Let me go back there. Just a moment.

17 Q Okay.

18 A You're referring to the three bullet
19 points of Granek?

20 Q No. Sorry. No, I was referring to the
21 first full paragraph on page 48 where it says:
22 Due to shortage of the p-type silicon

1 feedstock ...

2 A Yeah. Yeah, it is consistent. So the
3 p-type silicon was the most common and most used
4 wafer at the time. But in 2008 in particular,
5 there was, the solar industry was growing faster
6 than the wafer industry could supply wafers, and
7 so there was a shortage of p-type silicon. And
8 this inspired researchers in particular to start
9 looking for other types of silicon. I think I
10 mentioned before that there was a lot of
11 innovation and studies of wafers at the time.

12 So Granek is a researcher at an academic
13 lab expressing that there's new -- renewed
14 interest going on around a different wafer source
15 than the common and standard one, which is p-type
16 silicon. That's what that paragraph expresses.

17 Q Sorry. Were p-types more common, or was
18 there a shortage of p-types?

19 A They were more common, but the demand
20 for wafers was exceeding the supply and so there
21 was also a shortage in the sense that the supply
22 couldn't keep up with the demand. Both are true.

1 Q So by "common", you don't mean readily
2 available?

3 A No, I mean --

4 I'm sorry, I interrupted you.

5 Q In paragraph 427, you don't mean that
6 p-type is more readily available, you mean more
7 people are using it, thus it's less available?

8 MR. SELWYN: Objection. Form.

9 A I don't think I would necessarily say
10 that either. It was the most common. It was used
11 by more people than were using n-type wafers,
12 particularly in manufacturing. If you were to go
13 and buy a solar cell at that time, you would bet
14 that it was going to be on a p-type wafer.

15 But the growth of solar was going along
16 so quickly that if you didn't already have a
17 contract in from a wafer supplier, there was a
18 time, particularly around 2008, when you might
19 have trouble getting wafers. The price of them
20 started to go up as a result and so people started
21 to get innovative and look at other wafer
22 supplies, including n-type wafers.

1 Q I want to talk a minute about your
2 business ventures so I'll be referring to your CV.

3 A Okay.

4 Q And I believe there are three companies
5 that you have founded or co-founded or been a part
6 of.

7 A Yes. Yes. Co-founded, that is correct.

8 Q Okay. So that would be Swift Coats,
9 SunFlex Solar, and Beyond Silicon; is that right?

10 A Yes.

11 Q Can you please describe what the aim is
12 of Swift Coat, what solutions it means to provide?

13 A Yes. Swift Coat is a coatings
14 deposition technology company. It provides its
15 customers with equipment and recipes to deposit
16 coatings on a variety of substrates. Most of its
17 customers are in the glass industry. Some of them
18 in the architectural glass industry. Some of them
19 in the space photovoltaic module industry as one
20 example.

21 It provides some of its customers with
22 machines and processes to deposit anti-reflection

1 coatings on the glass that covers solar cells that
2 go up into space. So it's a coatings deposition
3 solutions provider.

4 Q Okay. Same question for SunFlex Solar.

5 A SunFlex Solar is a company that's
6 commercializing a new interconnection method for
7 back contact solar cells. Interconnection refers
8 to the way that they're wired together. So the
9 company's innovation isn't in the solar cell
10 technology, but rather in the connection
11 technology to make them a module. So it's a
12 module technology company, and it's -- yeah,
13 that's sufficient. That's my summary.

14 Q Okay. And then same question for Swift
15 Coat?

16 A We did Swift Coat. Beyond Silicon?

17 Q I'm sorry.

18 Yes, thank you. Beyond Silicon.

19 A Okay. Beyond Silicon is a tandem solar
20 cell company. It's developing solar cells in
21 which a perovskite solar cell is put on top of a
22 silicon solar cell to more efficiently convert the

1 sunlight to electricity than silicon could alone.

2 So its primary innovation is how to --
3 the structure and how to deposit, how to
4 manufacture that perovskite top cell on of
5 silicon.

6 Q So that cell does have silicon, it just
7 also has another material on top; is that right?

8 A Correct. That cell is purchased.
9 Beyond Silicon doesn't make silicon cells. It
10 purchases those from the supply chain, the global
11 supply chain and adds perovskite on top cells.

12 Q Do any of your ventures have agreements
13 with Hanwha?

14 A No.

15 Q And by Hanwha, I mean any entity under
16 or associated with the Petitioner in this case
17 Hanwha Solutions Corporation.

18 A No.

19 MR. SNODGRASS: Okay. I may have some
20 further questions if Hanwha counsel has anything
21 for you, but I'm done for now.

22 MR. SELWYN: Can we take just a

1 five-minute break?

2 MR. SNODGRASS: Okay.

3 (A recess was taken at 5:16 p.m.)

4 (Back on the record at 5:23 p.m.)

5 EXAMINATION BY COUNSEL FOR THE PETITIONER

6 BY MR. SELWYN:

7 Q Good afternoon, Dr. Holman.

8 A Good afternoon.

9 Q Dr. Holman, do you recall being asked
10 about the meaning of "metal impurities"?

11 A Yes.

12 Q Did you apply the plain and ordinary
13 meaning of that term in your analysis?

14 A Yes, I did.

15 Q Does Choi identify a set of metal
16 impurities in the first and second conductive type
17 regions?

18 A Choi does, yes.

19 Q And are the metal impurities identified
20 in Choi within the meaning of metal impurities in
21 the claims of the '315 patent?

22 A They are within the meaning of, the

1 plain and ordinary -- they're within the plain and
2 ordinary meaning of "metal impurities" which is
3 what appears in the claims.

4 Q Do you also recall being asked about the
5 meaning of the word "contaminant"?

6 A Yes.

7 Q Now, does the word "contaminant" appear
8 in the claims of the '315 patent?

9 A It does not.

10 Q Did you need to construe the word
11 "contaminant" to understand the scope of the
12 claims of the '315 patent?

13 A No, I did not.

14 Q Do you recall being asked whether Choi
15 and Cousins disclosed sort of metal impurities
16 like iron or copper in their silicon substrates?

17 A Choi and Cousins, I recall that Choi and
18 Cousins do not disclose iron or copper in their
19 substrates.

20 Q As of December 2014, would a POSITA have
21 known that silicon wafers used in solar cell
22 fabrication contained metal impurities such as

1 iron or copper?

2 A Yes. I write about this in my
3 Declaration, if you'll give me just one moment.

4 Beginning on paragraph 83, and I give
5 reference to citations from the time that talked
6 about, one, the need for the solar industry to use
7 less expensive silicon than, for example, the
8 semiconductor industry, which pushed them towards
9 wafers that often had metal impurities such as
10 iron.

11 And then the implementation of common
12 processes at the time, gettering being chief
13 amongst them, to render any detrimental effects of
14 those impurities reduced.

15 Q Would a person of ordinary skill in the
16 art have been motivated to move metal impurities
17 from Choi and Cousins' silicon substrates into
18 their polysilicon layers?

19 A Yes. If a person was using solar wafers
20 in Choi and Cousins' structures, then a POSITA
21 would be motivated to implement a gettering
22 process to remove them from the substrate.

1 MR. SELWYN: No further questions.

2 MR. SNODGRASS: Yes, just a few
3 follow-ups.

4 FURTHER EXAMINATION BY COUNSEL FOR

5 THE PATENT OWNER

6 BY MR. SNODGRASS:

7 Q Dr. Holman, if a person of ordinary
8 skill in the art was motivated to remove
9 impurities from a substrate in Choi or Cousins,
10 would they care whether the impurities were
11 gettered to the interface between the substrate
12 and the oxide or the interface between the oxide
13 and the poly as opposed to getting it into the
14 poly, the impurities?

15 (Court Reporter clarification.)

16 MR. SELWYN: Objection.

17 A A POSITA would be looking to move the
18 impurities to a location where they would not
19 induce recombination. And at the interface of the
20 wafer and the oxide, they would still likely
21 induce recombination.

22 At the interface -- you described a

1 second interface, maybe the oxide and the
2 polysilicon; is that correct?

3 Q Yes.

4 A They may still induce some recombination
5 there, although their effects should be reduced.
6 And if they are in this polysilicon, their effects
7 should be reduced further.

8 MR. SNODGRASS: Okay, that's all I have.

9 MR. SELWYN: I have no further questions
10 for the witness.

11 Thank you very much for your time.

12 (Off the record at 5:28 p.m.)
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1 CERTIFICATE OF SHORTHAND REPORTER - NOTARY PUBLIC

2 I, Dawn M. Hart, Certified Reporter and
3 Notary Public within and for the State of
4 Maryland do hereby certify:

5 That Zachary Holman, Ph.D., the witness whose
6 deposition is hereinbefore set forth, was duly
7 sworn by me before the commencement of such
8 deposition and that such deposition was taken
9 before me and is a true record of the testimony
10 given by such witness.

11 I further certify that the adverse party,
12 Hanwha Solutions Corporation, was represented by
13 counsel at the deposition.

14 I further certify that the deposition of
15 Zachary Holman, Ph.D., occurred remotely on
16 Thursday, May 1, 2025, commencing at 12:01 p.m. to
17 5:28 p.m. Eastern Time Zone.

18 I further certify the inspection, reading
19 and signing of said deposition was not discussed
20 on the record.

21 I further certify that I am not related to
22 any of the parties to this action by blood or

1 marriage, I am not employed by or an attorney to
2 any of the parties to this action, and that I am
3 in no way interested, financially or otherwise, in
4 the outcome of this matter.

5 IN WITNESS WHEREOF, I have hereunto set my
6 hand this 6th day of May, 2025.

7 My commission expires:

8 January 2, 2029

9
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11 _____

12 NOTARY PUBLIC IN AND FOR THE
13 STATE OF MARYLAND
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