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

- - - - - x
CANADIAN SOLAR INC., : Case Nos.
Petitioner, : IPR2024-01038,
v. : IPR2024-01194
MAXEON SOLAR PTE., :
LTD., : U.S. Patent No.
Patent Owner. : 11,251,315
- - - - - X

Deposition of SANJAY BANERJEE, Ph.D.
Conducted Virtually
Friday, March 21, 2025
10 a.m. EDT

Job No.: 575274
Pages 1 - 192
Reported by: Debra A. Whitehead

1 Deposition of SANJAY BANERJEE, Ph.D., conducted
2 virtually.

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4
5 Pursuant to notice, before Debra Ann Whitehead,
6 E-Notary Public in and for the Commonwealth of
7 Virginia.

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C O N T E N T S

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By Mr. Snodgrass	7
By Ms. Böll	187

EXHIBITS MARKED IN TODAY'S SESSION
(None Marked)

EXHIBITS MARKED IN PRIOR SESSIONS
(Attached to the Transcript)

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Exhibit 1001	9
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1 EXHIBITS MARKED IN PRIOR SESSIONS - CONTINUED

2 (Attached to the Transcript)

3 IPR2024-01194 EXHIBIT

PAGE

4 Exhibit 1003

7

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

2 SANJAY BANERJEE, Ph.D.,

3 having been duly sworn, testified as follows:

4 EXAMINATION BY COUNSEL FOR PATENT OWNER

5 BY MR. SNODGRASS:

6 Q Good morning, Dr. Banerjee.

7 A Good morning.

8 Q I want to ask you about a couple of
9 declarations that you submitted in two related IPR
10 proceedings.

11 MR. SNODGRASS: I am going to circulate
12 via chat Exhibit 1003 in IPR2024-01038.

13 (IPR2024-01038 Exhibit 1003, previously
14 marked, and is attached to the transcript.)

15 MR. SNODGRASS: As well as Exhibit 1003
16 in IPR2024-01194.

17 (IPR2024-01194 Exhibit 1003, previously
18 marked, and is attached to the transcript.)

19 Q And, Dr. Banerjee, I believe you have
20 hard copies of these as well.

21 Is that correct?

22 A Yes. Yes.

1 Q And your signature is at the end of both
2 of these declarations.

3 Is that correct?

4 A Well, in the copy that I have it's on the
5 second page at the front, but it's my signature.

6 Q Yes, I apologize. Okay. So on page what
7 is paginated as 2, it's also got a stamp in the
8 lower right-hand corner that says, Signature-1?

9 A That's correct.

10 Q And, Dr. Banerjee, did you review the
11 entirety of both declarations prior to signing
12 them?

13 A Yes.

14 Q And did you notice any errors before
15 signing them?

16 A Not that I can think of.

17 Q Have you had an occasion to review either
18 declaration since you signed those?

19 A Yes; I reviewed it last night.

20 Q Did you either last night or any other
21 time since you've signed it identify any errors in
22 your declarations?

1 A I did not see any.

2 Q In your declarations you memorialize your
3 opinions regarding the patentability of certain
4 claims of U.S. Patent 11,251,315.

5 MS. BÖLL: Object to form.

6 Q Is that correct?

7 A Yeah, I did opine on certain claims.

8 Q And today is it okay with you if we refer
9 to that patent as the '315 patent?

10 A Yes.

11 MR. SNODGRASS: And I am going to
12 circulate via chat Exhibit 1001 in U.S. IPR2024 --
13 01038. That is the '315 patent.

14 (IPR2024-01038 Exhibit 1001, previously
15 marked, and is attached to the transcript.)

16 A Okay.

17 Q Dr. Banerjee, can you describe your
18 general methodology in arriving at the opinions
19 that you've developed?

20 MS. BÖLL: Object to form.

21 A So before I take on any case, I read the
22 patent to make sure that it's my area of

1 expertise. Initially I give a cursory reading.
2 And then after I am hired, I read very, very
3 thoroughly to understand what the claims mean in
4 light of the specifications.

5 Q Did you do anything after that?

6 MS. BÖLL: Counsel, I am just going to
7 caution the witness that anything done at the
8 instruction of counsel or in connection with
9 counsel is privileged and should not be disclosed.

10 MR. SNODGRASS: I'm just trying to probe
11 kind of the methodology behind the opinions in his
12 declaration. So, I mean, I think there's room for
13 me to explore that short of getting down to the
14 details of any communications between counsel and
15 the expert.

16 MS. BÖLL: Maybe you can try something a
17 little more specific, just to sort of guide that
18 discussion.

19 MR. SNODGRASS: I mean, I'm trying to be
20 as abstract as I can so that I'm not getting down
21 into the details.

22 MS. BÖLL: Okay.

1 MR. SNODGRASS: So, you know, maybe I
2 jumped the gun a little bit too much in getting
3 into a side discussion here. I mean, I guess
4 the -- you just did a warning. Correct? You did
5 not do an instruction not to answer?

6 MS. BÖLL: Correct.

7 MR. SNODGRASS: Okay.

8 Q So, Dr. Banerjee, strike my pending
9 question, if I have one.

10 Can you describe at a very high level the
11 general steps you took to arrive at your opinions
12 in your declarations?

13 A So after I read the patent and form some
14 initial opinions, I formulate some preliminary
15 opinions of the patentability of the relevant
16 claims based on my knowledge of -- general
17 knowledge of the field as a POSITA, hopefully more
18 than a POSITA, as an expert. I've been working on
19 solar cells and related technologies going back to
20 the 1990s, in fact. So I have a pretty good idea
21 of the overall landscape of the field, I think.

22 And then we go to the next step of, you

1 know, trying to draft the report. So the report
2 is mine, and I stand behind every opinion
3 expressed in the report. And of course, you know,
4 when you write it, it is a collaborative effort
5 with counsel. I am not a lawyer, so all the legal
6 guidance was provided by counsel.

7 I provided a lot of the technical
8 background and the technical analysis. At the end
9 of the day, it is my report, I signed it, and I
10 stand by all the opinions expressed in the report.

11 Q To your best guess, how long did you
12 spend preparing the two reports -- excuse me,
13 declarations?

14 A So as you know, I worked on two
15 declarations connected with three patents. So I'm
16 trying to see how much I spent on the '315.

17 Q Dr. Banerjee, I apologize for
18 interrupting you, because I know you are answering
19 my question. I think maybe my question wasn't
20 clear.

21 When I said the two declarations, I meant
22 the two declarations for the '315 patent.

1 A Okay. Got it.

2 Q So we can put the other ones aside.

3 A Sure. Yeah.

4 I don't remember exactly, but off the top
5 of my head I would say less than 100 hours.
6 Probably 50 hours.

7 Q You mentioned reviewing the claims of the
8 '315 patent.

9 Is that right?

10 A Yes.

11 Q Did you understand the scope of the
12 claims of the '315 patent?

13 MS. BÖLL: Object to form.

14 A I've always been told to read each claim
15 as standing on its own. I'm always told to read
16 the claims in light of the specifications, but not
17 limited by the specs. So that's what I tried to
18 do.

19 Q And after having done that, did you have
20 confidence that you understood the scope of the
21 claims of the '315 patent?

22 MS. BÖLL: Object to form. Object to

1 scope.

2 A I mean, after the first read, you know, I
3 had some pretty good idea. But, of course, as you
4 dig deeper, look at prior art that I cited, you
5 form, you know, other opinions.

6 Q And your opinions are that certain of the
7 claims of the '315 patent are unpatentable as
8 being obvious.

9 Is that right?

10 A That's correct.

11 Q It seems to me in order to arrive at that
12 conclusion you must have understood what it is
13 that the claims purport to cover.

14 Is that fair?

15 MS. BÖLL: Object to form.

16 A I understood what the claims meant. I'm
17 not sure I understand what you mean by "cover."

18 Q I just mean their scope. They purport to
19 protect a certain type of solar cell.

20 Do you agree with that?

21 A Yes.

22 Q And do you have an understanding as to

1 what types of solar cells would be covered by the
2 claims and what type of solar cells would not be
3 covered by the names?

4 MS. BÖLL: Object to form.

5 A Once again, I read the claims -- if you
6 just read claims in isolation, they're often quite
7 cryptic and very terse, so you really can't tell
8 the scope. So you always need to read it in light
9 of the specs. And in doing so, yes, I had a good
10 idea of what types of cells would be covered.

11 Q And a lot of the inquiries we're going to
12 talk about today are done through the eyes of a
13 person of ordinary skill in the art.

14 Is that correct?

15 A Yes.

16 Q Is it your opinion that a person of
17 ordinary skill in the art, having read the
18 specification and the claims, likewise would have
19 had a pretty good understanding as to what the
20 claims cover?

21 MS. BÖLL: Object to form. Object to
22 scope.

1 A I think so. But I mean, since you asked,
2 not to denigrate the patentee or the folks who
3 wrote it, it is a fairly poorly drafted patent,
4 with a lot of ambiguity, I think.

5 But I -- with those caveats, yes, I think
6 a POSITA would understand.

7 Q The ambiguity that you mentioned, is that
8 found in the claims of the '315 patent?

9 A By ambiguity I meant in the claims, for
10 example, there are statements like "approximately
11 less than or equal to," or "the front portion."
12 Of course you get some guidance from the specs,
13 but I think a lot of the claims are somewhat
14 poorly drafted. But that's perhaps not terribly
15 relevant.

16 Q Did you have an understanding as to what
17 part of the solar cell was the front part as
18 recited in the claims?

19 A Yes.

20 Q All right. So is there ambiguity with
21 regard to the word "front"?

22 A No.

1 Q Is there ambiguity with the phrase
2 "approximately less than or equal to 2 times 10 to
3 the 18th"?

4 MS. BÖLL: Object to scope.

5 A There is a certain level of ambiguity, in
6 the sense that if one says "approximately less
7 than 2 times 10 to the 18th," does that mean 1.99
8 times 10 to the 18th, 1.9 times 10 to the 18th?
9 There is a certain level of ambiguity.

10 Q So what did you understand is that phrase
11 to mean in engaging in your analysis?

12 A I mean, within the bounds of the
13 ambiguity, I cited prior art which I felt, you
14 know, met the claims.

15 Q But the claims under what understanding
16 of the claims? So you've told me they're
17 ambiguous so they're open to multiple meanings.
18 What meaning did you ascribe to them?

19 MS. BÖLL: Object to form.

20 A So for instance, in this case if it was a
21 doping level on the order of 1 times 10 to the
22 18th, it's approximately less than 2 times 10 to

1 the 18th.

2 Q So you didn't really resolve the
3 ambiguity that you saw in the claims.

4 Is that right?

5 MS. BÖLL: Object to form.

6 A No; I read the claims with the eyes of a
7 POSITA and, you know, circa the priority date of
8 the patent, which I think is, what, 20 -- I don't
9 know exactly what the priority date is. I assume
10 parameters which I felt to be reasonably within
11 the bounds in the eyes of a POSITA.

12 Q Other than the phrase "approximately less
13 than or equal to 2 times 10 to the 18th," is there
14 any aspect of the claims that you considered that
15 is ambiguous?

16 A Not that I can think of off the top of my
17 head.

18 Q You didn't construe any claim term in
19 connection with your analysis. Correct?

20 A No, I did not.

21 Q Is it your opinion that the terms that
22 are used in the claims of the '315 patent are used

1 in their ordinary sense in the field?

2 MS. BÖLL: Object to scope.

3 A Yeah, I used the plain and ordinary
4 meaning in light of the specifications.

5 Q You mentioned the preparation of your
6 report being a collaborative process. And at a
7 high level -- it's not my intent to get into any
8 drafts or back-and-forth between you and
9 counsel -- did you draft any of your declarations?

10 A Yes, I did.

11 Q And to clarify, if I said "report" in my
12 question, I meant declaration.

13 Did you understand me to be referring to
14 your declarations?

15 A Yes.

16 Q But certain portions were prepared by
17 counsel or upon information that counsel provided
18 you; for example, the background of the law,
19 things like that?

20 A So all the legal stuff came from counsel,
21 our lawyer. A lot of the technical background
22 came from me. And then it's a collaborative

1 effort, as in most cases.

2 Q Dr. Banerjee, towards the end of your
3 report you have an Appendix B with a list of
4 exhibits considered. I'm looking here at Page 104
5 as they have been paginated in the footer.

6 Do you see that?

7 A Yes.

8 MS. BÖLL: Just to clarify, Counsel,
9 you're on Page 104 of the 1038 declaration?

10 MR. SNODGRASS: Yes, that's correct.

11 A Oh, that's the first declaration?

12 Q Yes.

13 A Okay. So I only kept the second
14 declaration because that's a super set of the
15 first. So let me go to the first one. So which
16 exhibit that again?

17 Q It's Exhibit 1003.

18 A Okay. You said Page 104. That's not the
19 appendix in the hard copy.

20 Q It may not be the PDF Page 104. It's in
21 the footer. In the hard copy it should be Page
22 104.

1 A No. It has the same number on my copy.

2 But I can go to the end. I know where the --

3 Q So it's the last three pages I believe,
4 or four.

5 A Yeah, so on my hard copy it says 115.

6 But anyway, go ahead.

7 You are talking about Appendix B. Right?

8 Q Yeah. Are you in the 1194 declaration?

9 A Yes.

10 Q I'm sorry, I meant to be referring to the
11 1038 declaration. That may be why the pagination
12 is wrong. So why don't I withdraw any pending
13 question.

14 So I would like to talk just for a minute
15 about the relationship between the two
16 declarations.

17 You mentioned the 1194 being a super set.

18 Is that right?

19 A Yes, because it covers two additional
20 claims.

21 Q With respect to Claim 10, is there any
22 material difference that you can recall right now

1 in your opinions between the two declarations?

2 A I haven't compared the two recently, but
3 off the top of my head I am tempted to say no.

4 Q So, Dr. Banerjee, what I'd like to do is
5 proceed with the 1038 declaration. And to the
6 extent the 1194 becomes relevant, we can refer to
7 that.

8 But I'll ask that you get the 1038 before
9 you. And if I today refer to "your declaration,"
10 will you understand that I'm referring to Exhibit
11 1003 in the IPR2024-01038?

12 A I don't see the declaration number on the
13 cover page. I see the case number and the patent
14 number.

15 Q So the exhibit number should be in the
16 lower right-hand corner in the footer, the Exhibit
17 1003.

18 A Correct. I see that, yes.

19 Q And the case number, if I said 1038 or
20 1194, I'm referring to the last four digits of the
21 IPR proceeding. So when I say 1038, I mean
22 IPR2024-01038.

1 A Oh, so the copy that I have is 194, so
2 that's the other one.

3 Q Yeah. I'd like to talk about the other
4 one today. Maybe 1194 as well, but I want to
5 focus on the 1038.

6 A Okay. You did not send me a copy of
7 that. Oh, no, maybe it is in the other file. Let
8 me get that.

9 Okay. Yeah, I set aside the first one
10 because that's a subset. So let me just focus on
11 the second one. Never mind. Okay. Go ahead.

12 Q And so again, if I refer to "your
13 declaration" today, will you understand that I'm
14 referring to the Exhibit 1003 in IPR2024-01038?

15 A Yes.

16 Q Okay. Very good.

17 So the last four pages of that
18 declaration include a list of exhibits considered.
19 Maybe at least the last three pages?

20 A Yes.

21 Q Did you review each and every one of the
22 exhibits listed in Appendix B?

1 A I did, but some to a greater degree than
2 others.

3 Q So you didn't read every exhibit cover to
4 cover. Correct?

5 MS. BÖLL: Object to form.

6 A I mean, if you have to read everything
7 cover to cover, you end up spending so much time.

8 Q No. I understand. So I just want to be
9 clear. So you did not read every exhibit cover to
10 cover. Right?

11 A No; but I read what I thought were the
12 relevant parts.

13 Q Did you review the prosecution history of
14 any family member of the '315 patent?

15 A I don't recall off the top of my head.

16 Q If you had, and if that would have
17 informed your opinions, you would have listed it
18 in Appendix B. Correct?

19 MS. BÖLL: Object to form.

20 A Yes.

21 Was there a question pending?

22 Q I apologize if you answered.

1 Did you answer my question regarding if
2 you had reviewed it, reviewed any of the
3 prosecution histories, and they would have
4 informed your opinions --

5 A Yes, I reviewed the prosecution history
6 of the '315. I don't think I reviewed any
7 prosecution history of associated -- associated
8 filings.

9 Q And do you say that because you don't see
10 any prosecution history other than the '315
11 prosecution history listed in Appendix B?

12 A Yes, that's correct.

13 Q Let me jump back to Paragraph 68 of your
14 declaration. It should be on Page 23. I
15 apologize. On 69, Paragraph 69, same page. You
16 said -- are you there, Dr. Banerjee?

17 A Yes.

18 Q You state, For purposes of my opinions, I
19 applied each claim's -- let me start over.

20 "For purposes of my opinions, I applied
21 each claim term's ordinary and customary meaning
22 to a skilled artisan read in light of the

1 specification and prosecution history, unless
2 otherwise specified."

3 Do you see that?

4 A Yes.

5 Q And I didn't see where you otherwise
6 specified a meaning that you were giving to a
7 claim term.

8 Is that your recollection as well?

9 A Yes.

10 Q All right. I'd like to jump forward to
11 Paragraph 74 of your declaration, on Page 27. And
12 before I read that, is there a good way of saying
13 the per cubic centimeters, the centimeter to the
14 negative third?

15 A Per cubic centimeter is fine.

16 Q So in that paragraph you state, "Before
17 December 2014, it had been known for decades that
18 the front portion of a silicon substrate of a
19 back-contact solar cell should be optimally doped
20 at a concentration of less than or equal to 2
21 times 10 to the 18th per cubic centimeter."

22 Do you see that?

1 A Yes.

2 Q What was specifically the optimal doping
3 concentration, to your understanding?

4 MS. BÖLL: Object to form.

5 A It's not a specific concentration; it's
6 more of a optimal range, if you will, of less than
7 2 times 10 to the 18th per centimeter cubed.

8 Q And why was it a range, not a specific
9 value?

10 MS. BÖLL: Object to form.

11 A When you are designing solar cells, what
12 you are trying to do is to achieve certain overall
13 metrics; such as, you know, the highest
14 efficiency, you know, at a reasonable cost,
15 et cetera, et cetera.

16 And then you have to, of course, specify
17 the type of solar cell, whether it's IBC,
18 interdigitated back-contact, or front-contact. So
19 there is different geometries of the solar cell.

20 And then if you pick a certain structure,
21 you have to choose, you know, values of certain of
22 the process parameters. And that will help a

1 POSITA decide what the optimal range is. But the
2 range is not going to be huge; it's going to span
3 orders and orders of magnitude. So in this
4 context it's going to be less than or equal to 2
5 times 10 to the 18th.

6 Q Would it ever be a range that would at
7 least partially encompass values greater than 2
8 times 10 to the 18th per cubic centimeter?

9 MS. BÖLL: Object to form.

10 A I mean, depending on the circumstance, it
11 may be marginally higher. And then it's an
12 engineering problem, and a POSITA would be trying
13 to optimize parameters such as a cell efficiency
14 and so on and so forth.

15 So there's always going to be a little
16 bit of engineering leeway.

17 Q Are you aware of any reference, any
18 technical paper, for example, that described a
19 doping concentration greater than 2 times 10 to
20 the 18th per cubic centimeter as being ideal or
21 optimal?

22 MS. BÖLL: Object to form.

1 A So the prior art that I cited was in many
2 cases less than 2 times 10 to the 18th. But I
3 think in a couple of cases in certain regions it
4 may have been marginally higher than 2 times 10 to
5 the 18th.

6 Q Are you aware of any reference other than
7 what you cited that describes higher doping
8 concentrations as being preferable, higher than 2
9 times 10 to the 18th?

10 MS. BÖLL: Object to scope.

11 A I believe your expert, Dr. Carroll, cited
12 the Granek reference where the doping levels are
13 higher.

14 Q Is the Granek reference wrong, in your
15 opinion?

16 MS. BÖLL: Object to scope.

17 A I looked at some of the results in Granek
18 last night, in fact. And interestingly, I
19 remember that there were Table 2 in Granek where
20 they compared -- they're trying to -- your expert
21 was trying to denigrate the prior art that we were
22 citing as being old, sort of not state-of-the-art

1 technologies.

2 But interestingly enough, in the Granek
3 paper, at the very end of I think it's Table 2,
4 they're comparing thick oxides, which are typical
5 of the art that I recited, and they're optimal.
6 Interesting enough, the values are pretty close.

7 If you look at the open circuit voltages,
8 I forget the exact numbers, but I think it was 703
9 versus 707. I don't know if Granek did any
10 statistically significant studies. But I can tell
11 from you my experience when you measure these
12 parameters of solar cells, there is always some
13 range of these values. You know, I think two or
14 three -- I forget the exact difference, but a
15 3-millivolt difference for an open circuit voltage
16 that is around 700 millivolts or so did not seem
17 like a very significant difference.

18 Q I believe you mentioned oxides in your
19 last answer. Do you have an understanding as to
20 the relationship, if any, between an oxide layer
21 on a surface and the preferable or desired dopant
22 concentration on that surface?

1 MS. BÖLL: Object to scope.

2 A Yes, oxides are used very often in solar
3 cells to act as a passivation layer to reduce
4 surface recombination.

5 Q So the presence of an oxide layer would
6 lessen the desired doping concentration, all other
7 things being equal.

8 Is that fair?

9 MS. BÖLL: Object to form.

10 A In doping and oxides you are trying to
11 address two related but not exactly the same
12 topic, and that is in the case of oxide
13 passivation you're trying to reduce what are
14 called dangling bonds at the surface of the
15 silicon, which then lead to high surface
16 recombination velocities. The doping, on the
17 other hand, depending on whether it's on the front
18 surface or the back surface, provides a so-called
19 front-surface field or a back-surface field. In
20 fact, you need a relation of the doping, which
21 will create an electric field, typically designed
22 to repel one type of carrier, in this case the

1 minority carrier, so that they don't go through
2 the surface and then recombine at the surface.

3 So they are both ultimately geared
4 towards reducing recombination of the carriers,
5 the minority carriers, and thereby improving the
6 cell efficiency, but you can't necessarily
7 conflate the two.

8 Q Would a designer of a solar cell consider
9 whether or not a surface was passivated in
10 determining the appropriate doping concentration?

11 MS. BÖLL: Object to form. Object to
12 scope.

13 A Passivation is certainly one of the
14 things that a POSITA should consider. And as far
15 as I know, I don't know of any practical solar
16 cells that do not use surface passivation, off the
17 top of my head.

18 Q Li did not have surface passivation.
19 Correct?

20 A Li?

21 Q Yes. Exhibit 1005. I'm going to drop it
22 in the chat.

1 (IPR2024-01038 Exhibit 1005, previously
2 marked, and is attached to the transcript.)

3 MR. SNODGRASS: And I guess just for the
4 record, any exhibit I refer to today will be the
5 exhibit in IPR2024-01038 unless I specify
6 otherwise.

7 Q Dr. Banerjee, do you recall the Li
8 reference?

9 A Yes, I am looking at the Li reference.

10 Q And it does not have a passivation on its
11 front surface, correct, a passivation layer?

12 A Yeah; but it does on the back surface,
13 which is more important because it's a
14 back-contact cell.

15 Q And one of the issues in these
16 proceedings is whether it would have been obvious
17 for a person of ordinary skill in the art to dope
18 the front surface at a concentration of 2 times 10
19 to the 18th per cubic centimeter or less.

20 Is that right?

21 A Yeah, that's what the challenged claims
22 are talking about.

1 Q So with regard to what -- with regard to
2 that question, would a person of ordinary skill in
3 the art have used the doping concentrations of a
4 reference that included a passivation layer on a
5 front surface when Li did not?

6 MS. BÖLL: Object to form.

7 A Well, from what I recall, Li does not
8 have any teaching as to the level of the dopant on
9 the front surface. And then I believe he has some
10 statements, as many patents do -- let me review
11 that quickly. I am saying from my memory here,
12 but I believe Li had some statements that they are
13 not describing every single aspect of the
14 technology that's common. So even if they did not
15 explicitly show a passivation on the front
16 surface, that does not mean that they are not
17 using it. Let me -- give me a second.

18 Yeah. If you look at Column -- Page 1 of
19 Li, Column 2 -- I guess it's easier to look at
20 Paragraph 21. Li states, "Methods of fabricating
21 back-contact solar cells and devices thereof are
22 described herein. In the following description,

1 numerous specific details are set forth," dot,
2 dot, dot.

3 Then the next sentence says, "It will be
4 apparent to one skilled in the art, a POSITA, that
5 embodiments of the present invention may be
6 practiced without" -- I guess the previous
7 sentence said, "In the following description,
8 numerous specific details set forth, such as
9 specific process flow operations, in order to
10 provide a thorough understanding of the
11 embodiments of the present invention. It will be
12 apparent to one skilled in the art that the
13 embodiments of the present invention may be
14 practiced without these specific details. In
15 other instances, well-known fabrication
16 techniques, such as lithographic techniques, are
17 not described in detail in order to not
18 unnecessarily obscure embodiments of the present
19 invention."

20 So even though the figures in Li may not
21 show a passivation on the front surface, there
22 it's quite commonly, if not universally used in

1 practical solar cells. So I would not state that
2 Li does not use a passivation necessarily on the
3 front surface.

4 Q Are your opinions premised on the notion
5 that there is, in fact, an unshown passivation
6 layer on Li's front surface?

7 MS. BÖLL: Object to form.

8 A In my analysis I did not make
9 anticipation arguments using just Li alone. So I
10 was using the other cited art, such as King,
11 Swanson, et cetera, in combination with Li, to
12 show that the claims, the relevant -- the
13 challenged claims of the '315 are invalid.

14 Q So, Dr. Banerjee, do you believe that the
15 solar cell described in Li includes a passivation
16 layer on its front surface?

17 A Li does not specifically describe a
18 passivation layer. But based on the statements
19 that -- the sentences that I read, it could have,
20 and very well likely did. But that's irrelevant.

21 I did not need to incorporate that
22 teaching in Li for my opinions. Like I said, I

1 used an obviousness argument of Li with either
2 King or Swanson or Marvin to reach my conclusions.
3 And those did show passivation layers.

4 Q But you -- strike that.

5 I believe you have four different
6 obviousness combinations in your declarations.

7 Is that right?

8 A Yes. In Section 5 we combined Li with --
9 that's one, two, three. I am looking at the table
10 of contents. So we combined Li with King, Swanson
11 '352, Marvin. And then in Section 6 we combined
12 Li with Muller.

13 Is that what you meant by four
14 combinations?

15 Q I meant, yeah -- I apologize,
16 Dr. Banerjee. I believe when you turned to look
17 at the paper it -- the microphone didn't catch
18 your voice all too clearly. So I'm not sure I
19 heard what you said.

20 I'm referring to an obviousness
21 contention based on Li, with King, Swanson '352,
22 or Marvin, that would be one.

1 A Yes.

2 Q Li with Muller, that would be two.

3 A Yes.

4 Q Li with King, Swanson '352 or Marvin in
5 further view of Hu, Ramappa, and then -- that was
6 three. And then Li with Muller in further view of
7 Hu, Ramappa. That would be four.

8 Are those your four grounds?

9 MS. BÖLL: Object to form.

10 A Yeah, those grounds are listed in my
11 table of contents. I'm struggling a little bit
12 with the count of four. How exactly are you
13 counting -- are you counting the four pieces of
14 key prior art? No. You are talking about the
15 four combinations?

16 Q Yes. So under section heading 5, I see a
17 combination, section heading 6 I see a
18 combination.

19 A Right.

20 Q And section heading 7 I actually see two.

21 A Okay. That's where I was confused.

22 Okay. So you are calling that two combinations.

1 Q Yeah. Because it says, In view of the
2 previous combinations. And I interpret that to
3 mean in view of the previous two combinations.

4 A Yes. So combined with either Hu or
5 Ramappa, that's how you come up with two more?

6 Q Yes.

7 A Okay. Got it.

8 Q And to be clear, it's not one is Hu, one
9 is Ramappa. It's that we have the Li with King,
10 Swanson '352, or Marvin with Hu or Ramappa. And
11 then we have Li plus Muller in view of Hu or
12 Ramappa?

13 A Got it. Okay. Yes.

14 MS. BÖLL: Object to form.

15 A Yeah, so that's four combinations. Yeah.
16 Okay.

17 Q And those are the four bases upon which
18 you are providing your obviousness opinions.

19 Correct?

20 A Yes.

21 Q In the first one, Li with King or Swanson
22 '352 or Marvin, it was my understanding that you

1 were relying on those secondary references only
2 insofar as they taught a doping concentration.

3 Are you telling me that you are actually
4 incorporating more and incorporating passivation
5 layers as well?

6 MS. BÖLL: Object to form.

7 Q And, Dr. Banerjee, I guess I arrive at my
8 conclusion based on Paragraph 122 of your
9 declaration, if that's helpful.

10 A Yeah, primarily looking at the doping of
11 the front surface. Because the challenged claims
12 in '315 are silent as to whether they use
13 passivation on the front surface or not.

14 Having said that, as I told you, all
15 practical solar cells that I am aware of do use a
16 surface passivation to improve the efficiency.

17 Q Did you have in your mind, when you were
18 developing your opinions, a specific combination
19 of these references?

20 MS. BÖLL: Object to form.

21 A No. I mean, so this is a question that
22 has often come up. You know, when you come up

1 with obviousness combinations, would a POSITA
2 operate in an absolute vacuum. And I think she or
3 he would have to read the asserted claims to see
4 what's at issue. Right?

5 So you read the claims and the dependent
6 claims and you see what the various claim elements
7 are. So at some level, of course, you want to
8 find art that is relevant for those claims or
9 claim elements. But it's not a -- you don't use
10 20/20 hindsight to, you know, put together pieces
11 of a jigsaw puzzle. No, that's not the way I do
12 the analysis.

13 Q All right. I want to stick with this
14 topic, but I want to jump to a different part of
15 your declaration. Paragraph 199.

16 This is on Page 87. In the third line
17 into that paragraph you state, comma, "Given that
18 Li does not disclose any other layers on the front
19 surface of the solar cell."

20 Do you see that?

21 A Yes.

22 Q And then you reference Exhibit 1005,

1 which is Li, and in particular Figure 5E.

2 Do you see that?

3 A Yes.

4 Q So we agree that Li does not disclose
5 anything on its front surface, any other layer on
6 its front surface. Right?

7 MS. BÖLL: Object to form.

8 A It does not explicitly disclose other
9 layers.

10 Q Does it inherently disclose another
11 layer?

12 MS. BÖLL: Objection. Form.

13 A Maybe not inherently. But when a POSITA
14 reads Li with her knowledge of the field, I think
15 she will be inclined to use a passivating layer.
16 But it's not inherently or explicitly disclosed in
17 Li.

18 Q And to be clear, when we talk about the
19 front surface of Li, for example with respect to
20 Figure 5E, that's the bottom surface. Right?

21 MS. BÖLL: Object to form.

22 A That is the bottom surface of Li.

1 May I refresh myself with Li just a
2 second?

3 Q Sure. Just let me know when you're done.

4 A Yeah. What I am searching for, just so
5 that you know, I see the texturization on the
6 front surface which is used to minimize
7 reflection. That's very often used in concert
8 with anti-reflection coatings, which can provide a
9 passivation benefit. So I am trying to look for
10 anti-reflection coatings.

11 Do you know if Li discloses that? That
12 will save time.

13 Q I don't believe it does, but I only have
14 my opinion. I did not commit it to memory.

15 A Well, I will take your word for it and
16 not waste time. If it doesn't, if it doesn't, it
17 doesn't explicitly. But as Li described, he is
18 not trying to describe every aspect of the
19 invention. Otherwise every patent would be
20 probably thousands of pages long.

21 Q Right. So but using Li as a base, or as
22 a primary reference, you then added to it with

1 disclosures of other references.

2 Is that fair?

3 A Yes.

4 Q And you reproduced in your declaration
5 Figure 5E in a number of instances and colored
6 some of the different layers.

7 Is that right?

8 A Yes.

9 Q And at one point you had an idea that you
10 would take that layer and -- or one of skill in
11 the art would take that structure and dope the
12 front surface with a certain doping concentration.

13 Right?

14 A Well, I believe Li does disclose doping
15 the front surface. The only thing that was
16 missing was the level of the doping.

17 Q Right. And so you thought that you
18 could -- or one of skill in the art would have
19 taken a value from another reference and used that
20 for the doping in Li.

21 Is that right?

22 A One would look to prior art that's

1 relevant in the same space as Li. And once again,
2 there has to be a motivation to combine. You
3 don't combine with prior art just for the sake of
4 invalidating a patent. There has to be -- I'm not
5 a lawyer, but if I look -- if you look at the
6 criteria for obviousness combinations, I believe
7 there has to be a motivation to combine.

8 And in this case the motivation would be
9 improving the efficiency of the solar cell. So if
10 the use of front-surface doping at the levels of
11 $1E18$ or so helps achieve that goal, I mean, that
12 would be a good motivation to combine.

13 So those are the types of rationales that
14 I had in the back of my mind.

15 Q Did you ever think one of skill in the
16 art also would have added a passivation layer on
17 the front surface of Li?

18 MS. BÖLL: Object to form.

19 A The claims that are being challenged are
20 silent as to the use of the passivation layer.
21 However, as I told you, the vast majority of the
22 commercial solar cells that I'm aware of do use a

1 passivation layer to achieve high efficiencies,
2 which is always the goal. So --

3 Q Do you believe Li is directed at a
4 commercial solar cell?

5 MS. BÖLL: Object to form.

6 Also, Dr. Banerjee, if you need to finish
7 your answer, please do.

8 Q Dr. Banerjee, did I interrupt your prior
9 answer?

10 A No, so when I said "commercial," I meant
11 solar cells with good metrics, such as high
12 efficiency. I don't see much point in patenting a
13 solar cell which has terrible performance metrics.
14 So I used the term "commercial" in that sense.

15 Q Did you ever think, in constructing this
16 obviousness combination, that we have a structure
17 depicted in Figure 5E of Li, we have a doping
18 concentration from another reference, be it King,
19 Marvin, Swanson '352, and we also have a
20 passivation layer on the front surface of Li; did
21 that hypothetical device enter your mind?

22 MS. BÖLL: Object to form.

1 A As I told you, you know, the front
2 surface passivation -- the front surface field and
3 the surface passivation are both geared towards
4 improving the cell efficiency, but they address
5 somewhat different physics. In the sense that a
6 doping gradation at the front surface, or if you
7 use a back-surface field at the back surface,
8 causes band bending of the bands in the
9 semiconductor, generating electric field which
10 will reflect back the minority carriers. And that
11 would inhibit them from recombining at the
12 surface.

13 Now, furthermore, if you have surface
14 passivation, that will tie up dangling bonds,
15 reduce defect density at the surface, which will
16 also help with reducing recombination. So you
17 could do one without the other. But if you do
18 both, you do get some concomitant benefits.

19 Q Can you direct me to where in your
20 declaration you described in your obviousness
21 combinations based on Li and either Marvin,
22 Swanson '352, or King, also adding a passivation

1 layer on the front surface of Li?

2 MS. BÖLL: Object to form.

3 A These combinations I was focusing on the
4 doping and not the passivation. Because once
5 again, the challenged claims of '315 were silent
6 as to the use of the passivation layer or not.

7 Q Is that another way of saying it doesn't
8 exist? You didn't describe that combination in
9 your declaration?

10 MS. BÖLL: Object to form.

11 A No, I did not say that.

12 Q Do you -- okay. Are you finished?

13 A I am trying to think to give a complete
14 and scientifically accurate answer.

15 So once again, you know, I read the
16 claims with the relevant claim elements. And
17 since it's recited surface doping level, but was
18 silent as to the passivation aspect at the
19 surface, whether it was present or not, I focused
20 on that aspect in my obviousness combinations.

21 Q If you knew that you had, in fact, in
22 your declaration described a combination with Li,

1 doping concentrations of either King, Swanson
2 '352, or Marvin, and a passivation layer, you
3 would tell me today where that is. Right? You
4 wouldn't hide that from me. Right?

5 MS. BÖLL: Object to form.

6 A Could you -- I don't understand your
7 question, frankly. Could you repeat that, please?

8 Q If you, in fact, right now know where in
9 your declaration you have described a combination
10 of Li, plus the doping concentration of either
11 King, Swanson '352, and Marvin, and a passivation
12 on the front surface of Li, you would tell me
13 where that is right now. Right?

14 MS. BÖLL: Object to form.

15 Q Because I have been asking where that is,
16 and you're not telling me. And I believe it's
17 because it doesn't exist.

18 A Yeah, I don't think I opined on it.

19 Q Do you believe a person of ordinary skill
20 in the art would have considered whether Li had a
21 passivation layer in selecting the appropriate
22 doping concentration for its front surface?

1 MS. BÖLL: Object to form.

2 A As I told you before, Li is silent as to
3 the presence or absence of passivation layer. But
4 given the statement that I cited earlier about not
5 describing every single aspect of the invention, I
6 believe a POSITA would be inclined to believe that
7 there was a passivation layer on the front surface
8 of Li.

9 But that's I think not terribly relevant
10 for my analysis. Because the challenged claims of
11 '315 are silent as to the use of a passivation
12 layer. Though I believe that even in '315, a
13 POSITA would have used a passivation layer in
14 addition to the front-surface field.

15 The primary focus of my analysis was do
16 these obviousness combinations disclose the right
17 front-surface doping, which is the only thing I
18 think that was missing in Li.

19 Q If you were asked to determine what the
20 appropriate doping concentration was for the
21 structure of Li as it is, which per Paragraph 199
22 of your declaration you admit there is no layer on

1 the front surface, would you consider the fact
2 that there is no surface on the front surface of
3 Li?

4 MS. BÖLL: Object to form.

5 A No; I believe there's a layer on the
6 front surface, only the doping concentration
7 wasn't shown. Let me look at Li again.

8 Yeah, Li does use front-surface doping.
9 So this is in Column -- Page 3, first column. I
10 guess Li uses paragraph numbers. So in Paragraph
11 Number 38, he talks about N-type dopants 318 at or
12 near the surfaces of a substrate. He does
13 disclose a front surface field doping. The only
14 thing that was lacking was the concentration of
15 that layer. But it does have a layer.

16 Q So if we can rewind to 2014 and you were
17 presented with Li and you were told, Dr. Banerjee,
18 Li tells us to dope the front surface but it
19 doesn't tell us the concentration, can you tell us
20 what the ideal concentration would be? Would you
21 be able to handle that task?

22 MS. BÖLL: Object to form.

1 A I guess the real question is would a
2 POSITA be able to handle that task. I believe so.
3 Because, you know, he or she would have general
4 knowledge of the landscape of the technology, and
5 then he or she presumably has access to the prior
6 art that's cited. And then that person would be
7 motivated to improve the cell efficiency, which as
8 I said is always one of the key metrics that a
9 POSITA is trying to maximize.

10 And then that person wouldn't have to
11 look at all the prior art. Want to look at
12 relevant structures, in this case I believe that
13 would be the IBC type cell structures. So that
14 narrows the field of the prior art significantly.

15 So with those caveats, I believe the
16 POSITA would be able to come up with the right
17 level of doping.

18 Q Do you believe that, notwithstanding that
19 there may be other prior art that discloses
20 concentrations other than the concentration you
21 identified in the King, Marvin, and Swanson '352
22 references?

1 MS. BÖLL: Object to form.

2 A You know, in the field of solar cells,
3 specifically in those devices in general, there
4 are so many papers, so many patents that are
5 published every year, it's hard to conclusively
6 say that, you know, a POSITA would be aware of
7 every single piece of prior art.

8 And the way you do these searches these
9 days are, of course, a lot easier than when I was
10 in graduate school, and we have access to all
11 types of databases, and presumably a POSITA would
12 have access to that also.

13 So she would start with Li as a base.
14 She will be motivated to maximize the efficiency
15 of the cell. And that would require, you know,
16 things like front-surface doping and also
17 passivation, even though Li is silent as to the
18 use of a passivation layer and the claims are also
19 silent as to that aspect.

20 But setting that aside, that person would
21 very easily do a smart search of relevant prior
22 art and come up with art such as Li, Swanson '352,

1 Marvin, and say, Oh, good, I mean, this is very
2 similar technology as Li, specifies doping at the
3 front surface in the range of $1E18$ or so, and
4 therefore she will conclude that the claims of
5 '315 are invalid.

6 I mean, that will be the process that I
7 would go through.

8 Q Do you think that person of ordinary
9 skill in the art would have said, But Li says
10 there is no layer on the front surface, and these
11 other references such as King, Swanson '352, and
12 Marvin do have passivation layers, so I don't want
13 to use those doping concentrations? Do you think
14 a person of skill in the art would have thought
15 that?

16 MS. BÖLL: Object to form.

17 A When you say Li has no layer, I presume
18 you mean the passivation layer, not the doping
19 layer?

20 Q Yes.

21 A Well, Li is silent as to that. Okay?

22 And as I told you before, Li clearly

1 states that he did not describe every bell and
2 whistle related to that technology. So I think a
3 POSITA would very well consider the use of a
4 passivation layer even in Li.

5 But setting that aside, that person would
6 look at other prior art such as Li -- such as
7 King, Swanson '352, Marvin. And despite the fact
8 that they do use a surface passivation layer in
9 addition to the front doping, I think that person
10 would find the disclosures in those prior art very
11 relevant and very applicable to Li in terms of the
12 doping concentration of the front surface.

13 Because --

14 MS. BÖLL: Counsel --

15 A Because, as I was telling you, the
16 surface passivation layer and the front-surface
17 doping are related but they're not exactly the
18 same. The front-surface doping reflects back the
19 minority carriers from the front surface because
20 of the built-in electric field, while the
21 passivation layer inhibits the recombination
22 through defects at the interface. And they both

1 relate to reducing recombination of the minority
2 carriers and improving the cell efficiency. But
3 there is a distinction between those two aspects
4 of it.

5 MS. BÖLL: Counsel, I was just going to
6 ask if we're reaching a good point for a break?

7 MR. SNODGRASS: It's as good a time as
8 any, I'll put it that way. So we can break.

9 Go off the record.

10 (A recess was taken.)

11 BY MR. SNODGRASS:

12 Q Dr. Banerjee, I want to continue this
13 discussion a little bit.

14 Can we imagine going back to 2014 and
15 handing a person of ordinary skill in the art the
16 Li reference, and telling them to fill in the
17 missing blank, i.e., the doping concentration, and
18 with the constraint that we don't want Li to be
19 modified such that there is a passivation layer on
20 its front surface?

21 Are you okay with that scenario?

22 A Okay.

1 Q Would a person of ordinary skill in the
2 art, under those constraints, have chosen the
3 doping concentration from either King, Swanson
4 '352, or Marvin?

5 MS. BÖLL: Object to form.

6 A I believe so. And let me tell you why.

7 So to minimize surface recombination of
8 the minority carriers, there is two aspects to the
9 problem. One is not letting the minority carriers
10 approach the front surface, and that's what the
11 doping gradation of the front surface field does
12 for you.

13 And then assuming they do reach the front
14 surface, preventing them from recombining with the
15 majority carriers, which is where the passivation
16 layer helps you.

17 So if for argument's sake one did not use
18 a passivation layer -- and that seems to be of
19 contention -- one would still benefit from the use
20 of the built-in electric field of the
21 front-surface field to reflect back the carriers.

22 Of course if you just did that and did

1 not use a passivation layer, the efficiency would
2 not improve quite as much as using both the
3 front-surface field doping as well as the
4 passivation layer. Because if you do both, you
5 get some sort of additive benefit.

6 But the teachings of King, Marvin,
7 Swanson '352 vis-à-vis the doping concentration of
8 the front surface field, regardless whether you
9 have a passivation layer or not, I think it would
10 still be very, very relevant.

11 Now, having said that, I still maintain
12 that, you know, even though Li may not explicitly
13 have described a passivation layer, there is a
14 good certainty that Li also would use one because
15 that's what cells with high efficiency use.

16 Q I want to discuss Marvin for a minute.
17 This is Exhibit 1035.

18 (IPR2024-01038 Exhibit 1035, previously
19 marked, and is attached to the transcript.)

20 Q I have just circulated it via chat. It
21 should be in your binder, Dr. Banerjee.

22 A Yes, I see that.

1 Q I want to discuss the portion that's on
2 Page 827. And that's what I want to focus on. I
3 suppose the relevant discussion is towards the
4 bottom of Page 826.

5 Are you generally there, Dr. Banerjee?

6 A Yes.

7 Q Okay. So there is a discussion in the
8 conclusion about near optimal design -- this is
9 the second sentence. "Near optimal designs have
10 been presented for missions using either planar or
11 100-sun concentrator arrays under high or
12 negligible radiation influences."

13 Do you see that?

14 A Yes.

15 Q If goes on. "In the low radiation
16 environment, the minority and majority carrier
17 collection regions should be of a comparable width
18 with thicknesses of 0.9 microns and 3.0 microns
19 respectively."

20 So far so good?

21 A Yes.

22 Q Okay. And then this is what I want to

1 focus on. The S F -- excuse me. Strike that.

2 Do you understand FSF to be front surface
3 field?

4 A Yes.

5 Q "The FSF should be an approximately 0.5
6 micron step with doping concentration of $5E18$ per
7 cubic centimeter."

8 Do you see that?

9 A Yes.

10 Q That's the same as 5 times 10 to the 18th
11 cubic centimeters -- excuse me. That's the same
12 as 5 times 10 to the 18th per cubic centimeter.

13 Correct?

14 A Yes.

15 Q So at least in that embodiment, Marvin is
16 telling us that a near optimal design is 5 times
17 10 to the 18th.

18 Is that right?

19 MS. BÖLL: Object to form.

20 A It is for the 100-sun operation, which is
21 a concentrator solar cell.

22 Q And the 1 times 10 to the 18th that you

1 find in Marvin is in a space application.

2 Correct?

3 A Where does Marvin say that?

4 Q Well, I guess before we get there, do you
5 believe a person of ordinary skill in the art
6 would have discounted that disclosure of Marvin
7 because it deals in a concentrator environment?

8 A No. I believe Marvin talks about both
9 1-sun, which is nonconcentrator and concentrator
10 environments.

11 Q Right. And do you believe a person of
12 ordinary skill in the art would have discounted
13 the portion addressing concentrator environments?

14 A So under the concentrator environments,
15 the photon flux is of course much higher than
16 under 1-sun conditions, and exact parameters for
17 optimal performance would be different.

18 However, generally teachings of what one
19 needs to do to improve cell efficiency very often
20 carry over from no concentrator conditions versus
21 concentrator applications.

22 Q Is that another way of saying they would

1 not have discounted the disclosure regarding
2 concentrators?

3 MS. BÖLL: Object to form.

4 A They would not have discounted it for the
5 purposes of general guidance. But the specific
6 value, such as 5E18 that's relevant for
7 concentrators may not be relevant for
8 nonconcentrator applications.

9 Q So then switching to the other situation
10 disclosed in Marvin, which I described as a space
11 application or something along those lines. I'm
12 getting that, to answer your question, I'm getting
13 that from the first full paragraph on the
14 right-hand column of Page 826 where it begins,
15 "For space use where radiation is present." And
16 I'm kind of joining that with the first full
17 paragraph on Page 827, which talks about a
18 high-radiation environment. And so I'm drawing a
19 connection between those two paragraphs.

20 Is that a fair reading of Marvin?

21 A Are you referring to the paragraph which
22 says, "For space use where radiation is present,

1 EoL" -- that's end of life -- "performance must be
2 considered"? That's the paragraph?

3 Q That's one of the paragraphs, yes.

4 And I'm again reading this reference in
5 its entirety. I'm seeing a similarity between
6 that disclosure and then the first full paragraph
7 on Page 827, which talks about a high-radiation
8 environment, and then equating that to a space
9 use. And I want to do that because that's where I
10 see the 1E18 is in Paragraph -- excuse me, on Page
11 827.

12 A Yes, I see the 1E18 for space
13 applications.

14 Q I apologize if that background noise is
15 bothering anyone.

16 A I don't hear anything.

17 Q Good. You guys are lucky.

18 Okay. So why would a person of ordinary
19 skill in the art in your opinion, if this is your
20 opinion, have been drawn towards the disclosure of
21 Marvin that relates to a space use, rather than
22 the disclosure of Marvin relating to a

1 concentrator?

2 A So the difference between space use and
3 terrestrial use is in space the sunlight is not
4 going to get absorbed by the atmosphere, and that
5 gives isometrical AM0, air mass zero, while on the
6 earth surface if the sun is right overhead that's
7 air mass 1. But the average performance during
8 the day you get air mass 1.5.

9 Now, you know, the '315 Li, Swanson, I
10 mean, they're all -- Swanson and then King,
11 they're all silent as to whether the intended
12 application is terrestrial or space. So I don't
13 think a POSITA would discount the teachings of
14 Marvin just because it's being used primarily for
15 space applications.

16 I mean, a cell that's used in space can
17 also be used with -- for terrestrial applications.
18 The performance will be different somewhat because
19 of the absorption of the sunlight. But the
20 general teachings, as I told you, would certainly
21 carry over between space and earth applications,
22 perhaps more so than between 1-sun and 100-sun

1 concentrator applications, because there the
2 photon flux is a lot higher, 100 times higher.

3 And therefore, although the general
4 principles still apply, the optimal parameters
5 would be more different I think than between space
6 and earth under nonconcentrator conditions.

7 Q I'm sorry, that last part, are you saying
8 that the optimum parameters between a 1-sun
9 terrestrial environment and a terrestrial
10 concentrator environment would likely be more
11 dissimilar than they would be between a 1-sun
12 space application and a 1-sun terrestrial
13 application?

14 A No. No. I am saying that the difference
15 between 1-sun and 100-sun both on earth or in
16 outer space I think would have more difference of
17 the optimal parameters than between 1-sun in outer
18 space, which is 1-sun on the earth surface.

19 Because outer space and the earth
20 surface, the only difference is the absorption of
21 some of the sunlight in the earth's atmosphere on
22 the earth surface. But it is not as drastic of a

1 difference between 1-sun versus 100-suns.

2 Q I'm sorry, so I understand the one -- the
3 second alternative, right, 1-sun space versus the
4 1-sun terrestrial. I get that.

5 But the first thing again is the 1-sun
6 versus 100-sun, are both of those terrestrial,
7 both of those space, one terrestrial, one space?

8 A You could have all those combinations.
9 What I am trying to say is there isn't as much
10 difference between terrestrial versus space, in my
11 opinion, as between not concentrated versus
12 concentrated 100 times. I mean, you can do
13 concentrations at lower ratios also, of course.

14 Q In your proposed Li plus either King,
15 Swanson '352, or Marvin combination, are you
16 envisioning a terrestrial solar cell or a space
17 solar cell?

18 A The patents, the '315 and Li, are both
19 silent as to that aspect. So at a high level, I
20 think the disclosures are somewhat agnostic to
21 that difference. Not completely, however, because
22 the optimal parameters would be different between

1 concentrator versus nonconcentrator. I'm tempted
2 to say, though there is no hard basis for this
3 statement, the vast majority of the applications
4 envisioned I think are terrestrial, and the space
5 application is a very niche market. So I think in
6 most cases one would look at terrestrial
7 applications.

8 Q We may get back to that issue, but I do
9 want to talk about other things as well.

10 Can you please turn to Paragraph 83 of
11 your declaration.

12 A I'm here.

13 Q This addresses gettering. Is that right?

14 A Yes.

15 Q Correct me if I'm wrong, but I believe,
16 in your four grounds or bases for invalidity,
17 you're relying on the concept of inherency;
18 specifically that Li inherently would getter
19 impurities from the substrate into the material
20 layer.

21 Is that right?

22 A Yes.

1 Q Did you, in your analysis, consider that
2 any impurities in Li would have to traverse two
3 interfaces to get from the substrate to the
4 material layer?

5 MS. BÖLL: Object to form.

6 A Yes, the impurities would have to travel
7 from the base, the substrate, to the interfaces to
8 be gettered. How far they have to travel depends
9 on the location of the impurities and the base to
10 begin with. They are not all at the same
11 location. They are spread out throughout the
12 substrate.

13 Q But for an impurity to reside in the
14 material layer of Li, according to your theory it
15 would have started in the substrate, have
16 traversed the substrate oxide interface, traversed
17 the oxide layer, traversed the oxide-polysilicon
18 interface, and then would reside in the
19 polysilicon material layer.

20 Is that right?

21 A Yes.

22 Q Did you in your declaration discuss the

1 opportunities for any impurities to be trapped in
2 either of those two interfaces?

3 MS. BÖLL: Object to form.

4 A I did not, but in some sense it's
5 irrelevant. The important thing is to get the
6 impurities away from the substrate where they can
7 have deleterious effects of enhancing bulk
8 recombination. Whether they're stuck in the
9 polysilicon emitter or the interface within the
10 polysilicon and the oxide interface I don't
11 believe would matter.

12 Q What factors impact whether gettering
13 occurs?

14 A It depends on the temperature or the
15 processing a lot. It also depends to a lesser
16 degree to the gettering time. So it depends
17 exponentially on the temperature according to
18 what's known as the Arrhenius relationship, which
19 is also dependent on the time.

20 For gettering to happen, you have to
21 allow the metal impurities to diffuse, which
22 depends on the time and the temperature, as I

1 mentioned. But then it has to be locked in a
2 location with the strain fields. And very often
3 these strain fields are created by high levels of,
4 say, phosphorous or boron doping, in this case in
5 the polysilicon.

6 Q Would gettering be impacted by dopants in
7 the substrate?

8 A It could if the doping levels are very,
9 very high. Because dopants are a different size
10 than silicon atoms, and that's what gives rise to
11 strain. However, the doping levels that one uses
12 in the base of a solar cell are much lower, where
13 I think any impact will be insignificant.

14 Q So when you say very high, I forget the
15 exact term, are you thinking -- specific order of
16 magnitude?

17 A There is a range. But on the order of
18 maybe 10^{19} to 10^{20} .

19 Q What about 5 times 10^{18} , the
20 number we saw in Marvin at least for the space
21 application -- at least for the concentrator
22 application; would that impact gettering?

1 MS. BÖLL: Object to form.

2 A It would depend on partly whether it was
3 boron or phosphorous. The boron atom is a lot
4 smaller than the silicon atom. The phosphorous
5 atom is also smaller, but not that much smaller.
6 So all things being equal, I suspect boron would
7 have more of an inhibitory effect.

8 Q In our discussion here the last couple of
9 minutes, are you envisioning a particular type of
10 impurity?

11 A So I did the analysis using iron as a
12 particular example. And not all impurities are
13 equally important. The ones that you want to get
14 out of the base are the so-called deep-level
15 impurities. And very often these are metals, such
16 as iron or maybe gold. But I did the analysis
17 specifically using iron.

18 However, a lot of these metal impurities
19 are very fast interstitial diffusers --
20 I-N-T-E-R-S-T-I-A-L, I will give you the spelling
21 later on if you need it. I am talking to the
22 court reporter.

1 So these interstitial metallic impurities
2 tend to diffuse much faster than substitutional
3 dopants such as boron and phosphorous. So
4 although I did my analysis using iron as an
5 example, I think the analysis would carry over to
6 many of the other harmful metallic impurities.

7 Q Do you believe that they would exhibit
8 different levels of gettering, "they" being the
9 other impurities other than iron?

10 A Yes, they could. Yeah.

11 Q Okay.

12 A But I may point out the patents are
13 silent as to the level of gettering that's
14 required to meet the claims.

15 Q So do you believe to meet the claims any
16 amount of gettering into the material layer would
17 suffice?

18 A Since the claims are silent as to that
19 aspect, my answer would be yes. This goes to the
20 ambiguity of these claims. Right? I mean, if you
21 had, you know, I don't know, 10 to the 20 iron
22 atoms per volume, and you gettered one out of the

1 10 to the 20, is that enough? Strictly speaking,
2 yes. But from a practical sense, maybe not.

3 Q Okay. So you never calculated how much
4 impurities would be in the material layer of Li.

5 Correct?

6 A No, those --

7 MS. BÖLL: Object to form.

8 Sorry. Go ahead.

9 A I don't believe those parameters are
10 disclosed in Li, or '315 for that matter.

11 Q And I think you are answering maybe the
12 next question I was going to ask. Which is,
13 correct me if I'm wrong, you did not calculate
14 what the impurities would be in the material layer
15 under your suspicions because you didn't think it
16 relevant to meeting the claims.

17 Is that fair? I don't want to put words
18 in your mouth. Is that fair?

19 MS. BÖLL: Object to form.

20 A I did not calculate the precise numbers.
21 However, given the processing conditions disclosed
22 in Li during the doping step, specifically I

1 believe they use temperatures of 950 C, maybe 975,
2 I can't remember exactly, and when I read that in
3 the context of the processing temperatures
4 disclosed in the art that we cited, such as, you
5 know, Liu 1, Liu 2, I believe it's '315 and Li
6 would inherently getter metallic impurities.

7 Q So just so I got that, because you saw a
8 similarity between the temperature used in the
9 '315 patent and the temperature used in Li, it was
10 your conclusion that gettering would have occurred
11 in Li.

12 Is that right?

13 MS. BÖLL: Object to form.

14 A Yes, the temperatures used in Li for the
15 diffusion purpose are high and either comparable
16 to or higher than those disclosed in, for example,
17 Liu 1, Liu 2. And therefore, in my opinion,
18 gettering must happen in Li. Because temperature
19 is the most important parameter.

20 The gettering process is exponentially
21 dependent on temperature. Because the diffusivity
22 of this metal impurity atoms goes as constant D

1 nought exponential, minus another constant EA,
2 which is known as the activation energy for the
3 diffusion, divided by KT , K being the volts when
4 constant and T being the temperature in kelvin.
5 The temperature is the most important parameter.

6 But then it also depends on the
7 processing time, because that determines what's
8 known as the diffusion length during diffusion,
9 which is the square root of the diffusivity times
10 the time.

11 So temperature is the most important
12 parameter, but time is also important. So given
13 all those, in my opinion Li would inherently
14 getter metal impurities.

15 Q And correct me if I'm wrong, but a
16 premise of your opinion is that Li starts off with
17 impurities in the substrate.

18 Is that right?

19 A Yes. I mean, otherwise there is nothing
20 to getter.

21 Q Would it have been possible to implement
22 Li without impurities in its substrate?

1 MS. BÖLL: Object to form.

2 A When there is no metal impurities to be
3 gettered, I think the question would be pointless.

4 But I believe many of these solar cells
5 from a cost point of view use a form of silicon
6 known as multi-crystalline silicon, which is not
7 single-crystal silicon, but silicon that's made
8 more cheaply than, say, CZ silicon. And those do
9 have metallic impurities in them. I mean, that's
10 the price you pay for the lower cost.

11 I don't remember offhand whether Li
12 discloses multi-crystalline silicon or not, but
13 that was very often what is used for solar cells.

14 Q But if someone with enough money, and
15 maybe more money than sense, wants to implement a
16 super high efficient solar cell whatever the cost,
17 they could implement something with silicon
18 without impurities.

19 Is that right?

20 A No. So if you say silicon with no
21 impurities, that would be impossible, if not
22 practically impossible.

1 Because, you know, there are cleaner ways
2 of making silicon, such as CZ silicon, Czochralski
3 silicon. And even there you get lower levels of
4 impurities, but you still do. And that's governed
5 by dynamics and the concept of segregation into
6 different phases and all that. We can get into
7 those details. I suspect you know that better
8 than I do, since you're a mechanical engineer. So
9 you will not be able to get a silicon crystal with
10 zero impurities.

11 Q Are we talking maybe 2 to the 10, 2 to
12 the 3 per cubic centimeter? That's achievable.

13 Right?

14 A It may be. So there's something of
15 float-zone silicon, which gives you higher purity.
16 Yeah, you could get down to levels low enough that
17 it doesn't matter from a practical point of view
18 in terms of degrading efficiency. But you are not
19 going to get a hundred percent pure silicon.

20 Q I am going to shift to maybe Paragraph 84
21 of your declaration. It begins with a reference
22 to a sink region.

1 Do you see that?

2 A Yes.

3 Q What is a sink?

4 A So this refers to the strain field that I
5 mentioned that's important for gettering.

6 For gettering to occur, you have to have
7 a high-enough temperature to give these metallic
8 impurities enough diffusivity. And you have to
9 diffuse them long enough so that the diffusion
10 length, which is the square root of the
11 diffusivity times the processing time, is
12 comparable to or longer than the dimensions in the
13 base that the impurities have to traverse across.

14 But that's not -- that's a necessary but
15 not a sufficient condition. You need to create a
16 region where you have mechanical strain in the
17 crystal. And some of these metallic impurities
18 are able to sense that strain fields over long
19 distances, over many lattice constants, and that's
20 where they get locked in.

21 It's like, you know, moths flying towards
22 a flame and getting fried.

1 Q So is it kind of a place where impurities
2 would go and collect?

3 A Yes. And they get locked in place so
4 they can't diffuse out back into the substrate.

5 Q The next paragraph, Paragraph 85, which
6 is on Page 32, or at least begins on Page 32, in
7 the first line you reference standard industry
8 practice.

9 Do you see that? I'll go ahead and read
10 a little bit more than that.

11 "In solar cell manufacturing, it was
12 standard industry practice before 2014 to use the
13 dopant diffusion step for simultaneously gettering
14 metal impurities because it was also well known
15 that gettering would occur during the
16 high-temperature formation and doping of emitter
17 regions."

18 Do you see that?

19 A Yes.

20 Q What's the basis for that statement?

21 A The basis for the statement is you want
22 to simplify your manufacturing process. And if we

1 can combine multiple steps and achieve two goals
2 for the price of one, that's always beneficial.

3 And Number 2, suppose I'm doing a
4 diffusion step for the dopants at 950 degrees C,
5 you cannot command the iron atom impurities to
6 stay put. If you heat it up, they are going to
7 diffuse. And if there is a region with high
8 strain, they will inherently get it over there.
9 You can order one species to diffuse, and while
10 the other species are diffusing. It's a function
11 of temperature primarily and then time.

12 Q So I may follow technically what you
13 said. But I guess my question is a little bit
14 more focused on the industry practice aspect of
15 that statement.

16 Did you survey the solar cell
17 manufacturers to ascertain what they were doing
18 before 2014?

19 MS. BÖLL: Object to form.

20 A So at the University of Texas I teach two
21 courses. One is a graduate course on
22 semiconductor processing in general involving

1 transistors -- could apply to solar cells -- where
2 I teach extensively about gettering process and
3 gettering physics. So gettering has been used a
4 long time before 2014 to improve the lifetime of
5 substrates for multiple applications, not just
6 solar cells but also things like bipolar ICs,
7 which the Hu reference discloses. That's Point
8 Number 1.

9 Point Number 2, I did not specifically go
10 into the web pages of the different manufacturers
11 to see what they do vis-à-vis gettering, but they
12 all want to maximize cell efficiency, and
13 gettering would be a very natural thing to do for
14 that aspect.

15 Q Is it also true that certain players in
16 the industry were trying to take steps to minimize
17 the introduction of impurities in the first
18 instance?

19 MS. BÖLL: Object to form.

20 A I mean, of course you'd like to start
21 with as clean of a starting material as possible
22 and have as few impurities.

1 However, you have to do that within the
2 bounds of reasonable cost, as we were discussing
3 before. Because all products are cost-sensitive.
4 But solar cells more so than, for example,
5 computer chips. And with that in mind,
6 multi-crystalline cells which cost less than, say,
7 CZ wafers, were preferred for a long time, and
8 they used to have the dominant market share, I
9 believe circa 2014. I haven't done a survey, so I
10 could be off. And those cells tend to have
11 significant amounts of these metallic impurities,
12 I believe on the order of 10 to the 16 or so.

13 Q All right. Are you aware of any solar
14 cell manufacturing techniques before 2014 in which
15 a gettering step and a emitter region forming step
16 were done separately?

17 MS. BÖLL: Object to form. Object to
18 scope.

19 A I haven't surveyed the processes of
20 different manufacturers.

21 However, as I told you, if one did do an
22 emitter-forming step at typical temperatures, that

1 would necessarily also getter any metallic
2 impurities, assuming those were present.

3 And as I told you, at least in the
4 cheaper wafers such as multi-crystalline cells,
5 which are predominantly used for cell
6 manufacturing, I believe in that time frame those
7 impurities would necessarily get gettered.

8 I mean, you can't command the iron atoms
9 to stay put while I am doing a diffusion of
10 dopants in the emitter at, say, 950 C or 975 C; it
11 will happen. The gettering will happen.

12 Q Okay. I would like to shift forward to
13 Paragraph 89 of your declaration. This is on Page
14 35. It states, "And the iron impurities in
15 multi-crystalline silicon substrates were known to
16 be as high as 10 to the 14 to 10 to the 16 per
17 cubic centimeter in concentration."

18 Do you see that?

19 A Yes.

20 Q And I assume that you are citing that
21 number because you believe it to be quite large.

22 Is that right?

1 MS. BÖLL: Object to form.

2 A Yeah, it's quite large. Yes.

3 Q And if you were aware of a higher number,
4 you probably would have put that in instead in
5 your declaration. Right?

6 MS. BÖLL: Object to form.

7 A I didn't do a search for wafers with
8 higher numbers. These are the typically high
9 numbers that I think I saw for multi-crystalline
10 cells. And they are high enough to have a
11 significant degradation of the bulk recombination
12 over the lifetime.

13 Q Did you do a search for what might be low
14 numbers at, you know, the 2014 time frame?

15 MS. BÖLL: Object to form.

16 A No, I did not do a search.

17 Q I think we agreed that 10 to the 2 or 10
18 to the 3 would have been achievable in 2014.

19 Is that right?

20 MS. BÖLL: Object to form.

21 A No, I don't know if I agree or not. I
22 have not done any analysis of that aspect.

1 Q So you have no reason to dispute that 10
2 to the 2 or 10 to the 3 was achievable in 2014?

3 A Those numbers sound awfully, awfully low.
4 And the reason I say that is, the silicon atomic
5 density is 5 times 10 to the 22 per centimeter
6 cubed. And the reason I remember the number is, I
7 have been teaching this graduate course dealing
8 with the subjects for almost 40 years now.

9 So one part per billion will still be 5
10 times 10 to the 13. One part per million would be
11 5 times 10 to the 16. Achieving even parts per
12 billion is quite challenging. So to go down to 10
13 to the 2, you divide 10 to the 2 by 5 times 10 to
14 the 92, I mean, that's an astronomically small
15 number.

16 So I am not aware of commercial cells
17 with that low level of metallic impurities.

18 Q What is the lowest number you're aware of
19 in the 2014 time frame? I believe you've worked
20 with computer chips as well. What are kind of low
21 achievable numbers in 2014?

22 MS. BÖLL: Object to form. Object to

1 scope.

2 A I don't remember off the top of my head,
3 but I can tell you there is a way of growing
4 silicon using the so-called float-zone technique,
5 FZ silicon, that I think some of the art talks
6 about. Those are the lowest levels that are
7 achievable.

8 But those are so expensive that they're
9 not used for practical solar cells, or in fact for
10 practical integrated circuits. Because although
11 they are very pure, they have other disadvantages.
12 They are mechanically weaker than impure crystals,
13 which is kind of contra-intuitive.

14 Q Do you know offhand what the impurity
15 concentration is in those?

16 A What kind of impurity?

17 Q Well, you've been mentioning 10 to the
18 13, 10 to the 16. I mean, whatever you're
19 referring to when you throw those numbers out.

20 I assume that's atoms of an impurity per
21 cubic centimeter?

22 A Right. So different impurities would

1 have different concentrations depending on what's
2 known as a segregation coefficient of the impurity
3 between different phases.

4 I assume you are talking about iron.
5 Those would be -- 10 to the 13 would generally be
6 a low enough number, I think. Because that's
7 lower than parts per billion levels, where the
8 impact on degradation may not be that strong. But
9 I have not done any analysis of that.

10 Q And these FZs -- excuse me, this FZ
11 silicon that you mentioned, what was the iron
12 concentration in the 2014 time frame, if you
13 recall?

14 A No, I don't recall.

15 Q Do you recall any iron concentration of
16 any, quote/unquote, practical semiconductor device
17 in the 2014 time frame?

18 A I couldn't tell you off the top of my
19 head.

20 Q Do you know if it would be less than 10
21 to the 13?

22 MS. BÖLL: Object to form. Foundation.

1 A I haven't done any analysis or survey.

2 Q Do you think that you were once exposed
3 to those numbers and have just not recalled them,
4 or that you just never -- that you never knew what
5 were iron concentrations in silicon?

6 MS. BÖLL: Object to form.

7 A I have been in the field for 40 years
8 now, and I couldn't even tell you how many papers
9 and patents I have read. So I can't tell you if I
10 have been exposed to those and forgotten those.

11 Q Do you consider impurities in silicon to
12 be an important aspect of semiconductor devices?

13 A Yes.

14 MS. BÖLL: Object to form.

15 A Depending on the type of impurity.
16 Actually, some impurities are actually good. So
17 not all impurities are bad. Some impurities are
18 intentionally introduced.

19 So if you look at boron and phosphorous,
20 they are impurities, but they are beneficial
21 impurities.

22 Q Does the phrase "pure silicon" mean

1 anything to you?

2 A That would depend on the context.

3 Q If I said "I want a wafer of pure
4 silicon," would that mean anything?

5 MS. BÖLL: Object to scope.

6 A That's very context-specific.

7 Q Have you ever used the phrase "pure
8 silicon"?

9 MS. BÖLL: Object to form. Object to
10 scope.

11 A Off the top of my head, I couldn't tell
12 you. I certainly haven't provided any opinions
13 for that in my report.

14 Q Do you recall anyone ever using that
15 phrase, "pure silicon"?

16 A Once again --

17 MS. BÖLL: Object to form. Object to
18 scope.

19 A Once again, I have not opined on that,
20 and I couldn't tell you offhand. It's also
21 context-specific, as I told you.

22 Q Yeah. Well, I mean, if you had, then --

1 if you had heard it that would be a context, the
2 context in which you heard it, so that's why I
3 asked.

4 But it sounds like you have not heard
5 that or you don't recall hearing that.

6 Is that right?

7 A I don't recall whether I have heard it or
8 not.

9 Q I want to shift to Paragraph 107 of your
10 declaration, which starts on Page 41, but I'm more
11 interested in the footnote which is at the bottom
12 of Page 42.

13 Do you see that footnote?

14 A Yes.

15 Q I'm not sure how you pronounce that. Do
16 you know how to pronounce that handbook?

17 A No. Lock, I guess.

18 Q Do you have a copy of that handbook?

19 A Not for the -- not the entire handbook.
20 I don't know if I have a copy of Chapter 7 that
21 was provided.

22 Q No, I'm sorry -- okay. I'll ask a

1 different question.

2 Do you in your office or at your home or
3 anywhere, your lab, wherever, do you have a copy
4 of that handbook?

5 A No.

6 Q There is a mention there of 5 to 15
7 minutes.

8 Do you see that?

9 A Yes.

10 Q Do you believe that a person of ordinary
11 skill in the art, reading Li, would understand
12 that it would have gone -- it would have undergone
13 the processing described in this footnote, i.e.,
14 900 to 950 degrees C at 5 to 15 minutes?

15 A Those are very typical numbers that I use
16 in my research. Also, this course that I
17 mentioned, we have students fabricating devices
18 using this kind of a source, using typical times
19 and temperatures like this. So I'm not surprised.

20 Q And I guess getting back to this person
21 of ordinary skill in the art and Li, would a
22 person of ordinary skill in the art have believed

1 that while Li may not disclose the times at which
2 the emitter regions are formed, it probably would
3 have been 5 to 15 minutes?

4 MS. BÖLL: Object to form.

5 A It probably would have been in that
6 range. So it could be 30 minutes also. But it's
7 not going to be half a minute. It's also not
8 going to be 200 hours.

9 Q Would they have understood, a person of
10 ordinary skill in the art, would they have
11 understood that the emitter region formation most
12 certainly would never have exceeded 30 minutes?

13 MS. BÖLL: Object to form.

14 A No, I cannot guarantee that. Because
15 what's relevant is the diffusion length that I
16 talked about a few minutes earlier.

17 Diffusion length is the average distance
18 that the dopants would diffuse for a particular
19 time/temperature step. And that's given by this
20 parameter square root of DT , where D depends
21 exponentially on temperature.

22 So the dependence of how far they diffuse

1 on average basically varies as a square root of
2 the processing time. So it's not as strong of a
3 dependency as temperature, which is an exponential
4 dependency.

5 So based on my experience in the field,
6 and I believe a POSITA would also know, that in
7 furnace processing at these sorts of temperatures,
8 5 to 15, maybe 30 minutes, maybe an hour, would be
9 quite typical. Once again, you will not process
10 it for a thousand hours.

11 What you need to do is achieve the goal
12 of doping your polysilicon emitter at high enough
13 level completely to achieve low contact resistance
14 and all those things. And in the case of
15 polysilicon, you have the advantage that you have
16 grain boundaries which enhance the diffusivity
17 compared to silicon, single-crystal silicon.

18 So at 5 to 15 minutes sounds quite
19 adequate for that purpose.

20 Q And a person of ordinary skill in the art
21 would not have been motivated to subject the solar
22 cell of Li beyond what was necessary to achieve a

1 functioning emitter. Right?

2 MS. BÖLL: Object to form.

3 A You want enough processing to get the job
4 done. Beyond that you are wasting time and money
5 keeping the furnace hot.

6 Q I want to shift to Paragraph 125 of your
7 declaration. You reproduced a table, this is
8 on -- I want to focus on the latter part of
9 Paragraph 125. So this is going to be at Page 51.
10 You have reproduced a table from ...

11 A Marvin.

12 Q It says Marvin. It also says Exhibit
13 1007, so I need a second. Oh, it's a different
14 Marvin. I see. Okay. Yes. All right. Here,
15 I'll go ahead and circulate that.

16 MR. SNODGRASS: This is Exhibit 1007.

17 (IPR2024-01038 Exhibit 1007, previously
18 marked, and is attached to the transcript.)

19 Q And in the caption there is a reference
20 to 100-suns.

21 Do you see that?

22 A Yes.

1 Q Did that reference to 100-suns impact
2 your analysis?

3 MS. BÖLL: Object to form.

4 A So 100-suns is a concentrator cell. And
5 for the specific optimal parameters would depend
6 on the fact. But here we are looking at the
7 general teaching. And that is, under concentrator
8 conditions we are better off going from a
9 front-surface doping of $5E18$, to a lower doping of
10 $1E18$ that improves end of -- end-of-life
11 efficiency.

12 Q Not only is the doping concentration
13 differing, but the way in which the dopant profile
14 is presented is different.

15 Is that fair?

16 MS. BÖLL: Object to form.

17 Q I am referring to the Graded FSF and the
18 Step FSF columns.

19 A Yes, so the grading is better because
20 that will create this electric field which can
21 repel the minority carriers.

22 Q Better than the step.

1 Is that right?

2 A Yes.

3 Q Do you believe that a solar cell that is
4 in a space environment must endure greater
5 temperature gradients than a solar cell in a
6 terrestrial environment?

7 MS. BÖLL: Object to form.

8 A What temperature gradient are you
9 referring to?

10 Q I'm sorry, I didn't catch that.

11 A What temperature gradient are you
12 referring to?

13 Q Just the extreme, just the expected
14 highest temperature and expected lowest
15 temperature. Gradient may be the -- may be an
16 incorrect or imprecise way of putting it. So I'll
17 ask a different question.

18 Do you believe that a solar cell in a
19 space environment is going to be subjected to a
20 greater temperature difference relative to a solar
21 cell in a terrestrial environment? And by
22 "difference" I mean highest temperature to which

1 it is exposed and lowest temperature to which it
2 is exposed.

3 A So it's, you know, very cold in outer
4 space, of course, much colder than on the earth's
5 surface. So the lower temperatures in space will
6 almost certainly be lower.

7 The highest temperature would depend on
8 whether it's 1-sun or concentrator. Obviously if
9 it's concentrator, you would be hotter. And then
10 how hot it gets would depend on solar parameters.
11 I mean, in space it would cool off radiatively,
12 while on the earth's surface it would cool off
13 more because you have radiative and convective
14 cooling.

15 But it also depends on how the module is
16 made and what the thermal conductivity of the cap
17 on top of the cell is.

18 Q Is that maybe, maybe not, depending on
19 other considerations?

20 A Yeah, you have to give me more specifics
21 to answer that definitively.

22 Q I want to shift to Paragraph 127 of your

1 declaration. In the first sentence there is a
2 reference to Dr. Richard Swanson.

3 Do you know who Dr. Swanson is?

4 A Yeah, I met him. And actually served on
5 him on the advisory board of the Bay Area
6 Photovoltaics Consortium, which is a DOE program
7 out of Berkeley, Stanford, and then many other
8 universities. I was head of the silicon solar
9 cell thrust for the entire U.S. And Dr. Swanson
10 and I were both members of the advisory board.

11 Q And you referenced a statement in
12 Maxeon's complaint in the district court
13 litigation where Maxeon referred to Dr. Swanson
14 as, quote, "the father of solar in the U.S."

15 Do you see that?

16 A Yes.

17 Q Do you believe that Dr. Swanson is the
18 father of solar in the U.S.?

19 MS. BÖLL: Object to scope.

20 A I have no opinion on that. I mean, he
21 did a lot of work on solar, but there are many
22 other people who also did pioneering work.

1 Q So when you go on in your paragraph and
2 you say "in that situation," and you proceed,
3 those aren't opinions that you have. Right? You
4 don't have an opinion on whether it's true or not.

5 Right?

6 MS. BÖLL: Object to form.

7 A Yes, using the precondition that he's
8 regarded as one of the leaders of solar in the
9 U.S.

10 Q Correct me if I'm wrong, I believe you
11 said that a person of ordinary skill in the art,
12 reading Li, would have believed it was directed at
13 a terrestrial solar cell.

14 Is that right?

15 MS. BÖLL: Object to form.

16 A I think I said that Li was silent as to
17 whether it was meant to be used on earth or in
18 space. But I did say that the vast majority of
19 solar cells are used for terrestrial applications.

20 Q Does your Li plus either King or Swanson
21 '352 or Marvin combination, is that specific to
22 terrestrial or space, or is that able to be used

1 in either?

2 A So Swanson '352 and King I think are
3 silent as to whether it's meant for one or the
4 other application. Marvin does talk about space
5 applications. However, as I told you, while the
6 specific parameters vis-à-vis the front-surface
7 doping may depend somewhat on whether it's outer
8 space versus terrestrial or 1-sun versus
9 concentrator, the general teachings do carry over.

10 That's Point Number 1.

11 Point Number 2, I don't refer -- I can
12 look at Swanson, for example, and see they
13 specified whether it's meant for one or the other
14 application. So Swanson '352 looks like it is for
15 concentrators. And most concentrator cells that I
16 am aware of are used for terrestrial applications,
17 not in space. Or they may be contrary examples.
18 But I think having large mirrors and then tracking
19 motors and all, I think it's practical --
20 impractical for outer space. Though I could be
21 wrong. I have not done any search for that
22 matter.

1 And then King, let me look at King. King
2 was the first author, and I believe he was a Ph.D.
3 student of Dr. Swanson at Stanford University. So
4 his study was more of a fundamental study of
5 saturation current and surface recombination
6 velocity and quantum efficiency as it pertains to
7 applications in solar cells. But I don't think
8 they actually made solar cells. But the studies
9 are very relevant for solar cells.

10 Q In constructing your Li plus either King
11 or Swanson '352 or Marvin combination, did you
12 consider whether that combination would be used in
13 a terrestrial environment or in a space
14 environment?

15 A I think the overarching conclusions would
16 be agnostic as to whether it's for one application
17 or the other.

18 Having said that, as I told you, the vast
19 majority of solar cells are for terrestrial. And
20 I believe the vast majority of them do pertain to
21 terrestrial applications, but I think the broad
22 conclusions, I think, with some caveats that we

1 have talked about.

2 Q Did you in arriving at your opinions ever
3 have in your mind an idea as to what this Li plus
4 either King or Swanson '352 or Marvin combination
5 would be?

6 MS. BÖLL: Object to form.

7 A Yeah, so Li was the base reference. And
8 for the challenged claims, it is an IBC cell. So
9 that's why I looked at -- but it was -- I
10 disclosed front-surface doping. The only thing
11 that was missing was concentration of the doping.
12 So I looked at the recited prior art that I
13 mentioned, those are also IBC cells. A POSITA
14 would be motivated to improve the efficiency of
15 these cells. These are all related art. And they
16 would want to look to King, Swanson, Marvin, for
17 guidance as to the right concentration level of
18 around $1E18$ in many cases.

19 Q So you had in your mind some idea as to
20 what this combination would be. It would be the
21 structure of Li with the doping concentration of
22 one of the secondary references.

1 Is that right?

2 A In broad strokes, yes.

3 Q Did you ever think this would be
4 applicable to a terrestrial environment or this
5 would be applicable to a space environment, or did
6 you not think about that aspect of the
7 combination?

8 MS. BÖLL: Object to form.

9 A I think my baseline assumption is it is
10 meant for terrestrial applications, because
11 that's -- that's I dare to say maybe 99 percent of
12 the applications. There are so few solar cells in
13 outer space.

14 And having said that, I think my broad
15 conclusions would apply to both. The specific
16 exact optimal concentrations may be different for
17 one application or the other.

18 Q I want to shift to Paragraphs 145 and 146
19 of your declaration. This is on Page 62.

20 Paragraph 145 begins, "In the solar cell
21 art, emitter usually refers to the doped region
22 that has an opposite dopant polarity as the

1 substrate, while surface field (either back or
2 front) refers to the doped region that has the
3 same dopant polarity as the substrate."

4 Do you see that?

5 A Yes.

6 Q Do you believe that the '315 patent uses
7 the term "emitter" differently than how it's
8 usually used in the field?

9 A Yes and no. So '315 has two emitters
10 disclosed. One of them has the opposite doping
11 type, so that's a conventional meaning of emitter.
12 But then it has a second emitter having the same
13 doping type as the substrate, so that's an
14 unconventional use of the term "emitter."

15 Q So within the context of the patent, a
16 person of ordinary skill in the art would not
17 believe that emitter requires a dopant polarity
18 opposite that of the substrate.

19 Is that right?

20 MS. BÖLL: Object to form. Object to
21 scope.

22 A The usual meaning of an emitter is, it

1 has to have the opposite dopant type as in the
2 substrate. However, in '315, since it has two
3 different emitters of two different doping types,
4 of course one of them has to be opposite, the
5 other one has to be the same type as the substrate
6 doping type. But calling the same doping type in
7 the emitter an emitter, it's an unconventional use
8 of the term. However, I use the plain and
9 ordinary meaning of emitter as disclosed in '315
10 for the purposes of my analysis.

11 Q Which would include a region that has the
12 same polarity as the substrate. Right?

13 MS. BÖLL: Object to form.

14 A That's right.

15 Q Dr. Banerjee, I apologize, did you answer
16 my question?

17 A So one of the emitters will have the same
18 doping type as the substrate, the other one would
19 have the opposite doping type.

20 Q So Claim 10 refers to a first emitter
21 region. Do you have an opinion as to what in Li
22 is the, quote/unquote, first emitter region?

1 A Yes.

2 Q What is that?

3 A So in my report I did a side-by-side
4 comparison of the two. If we look at Paragraph
5 149, that's an example, of my report. I believe
6 Figure 5E is from Li and Figure 5 is from the
7 '315. I colored the two structures to show the
8 one-to-one correspondence. So the greens
9 correspond to the greens and the yellows
10 correspond to the yellows.

11 Q Is the emitter region green or is it
12 yellow?

13 A Let me look at the specs.

14 The first emitter has to be oppositely
15 doped to the substrate because you need a p-n
16 junction. I believe the green is the first
17 emitter and the yellow is the second. But it
18 really doesn't matter, you could always flip it if
19 need be. But let me just look at the text for
20 just a second.

21 Yeah, so if you look at Column 6, Line
22 54, I guess, that talks about a solar cell 300

1 having first and second emitter regions 312 and
2 314. In my report 312 is colored green, that's on
3 the left-hand side of the figure, Figure 5 of
4 '315. And yellow would be your second emitter.
5 And you have first and second emitter, green and
6 yellow, in the Li patent shown in Figure 5E.

7 Q So 514 is the first emitter and 512 is
8 the second emitter, or -- well, strike that.

9 So 514 is the first emitter?

10 A Like I said, in Figure 5 it is called 312
11 and 314. But I think the numbers in other figures
12 kind of correspond to that.

13 In the color figure it's 512 and 514, but
14 that's a slightly different embodiment than the
15 one that I was using. So they have done a nice
16 job of numbering them. So 512 in one of the
17 figures correspond to 312 in the other figure.
18 Similarly, 514 in the color figure corresponds to
19 314 in Figure 5.

20 Q I didn't want to interrupt. Are you
21 finished, Dr. Banerjee?

22 A Yes.

1 Q Did you consider the thermal history of
2 the oxide layer in Li and how that would affect
3 gettering?

4 MS. BÖLL: Object to form.

5 A What do you mean by "thermal history
6 of" --

7 Q The temperatures at which that layer had
8 been subjected to.

9 A After growth or during growth?

10 Q I guess both.

11 Did you consider the temperature at which
12 it was grown?

13 MS. BÖLL: Object to form.

14 A I was primarily looking at the thickness
15 of the oxide, which would depend on the
16 temperature at which was grown and the time for
17 which it was grown. Then after the oxide is grown
18 of course you deposit the polysilicon emitters,
19 and when you drive in the dopants, that's when you
20 are going to getter the impurities both in Li as
21 well as in presumably '315.

22 Q Did Li inform us what the temperature was

1 at which that oxide layer was formed?

2 A Let me look through Li. Just a second
3 here. I know Li disclosed the thickness range,
4 but I don't recall if it disclosed temperature. I
5 don't see any temperatures mentioned in Li, but I
6 do see the thickness mentioned, 1 to 2 nanometers
7 in the embodiment, disclosed in Paragraph 39, for
8 example.

9 Q Did you ever calculate the temperature at
10 which the oxide layer in Li would have been grown?

11 A I did not. But, I mean, I assign these
12 as homework problems to my students. So if you
13 know what the oxidation process is, dry or wet,
14 and if you know what the thickness you want, I can
15 tell you for a certain temperature how long you
16 have to grow the oxide for or vice versa. I mean,
17 these are well-known equations, the Deal-Grove
18 equations. But I did not do the calculation, no.

19 Q Does Li inform you if it's a dry or wet
20 process?

21 A I don't think he does. But a smart
22 POSITA would use a dry process because dry oxides

1 are better than wet, and they grow slower so they
2 are more controllable, get a better interface. So
3 a smart inventor would choose dry, but I don't
4 think Li specifies that.

5 Q Is a smart POSITA something other than a
6 POSITA?

7 A I guess a POSITA, strike "smart."

8 Q Would the process at which an oxide layer
9 is formed affect the diffusivity of that oxide?

10 A It could to some extent. Wet oxides tend
11 to be more -- less tightly bound than dry oxides.
12 So everything else being the same, I would expect
13 higher diffusivity through wet versus dry.

14 Q Could one of skill in the art have used a
15 wet process to form the oxide layer in Li?

16 MS. BÖLL: Object to form.

17 A It could. But as I told you, wet oxides
18 tend to grow much faster than dry, and they tend
19 to be inferior in quality. So to grow tunnel
20 oxides one would generally use a dry oxidation
21 process so that they have control over these very
22 small thicknesses, 1 to 2 nanometers. Because

1 remember you have to be able to tunnel the
2 carriers through them and you want a high-quality
3 interface. So both of those would direct a POSITA
4 towards using a dry rather than a wet oxide.

5 Q Would it have been possible to grow an
6 oxide layer thicker than 1 to 2 nanometers and
7 then process it down to that thickness?

8 MS. BÖLL: Object to form.

9 A It could, but that seems like a silly way
10 of doing things.

11 Q So you're saying as a homework assignment
12 you could give your students the desired thickness
13 and wet or dry, and they would tell you what the
14 proper temperature was.

15 Is that right?

16 A So there are two parameters, temperature
17 and time. You'd need to give them one to
18 calculate the other.

19 Q So if you did it, two students could come
20 back and say here is a temperature and here is a
21 time, another student could say here is a
22 different temperature with a different time.

1 Right?

2 A Yes.

3 Q Would those two different sets of
4 parameters impact the diffusivity of the oxide
5 layer?

6 MS. BÖLL: Object to form.

7 A Are you talking about diffusivity of the
8 metal impurities through the oxide?

9 Q Yes.

10 A So in general higher temperatures would
11 allow more diffusion of the metal purities. But
12 remember, at this stage you still don't have the
13 highly doped polysilicon on top of the oxide. So
14 you are giving the metal impurities maybe high
15 diffusivity at a high oxidation temperature, but
16 you still haven't provided the sink. And you need
17 both to perform gettering.

18 Q So what about -- so different question.
19 So what about the diffusivity of the
20 oxide for a later gettering process?

21 In other words, if I grow that same oxide
22 layer, same thickness both under dry conditions,

1 but I do one at a certain temperature and a
2 certain time, I do another one at a different
3 temperature and a different time, later on I'm
4 going to do a gettering step, will the gettering
5 be different in those two scenarios?

6 MS. BÖLL: Object to form.

7 A I haven't opined on those aspects, but I
8 would not expect any differences. Because the
9 diffusivity would depend on how dense those oxides
10 are, and there is a difference between wet versus
11 dry. There isn't that much difference between a
12 dry oxide grown at different temperatures. But I
13 haven't really analyzed those aspects, and I have
14 not opined on those issues in my report.

15 Q So after the oxide layer is formed, it
16 can be subjected to temperatures for various
17 reasons. Right?

18 A Yes.

19 Q Will those impact its ability to getter?

20 A What's ability to getter?

21 Q I am using that as I guess a more easy
22 way to say diffusivity, which I am having trouble

1 with.

2 Does that concept make sense to you?

3 A No.

4 Q The diffusivity is the ability of a
5 material to allow something to pass through it.

6 Is that a proper understanding of
7 diffusivity?

8 A Diffusivity is the ability of atoms to
9 move at a certain temperature if there is a
10 concentration gradient. So you need a
11 concentration gradient for stuff to diffuse. But
12 you also need high-enough temperature so that the
13 atoms have enough kinetic energy so that they can
14 move statistically from high to low concentration
15 regions.

16 Q Will subjecting an oxide layer to a
17 temperature for a period of time affect its
18 diffusivity?

19 MS. BÖLL: Object to form.

20 A I don't quite understand your question.

21 Q The oxide layer in Li has a diffusivity
22 value, does it not?

1 A You are talking about the diffusivity of
2 metal impurities through that oxide, is that what
3 you're talking about?

4 Q Yes.

5 A Yes, it will have a certain diffusivity
6 depending on the temperature.

7 Q Will that diffusivity also depend on
8 prior thermal processes to which that oxide layer
9 was subjected?

10 A I haven't opined on those, but in broad
11 strokes it could. Denser oxides tend to be --
12 tend to have a lower diffusivity than a looser
13 oxide structure such as the wet oxides.

14 MR. SNODGRASS: Now is a decent time to
15 break, if it works for you guys.

16 THE WITNESS: Yes, yes.

17 MR. SNODGRASS: Let's go off the record.

18 (A recess was taken.)

19 BY MR. SNODGRASS:

20 Q Dr. Banerjee, please feel free to raise
21 your hand and ask for a break at any time. I
22 didn't mean to take you longer than you cared to

1 go.

2 A No, no. No problem.

3 Q I want to talk a little bit further about
4 diffusion. I want to talk about diffusion across
5 interfaces.

6 Do you agree that the quality of the
7 interface between a silicon substrate and an oxide
8 layer over that substrate will impact diffusion?

9 MS. BÖLL: Object to form.

10 A Quality of the interface between the
11 oxide and the substrate will impact diffusion of
12 the metallic impurities through the oxide?

13 Q The metallic impurities into the oxide in
14 the first instance.

15 A Okay. So as I have told you before, the
16 concentration of impurities between two dissimilar
17 materials are phases. Depends on something known
18 as the segregation coefficient, which is dependent
19 on the material combinations and the impurity
20 impression.

21 So depending on the impurity, some of
22 them may pile up at the oxide-silicon interface or

1 the oxide-polysilicon interface, but the
2 diffusivity of the impurities through the oxide
3 would primarily be dependent on the temperature,
4 because that is an exponential dependence on
5 temperature, as I mentioned before. And
6 secondarily on the time. Because there is a
7 square root dependence on the time. But it also
8 depends on the way the oxide was grown vis-à-vis
9 the density of the oxide, whether it's dry or wet.

10 But the most important parameter is
11 temperature, that's a dominant thing.

12 Q So I just want to make sure I am using
13 the terminology the way it should be used.

14 You talk about pile-up. Would pile-up be
15 an inhibition to diffusion?

16 MS. BÖLL: Object to form.

17 A Well, arguably you do want the impurities
18 to pile up in this case in the polysilicon and be
19 stuck there. However, a few of the impurities may
20 pile up in the interfacial layer and, therefore,
21 not be able to go through the oxide into the doped
22 polysilicon.

1 But the data that we found in, for
2 example, Liu 1 and Liu 2, tells us that that's not
3 a significant issue at all. I mean, I can look at
4 Liu 1, Liu 2. It seems to go right through the
5 oxide of thicknesses in the range that you are
6 talking about, 1 to 2 nanometers, at the
7 temperatures we are talking about, 950 degrees C
8 or so, as disclosed by Li.

9 So the metallic impurities could
10 inherently go through that kind of an oxide at
11 that sort of a temperature and be gettered or, if
12 you will, pile up in the polysilicon doped
13 emitter.

14 Q We don't know anything about the oxide of
15 Liu 1 or Liu 2, the temperature at which it was
16 formed, the quality of the surfaces. Right?

17 MS. BÖLL: Object to form.

18 A If you give me Liu 1 and Liu 2.

19 Q Sure.

20 A Which exhibit?

21 Q Liu 1 is Exhibit 1028.

22 (IPR2024-01038 Exhibit 1028, previously

1 marked, and is attached to the transcript.)

2 Q Exhibit 1029 is Liu 2. I'm going to
3 circulate them.

4 (IPR2024-01038 Exhibit 1029, previously
5 marked, and is attached to the transcript.)

6 A Is it in the other file? Maybe it is in
7 the other file.

8 Q They are not hard copies, Dr. Banerjee,
9 that we supplied.

10 A Oh, okay. Let me look at my report,
11 then.

12 MS. BÖLL: And there are copies it looks
13 like Mr. Snodgrass is dropping into the chat if
14 you want to look at them electronically.

15 THE WITNESS: Oh, okay. Let me do that.

16 A I just downloaded them on my desktop. I
17 can take a quick look at it.

18 I downloaded the wrong documents. What
19 are the numbers? I'm sorry.

20 Q The exhibit numbers are --

21 A No. What did you put it in as the chat?
22 Oh, the very latest ones. Right? The two latest

1 ones?

2 Q Yes.

3 A Yeah. Okay. Sorry. So looking at I
4 guess Liu 1, I think, it says over here they grew
5 an oxide of 1.3 to 1.4 nanometers, and this says
6 there is grown a chemical oxide, so they dip it in
7 nitric acid in 90 degrees, nitric acid is a strong
8 oxidizing agent, so that will be what in my other
9 report I called a chemox. Okay.

10 But remember, in our -- in our analysis
11 we looked at Liu in view of Ramappa, I believe.
12 And Ramappa shows that even for much, much thicker
13 oxides, iron on the surface is able to diffuse
14 through. So certainly for 1 to 2 nanometers it
15 will go through the oxide like a hot knife through
16 butter, there will be no problems at all. And
17 then furthermore, with Liu chemical oxide being
18 chemically grown, it's going to be more porous
19 than a thermally grown oxide. So if anything, the
20 diffusivity of the iron through that would be a
21 little bit higher. Not a whole lot higher, but a
22 little bit higher.

1 Q Were you referencing any particular
2 portion of Liu 1 in your prior answer?

3 A I was looking at Page 2276, the second
4 column. If you look at the first paragraph,
5 around the fifth or sixth line, it talks about how
6 the oxide is grown on the silicon wafers via
7 immersion in nitric acid to 90 degrees centigrade
8 for 30 minutes, resulting in an oxide of 1.3 to
9 1.4 nanometers.

10 Do you see that?

11 Q How does that process relate to the
12 process that the oxide layer in Li is grown?

13 MS. BÖLL: Object to form.

14 A I believe Li was silent as to how the
15 oxide was grown. I think it just mentioned a
16 range of oxide thicknesses, a 1 to 2 nanometers,
17 which is right in the range of the thicknesses
18 mentioned by Liu.

19 There is also Liu 2, I don't know if that
20 has a different description. Let me quickly
21 download that. Did you upload Liu 2 also?

22 Q Yes, it should be the most -- the one at

1 the very bottom, I think.

2 A Yeah, let me see. It is the same set of
3 authors, so it is probably similar conditions.

4 Great. In Liu 2 is even better. It does
5 a comparison of this chemical oxide that I
6 mentioned in the previous paper, but it also
7 studies thermal oxide 1.3 nanometers and a thermal
8 oxide of 4 nanometers.

9 So assuming for argument's sake that Li
10 was talking about a thermal oxide, Liu 2
11 corresponds to that.

12 Q And I guess at the end of the day we just
13 don't know what process Li used to grow the oxide.
14 Right? Whether either of these disclosed
15 processes or something different. Right?

16 MS. BÖLL: Object to form.

17 A Well, Li doesn't, but there's only a
18 finite number of ways of growing this oxide. So
19 it's not as if there are an infinite number of
20 techniques. Right? So chemical versus thermal at
21 two of the dominant base. And looking at Figure 3
22 of Liu 2, I see that regardless of the thickness

1 of the oxide and how it's grown, they're all
2 effective in terms of causing a certain degree of
3 gettering.

4 Because the starting value of the iron is
5 what they are calling 100 percent on the
6 right-hand figure, I believe is 10 to the 13. And
7 you'll notice that after any degree of thermal
8 processing, regardless of the temperature,
9 regardless of the thickness of the oxide,
10 regardless of whether it's thermal or chemox, the
11 histograms always have a lower height than hundred
12 percent. So in the best-case scenario, and they
13 go down to, what, .05 percent or so maybe, and
14 even in the worst case it goes down to
15 approximately, what, 60 percent perhaps.

16 So even in the worst case there is, you
17 know, 40 to 50 percent gettering.

18 And remember, the '315 patent is silent
19 as to the degree of gettering required. So any
20 degree of gettering, in my opinion, would meet the
21 claims.

22 Now, yeah, I'm not even taking an extreme

1 position as, you know, 1 atom being gettered
2 suffices. You're talking about significant
3 percentages, right, 30, 40, 50 percent, or more.

4 Q When you say "getter" in your answer, are
5 you referring to the transmission of an impurity
6 from the substrate through the oxide layer into
7 the material layer of Li?

8 A Yes. Because Liu has this oxide
9 intervening between the substrate and the
10 phosphorus or boron-doped polysilicon.

11 Q It doesn't measure the concentration of
12 the impurities in the polysilicon, though, does
13 it? "It" being Liu.

14 A Yeah, I understand.

15 I don't know if it does. But whatever it
16 is, it's showing effective gettering, that's Point
17 Number 1. And Point Number 2, there is something
18 known as a solid -- solubility limit of dopants.
19 So for boron it's 10 to the 20 per centimeter
20 cubed. For phosphorous it's 10 to the 21.

21 And depending on how they are doing the
22 diffusion, which is described on Page 137, I don't

1 know if it's Liu 1 or Liu 2. This one is Liu 2.
2 Okay. They are doing POCl diffusion for the
3 phosphorus and boron tribromide, and they have
4 given some temperatures, for 40 minutes.

5 So under these conditions one could
6 typically get these high concentrations near the
7 solid solubility. And that's, in fact, what Li
8 and the others would also use, for a different
9 reason.

10 Because remember, these poly emitters are
11 then contacted with metal contact. And you want
12 the resistance of these poly emitter to be as low
13 as possible, because that impacts the series
14 resistance of the solar cell.

15 And if the doping in the poly emitter was
16 not high enough, the internal resistance of the
17 cell would be too high, and that would degrade
18 something known as the fill factor of the cell,
19 which in turn would degrade efficiency of the
20 cell.

21 So all of that would lead one to use a
22 poly emitter with high doping to achieve the low

1 resistance. Which in turn will give you the
2 strain in the poly emitter. Which in turn will
3 inherently lead to gettering of the iron under
4 these conditions. It all fits together nicely.

5 Q And earlier you were looking at Figure 3
6 of Exhibit 1029. Correct?

7 A Yes, that's Liu 2. Right? Yeah.

8 Q Yes. And when you were referencing the
9 percentage of the impurity that remains in the
10 substrate you were referencing the bars on this
11 figure here?

12 A Yes.

13 Q And in your opinion, even on the far
14 right of the first graph where at least under the
15 890 degree condition there is still half of the
16 impurities in the substrate, you think that's
17 effective gettering.

18 Is that right?

19 A Whether it is effective or not, I mean,
20 the '315 patent is silent as to that. Right? I
21 mean, '315 mentions gettering. And my position
22 is, you know, certainly 50 percent gettering

1 indicates inherence of this gettering process at
2 these temperatures.

3 Q Do you know how much of the -- with
4 reference to Figure 3, how much of the impurities
5 have been trapped at the interfaces?

6 A Let me see. For that you need the
7 profiles. Let's see.

8 For that one I would like to look at the
9 other Liu, which is Liu 1. Liu 1 has data about
10 the concentration profiles.

11 So, for example, in the figure on the
12 abstract, right, they show these concentrations is
13 a function of depth. And these are measured by
14 techniques known as SIMS that I have been using
15 ever since grad school.

16 So what you do here is you integrate the
17 concentration as a function of depth, to get the
18 total concentration. So you can see in this case
19 that, you know, in the substrate it's dropped down
20 by orders of magnitude.

21 So I can basically multiply the
22 concentration by the thickness of the polysilicon.

1 So this is, what, about 150 angstroms -- 150
2 nanometers, times roughly, what, 10 to the 17th
3 per centimeter cubed. So you convert nanometers
4 to centimeter cubed. It is a trivial calculation
5 to get the amount that's locked up in the
6 polysilicon. And you can do similar calculations
7 for the boron.

8 Q Do you see in that figure that you were
9 just referencing there is the detection limit?

10 A Yes.

11 Q Do you see that?

12 Is that in reference to the dashed
13 horizontal line at 5 times 10 to the 15th?

14 A Yes.

15 Q And what does that mean?

16 A So when you do these measurements, I
17 think that it seems -- yeah, they use SIMS. Like
18 I said, I've been using that for 40 years. So you
19 shoot a primary ion beam of either oxygen or
20 cesium at the target. This iron-contaminated
21 silicon will eject, through a process called
22 sputtering, atoms of iron and atoms of the

1 silicon.

2 And then you ionize them and you pass
3 them through what is called a mass spectrometer,
4 which is basically across magnetic field. The
5 Lorentz force will cause those ions to bend to
6 different degrees, depending on how heavy they
7 are. Heavier ions will bend less, lighter ions
8 will bend more.

9 You have a detector, which then does a
10 count of the ions so you can keep track of the
11 number -- in this case I would be monitoring the
12 iron. And keep count of the iron count as a
13 function of the sputtering time. Then after the
14 measurement is done, you measure the sputter
15 depth. That's how you get the depth information.

16 So this methodology, I think like all
17 techniques, has a detection limit before
18 signal-to-noise kicks in. So in this case it's
19 about maybe 10 to the 15th, I guess.

20 Q So it would be unable to detect the
21 presence of impurities in a concentration less
22 than 5 times 10 to the 15th?

1 A Right. In this particular case, yes.

2 Q Okay.

3 A But there are other techniques also that
4 Liu doesn't discuss which has lower detection
5 limits.

6 Q I want to go to Paragraph 169 of your
7 declaration. I want to focus on the second
8 sentence which joins Pages 73 and 74. It says,
9 "In my opinion, it would have been obvious to the
10 skilled artisan to combine the two heating steps
11 of Li to a single heating step for both the doping
12 of the front and back sides of the solar cell."

13 Do you see that?

14 A Yes.

15 Q How does that assertion impact your
16 opinions? In other words, are your opinions
17 premised on that modification of Li?

18 MS. BÖLL: Object to form.

19 A No, they are not premised on that.

20 Q So whether or not the Board accepts that
21 contention doesn't really impact the obviousness
22 analysis, does it?

1 MS. BÖLL: Objection.

2 A What matters is the thermal processing
3 steps that a wafer sees once the iron is in place,
4 which in this case is right from the get-go.

5 Now, whether those thermal processing
6 steps are a single step or a two step, it doesn't
7 really matter.

8 Q And in Li there are I think at least two
9 thermal processes. Correct? I mean, you say
10 combined the two heating steps of Li.

11 A Yeah, it looks like it, yeah. Yeah. But
12 it's irrelevant.

13 Q So if it was one step, as you suggest is
14 obvious, it wouldn't really impact Li. Right?

15 A As long as the temperature was high
16 enough, that's the most critical parameter.

17 Q Perhaps it does impact whether diffusion
18 masks would be required. Right? Because later in
19 that paragraph you talk about diffusion masks?

20 MS. BÖLL: Object to form.

21 A Yeah, so here I am talking about blocking
22 the diffusion of the dopants. So that is the

1 same. So now you look at the diffusivity of the
2 dopant species in the mask material. You have an
3 average depth to which they are diffusing the mask
4 material, the so-called diffusion length. And you
5 typically design the mask thickness to be at least
6 three to five times thicker than the diffusion
7 length so that they don't penetrate through into
8 the substrate. Those are the typical design
9 parameters.

10 Q Adding in a diffusion mask would
11 complicate the process, right, and increase cost.

12 Is that fair? I mean, there are process
13 steps that need to be taken to put a mask on and
14 to take a mask off. Correct?

15 A Yes. But these are, you know, fairly
16 routine, fairly simple steps. There are certain
17 steps in manufacturing which are very expensive
18 and time-consuming, certain steps are very simple.
19 And these are simple process steps.

20 Q Does applying a mask and taking a mask
21 off introduce the opportunity for lift-off?

22 MS. BÖLL: Object to form.

1 A Lift-off of what layer are you talking
2 about?

3 Q Any layer. Wherever you're wanting to
4 put the mask on, which I'm not sure where that is.

5 A I mean, generally you could do wet
6 chemical etching to lift off the -- to etch the
7 mask. It could in some circumstances cause
8 lift-off. If you etch the mask with a dry
9 plasma-based etch, lift-off is generally not an
10 issue.

11 MR. SNODGRASS: I have dropped Exhibit
12 1017. This is Hu, H-U. This should be in your
13 binder as well, Dr. Banerjee.

14 (IPR2024-01038 Exhibit 1017, previously
15 marked, and is attached to the transcript.)

16 A Yes, I have it.

17 Q And I hit send. All right.

18 You agree with me that Hu discloses an
19 oxide layer acting as a barrier to gettering.

20 Correct?

21 MS. BÖLL: Object to form.

22 A Hu discloses two different oxide

1 thicknesses. And I am looking at the figure on
2 the cover. And in Region 2 they have a thick
3 oxide 54 which under these conditions appears to
4 block gettering.

5 Q Do you know what the thickness is in that
6 layer, of that layer, excuse me?

7 A Yeah. It says in Column 8, Line 27, that
8 they're growing 2700 angstroms of silicon dioxide
9 on both sides of the wafer. And then for the test
10 structure shown on the cover page they etched off
11 half of the oxide, that would correspond to your
12 Region 1 of the figure on the cover page, where
13 they retained it in the other half, which would
14 correspond to Region 2. So that's Layer 54. So
15 that will be 2700 angstroms thick.

16 I mean, I noted in passing that even in
17 Region 1, even though they etched off the oxide,
18 when you subsequently deposit the polysilicon,
19 it's very common to regrow an interfacial oxide as
20 Gan disclosed. I guess that was in our other
21 declaration. But anyway, you likely have a very
22 thin, 1 to 2 nanometers interfacial oxide even in

1 that region. And that clearly did not block the
2 gettering.

3 Q Ramappa, you referenced Ramappa earlier.
4 I'll drop this in.

5 (IPR2024-01038 Exhibit 1025, previously
6 marked, and is attached to the transcript.)

7 Q This should be in your binder,
8 Dr. Banerjee.

9 A Yes.

10 Q This is Exhibit 1025.

11 And I believe you reproduced one of the
12 figures of Ramappa and drew a vertical red line
13 maybe at the bottom of Paragraph 161 of your
14 declaration. So this will be Figure 1 of Ramappa.
15 So if we could, Dr. Banerjee, either reference
16 Paragraph 161 of your declaration or Figure 1 of
17 Ramappa.

18 If I understand correctly, you have drawn
19 a line at approximately the thickness of the oxide
20 layer in Li.

21 Is that right?

22 A Yes.

1 Q And because we don't see -- I guess
2 because we see perhaps modest decreases in the
3 iron concentration, it's your opinion that that
4 means gettering would occur from the substrate to
5 the material layer of Li.

6 Is that right?

7 A No. The teaching of this figure is to
8 show the very high diffusivity of iron through
9 oxide, even at temperatures as low as 900 degrees
10 centigrade. At 1100 the diffusivity is even
11 higher. So high, in fact, that it diffuses
12 straight through, like my old analogy, super hot
13 knife through butter. And then it's getting
14 blocked by the silicon substrate, that's through
15 the segregation coefficient of iron between oxide
16 and single-crystal silicon. Undoped silicon I
17 guess in this case.

18 So the point being, if it was a
19 2-nanometer type of oxide as shown by this
20 vertical red line, red line, the oxide would
21 hardly present any barrier at all.

22 So if on the -- so to put this in context

1 of Li and others, the iron would not be present on
2 the top surface of this oxide; it would actually
3 be present in the silicon, because that's what I
4 am trying to getter. And then on the left-hand
5 side of this figure you would be depositing a
6 doped polysilicon as shown in Liu 1, Liu 2, for
7 example.

8 And then the impurities, the iron
9 impurities in the single-crystal silicon shown on
10 the right would go straight, diffuse straight
11 through to the oxide, and then gettered in the
12 polysilicon on the left-hand side.

13 Now, Ramappa doesn't show that
14 polysilicon gettering process. We are only using
15 Ramappa to show the very high diffusivity of iron
16 in oxide.

17 Q In your review of Ramappa, did you find
18 it to be technically sound?

19 A Yes.

20 Q So there's other portions of Ramappa. I
21 want to focus on a passage at the right-hand
22 column of Page 3775. This is the second sentence

1 of that first paragraph. It begins, "The silicon
2 dioxide-silicon interface."

3 Do you see that?

4 A I am on Page 3775. The first column or
5 the second column?

6 Q Second column, right-hand column.

7 A Okay.

8 Q Second sentence. "The silicon
9 dioxide-silicon interface" --

10 A Yes, I see that now.

11 Q "The silicon dioxide-silicon interface is
12 known to act as a sink for impurities."

13 Do you see that?

14 A Yes.

15 Q Do you agree?

16 A As I told you before, there could be a
17 certain level of dopant pile up at that interface
18 also.

19 Q And then in Figure 5 on Page 3776, there
20 is a figure that shows the degree to which that
21 interface can act as a sink. We have iron
22 concentrations greater than 10 to the 19th in the

1 silicon dioxide, and we have concentrations below
2 10 to the 14th in the silicon. Right?

3 Do you see that?

4 A Right. Yes.

5 Q So that's an order of -- that's, like,
6 five orders of magnitude difference. Right?

7 A Yes.

8 MS. BÖLL: Object to form.

9 Q And do you have any reason to doubt the
10 accuracy of Figure 5?

11 A No. But I think you are misinterpreting
12 what the teaching is.

13 So what this shows is between silicon
14 dioxide and single-crystal undoped, low-doped
15 silicon, the iron prefers to be in the silicon
16 dioxide. But that's not the right teaching from
17 this. So if you had a highly doped polysilicon in
18 proximity to the oxide, that creates even more
19 strain, and then the doped polysilicon would suck
20 up the impurities from the single-crystal silicon,
21 through the oxide, into the doped polysilicon.
22 That's taught by Liu 1, Liu 2.

1 Q Your contention is that if you were to
2 add a polysilicon layer on top of the oxide layer,
3 that you would not see the interface between the
4 silicon and the oxide acting as a sink?

5 MS. BÖLL: Object to form.

6 A You compare -- you are comparing apples
7 to oranges, if I may.

8 Q I'm just asking what your contention was.

9 A The contention is the iron tends to be
10 and be locked in the location where there is a
11 high degree of strain. And doped polysilicon
12 provides a high degree of strain, unlike
13 single-crystal silicon.

14 So if you have such layers in the
15 structure, as in Liu 1, Liu 2, or as in Li or as
16 in '315, that will be the preferred sink of the
17 iron.

18 Q So the iron would -- would the iron go
19 around the silicon oxide-silicon interface to get
20 to the polysilicon?

21 A It would go through, it would diffuse
22 through. And that's what Figure 1 -- that's what

1 Figure 1 of Ramappa is showing. Okay?

2 So --

3 Q You said the sink is where it traps
4 impurities and the impurities can't leave.

5 Did I misunderstand the concept of a
6 sink?

7 A No, that is a sink.

8 Q Okay.

9 A So if you want to combine, if you will,
10 Figure 1, the teachings of Figure 1 and Figure 5,
11 in the context of Li, Liu 1, Liu 2, you have to
12 think of on the left-hand side of the oxide this
13 doped polysilicon layer which corresponds to the
14 structures in Li '315, Liu 1, Liu 2. And then you
15 start with the doping of -- you start with the
16 concentration of iron in the single-crystal
17 silicon. Are you with me so far?

18 Q Yes.

19 A And there is no iron to begin with in the
20 oxide or in the polysilicon. Then you do the heat
21 treatment. So now diffusion always happens from
22 high-concentration region to low-concentration

1 region. So assume that the single-crystal silicon
2 that I can cite had an iron concentration of, say,
3 10 to the 15 or 10 to the 16, as discussed in some
4 of the other art. There is a concentration
5 gradient of the iron to the left. And Ramappa
6 teaches us that you have no difficulty at these
7 temperatures to diffuse from the
8 high-concentration region of iron in the
9 single-crystal silicon through this oxide, even
10 for this thicker oxide, and certainly through 1-
11 to 2-nanometer oxide. And then it will go into
12 the polysilicon, which would be deposited on top
13 of the oxide, in this figure it would be on the
14 left of the oxide. And that's where it gets
15 stuck.

16 Q But to borrow a phrase I think you have
17 used, the iron would go through the silicon
18 oxide-silicon interface like a hot knife through
19 butter. Right? I think --

20 A It was initially in the silicon. Right?
21 That's what it started out with. Are we straight
22 with that?

1 Q Not in Ramappa. But in your
2 understanding of Li, I understand that's your
3 contention, yes.

4 A Right. Actually, in all the solar cell
5 products, you start with this generally
6 multi-crystalline silicon, so that's the structure
7 on the right-hand side of Figure 5 of Ramappa. I
8 agree, Ramappa is not a solar cell. But that's
9 not the issue. Right?

10 So the single-crystal silicon starts with
11 the starting iron contamination level that I am
12 trying to get rid of, right, through this
13 gettering process.

14 And then if I grow the oxide and deposit
15 doped polysilicon, this doped polysilicon on the
16 left-hand side would attract the iron from the
17 silicon, through the thin oxide, into the
18 polysilicon.

19 To use my other analogy, these are these
20 moths flying left towards the flame and getting
21 cooked there.

22 Q But Ramappa says that there is a sink

1 that those moths go into between where you want
2 them to start and where you want them to end.

3 Do you agree with that?

4 MS. BÖLL: Object to form.

5 A You're confusing the issue, I think.

6 So any time you have two different
7 materials in contact and you heat it up, there is
8 a preference of an impurity, in this case the
9 iron, to be in one or the other. Okay?

10 So here Ramappa doesn't even show a doped
11 polysilicon layer. That's shown in Liu 1, Liu 2.
12 So had that been present, reading Ramappa in terms
13 of the diffusivity of the iron through the oxide,
14 under the rubric of Liu 1, Liu 2 would tell a
15 POSITA that the starting iron in the
16 single-crystal silicon would diffuse straight
17 through, through 1 to 2 nanometer of silicon
18 dioxide and is sunk in the polysilicon on the
19 left.

20 Q So you agree with me that if we don't
21 have a polysilicon layer in Ramappa, we have a
22 sink between the silicon and the oxide layer.

1 Right? Ramappa says that. Right?

2 MS. BÖLL: Object to form.

3 A If you didn't have a sink -- if you
4 didn't have a polysilicon layer in Ramappa, that's
5 different from the structures in '315, Li, Liu 1,
6 Liu 2. So that comparison is a false analogy, in
7 my opinion.

8 Q Okay. Well, Ramappa is your reference,
9 Dr. Banerjee. So, you know, you want to say it's
10 irrelevant, that's fine. I mean, you rely on it?

11 A I did not say it is irrelevant. Ramappa
12 is very relevant in showing the high diffusivity
13 of iron through oxide, that's what you glean from
14 Ramappa. Okay?

15 Q I glean something else. Am I fair to
16 glean something else, that Ramappa teaches a sink
17 between the silicon and the oxide layer, or is
18 that an unfair reading of Ramappa?

19 MS. BÖLL: Object to form.

20 Q And I will remind you, the silicon
21 oxide-silicon interface is known to act as a sink
22 for impurities.

1 A Yes. But this is only in the absence of
2 any doped polysilicon. Okay?

3 Q So that's my question. Is it your
4 contention that once you put a polysilicon layer
5 on the other side of the oxide layer, that the
6 silicon-oxide interface no longer is a sink?

7 A There may be some iron stuck over there,
8 but it does not preclude a significant portion of
9 the iron to diffuse through the oxide and be sunk
10 in the doped polysilicon.

11 And remember, the claims are silent as to
12 the level of segregation. Okay? So the essential
13 point that we made is, there will be some
14 segregation of iron impurities in the doped
15 polysilicon emitter. That's the essential
16 teaching. And that's what's required from the
17 claims.

18 There's no discussion in the claims about
19 the percentage of gettering. So there may be some
20 iron still stuck at the oxide single-crystal
21 silicon interface, but that does not change the
22 fact that there will also be iron getter in the

1 doped polysilicon. Okay?

2 And as long as that happens, as taught by
3 Liu 1, Liu 2, with the background of Ramappa in
4 terms of the diffusivity of iron in the oxide at
5 the back of our mind, there has to be gettering of
6 iron in the doped polysilicon layer as described
7 by Liu 1 and Liu 2, and also as disclosed by Li
8 and '315. Over there they don't go into the
9 specifics of the degree of gettering.

10 Q So you're not contenting that once you
11 put a polysilicon layer over an oxide layer, that
12 through some process unknown to me, that would
13 somehow reduce the impact that the interface has
14 as a sink, the interface being the oxide-silicon
15 interface.

16 MS. BÖLL: Object to form.

17 Q Right?

18 A My contention is even in that scenario
19 when you have doped polysilicon on top of oxide,
20 on top of single-crystal silicon, even if there is
21 some iron pile-up at the oxide single-crystal
22 silicon interface, it will not stop from at least

1 some iron diffusing through the oxide and the
2 getter in the doped polysilicon, and that's all
3 the claims of '315 require. Because there is no
4 degree of gettering in the polysilicon that's
5 necessary.

6 In fact, if you look at the figures in
7 '315 where the impurities are shown by these
8 crosses, you will notice that they show, even
9 after the gettering process, they show some
10 crosses left behind in the single-crystal silicon
11 substrate. Right? So even '315 isn't claiming
12 that they are getting rid of all the iron.

13 Similarly, there may be some iron stuck
14 at the interface between the single-crystal
15 silicon and silicon dioxide as shown in Ramappa.
16 But that does not change the fact that some iron,
17 in fact a significant portion of the iron at these
18 processing temperatures, goes straight through the
19 oxide, certainly at 1- to 2-nanometer thicknesses,
20 and be gettered in the doped polysilicon. I mean,
21 that's the essence of that argument.

22 Q Yeah, I understand what you're saying.

1 It's unclear to me, though, if you are contending
2 that your conclusion is based on this idea that
3 once you put a polysilicon layer, it will suck
4 iron through what is otherwise a sink? I believe
5 you used the term "suck." And I understand that
6 to mean that it is -- that the presence of the
7 polysilicon is actually creating some differential
8 that is causing the dopant concentration to --
9 excuse me, the dopant differential to be different
10 than it otherwise would be, differential between
11 one side of the oxide and the other side -- and
12 the other side being the substrate?

13 A That is --

14 MS. BÖLL: Objection.

15 THE WITNESS: Sorry.

16 A That is right.

17 Q So you are taking that position, that the
18 presence of the polysilicon is going to impact the
19 differential across the sink of the silicon and
20 the oxide?

21 MS. BÖLL: Object to form.

22 A Presence of doped polysilicon, doping is

1 necessary also because it's a doping by the
2 smaller size dopant atoms, which create the strain
3 fields in the polysilicon.

4 And yes, once you have those strain
5 fields and a high-enough temperature where the
6 iron has enough diffusivity, it will suck the iron
7 out of the single-crystal silicon where the iron
8 initially was, through the intervening oxide, into
9 the doped polysilicon, and then get locked into
10 the strain fields. I mean, that's how gettering
11 works.

12 Q It seems to me that it would depend --
13 the degree of the phenomenon that you're
14 describing would depend on specifics of the
15 polysilicon layer. Correct?

16 MS. BÖLL: Object to form.

17 A The degree of gettering would depend on
18 the doping level. But in the context of Li and
19 '315, a POSITA would know that the doping level
20 has to be high. Because remember the other
21 aspects of the invention. Right?

22 I mean, you want highly doped emitters so

1 that the contact resistance and the series
2 resistance of the cell is low. Right? And that
3 in turn will introduce a very high level of
4 strain, which then helps with the gettering. It
5 is all inherent. I mean, it is not a matter of
6 if. It is going to happen.

7 Q Does it depend on the thickness of the
8 polysilicon layer?

9 A To some extent, yes.

10 Q Does it depend on the grain boundaries of
11 the polysilicon?

12 A It could to some extent, yes. So the
13 total numbers of dopants that are sucked in would
14 be equal to the maximum solid solubility of iron
15 in polysilicon -- I don't remember offhand what
16 that is -- times the thickness of the polysilicon.
17 But even if it is a thin layer it will suck out
18 some of the iron. If it's a thicker layer it will
19 suck out more. And once again, given the fact
20 that '315 is silent as to the degree of gettering,
21 they all meet the claim limitations, in my
22 opinion.

1 Q Does Li describe the thickness of the
2 material layer or the grain boundaries of the
3 material layer?

4 A I don't believe it -- it may discuss a
5 thickness, but it does not I think discuss a grain
6 boundaries. But one would have a general sense of
7 the grain boundaries based on the knowledge of a
8 POSITA. So thermal dynamics tells you that the
9 average size of grain boundaries is kind of
10 limited by the thickness of the polysilicon film.

11 Q So let's take Ramappa. Let's put the
12 material layer of Li on the oxide layer. What
13 effect will that have on Figure 5 of Ramappa?

14 A So --

15 MS. BÖLL: Object to form.

16 A If you put polysilicon on the left of
17 layer SiO₂, it would cause the iron have a doping
18 gradient sloping to the left. Okay?

19 So you are misinterpreting this Ramappa
20 figure. Right? Because this Ramappa they have
21 purposefully put iron to the left of the silicon
22 dioxide layer to study the diffusivity of the iron

1 through the oxide. But in the context of Li '315,
2 Liu, et cetera, the iron is not present on the
3 left-hand side of the oxide layer; it's present in
4 the silicon on the right-hand side. Okay? So it
5 is going to the left, not diffusing to the right,
6 as shown in this figure. Okay? So you have got
7 it all backwards.

8 And then what --

9 Q Go ahead.

10 A No. No. Your interpretation is wrong,
11 that's what I meant.

12 Q No. I mean, it's your figure. It's your
13 reference.

14 A Right.

15 Q So I have it backwards, it's fine.

16 A No. Your understanding is backwards.

17 That's what I meant, respectfully, yeah.

18 Q Okay.

19 A Anyway, so you would not have iron on the
20 left-hand side of the silicon dioxide layer in the
21 '315 patent or Li. It will be only on the
22 right-hand side of the silicon dioxide layer in

1 the single-crystal silicon, at levels of 10 to the
2 15, 10 to the 16 or so if it is multi-crystalline
3 silicon.

4 So there is no iron in the oxide to begin
5 with. There is no iron in the polysilicon that's
6 being deposited on the left of the oxide. So then
7 when you do the heat treatment at temperatures of
8 the order of 950 degree or so, the iron gradient
9 actually points to the left. Diffusion always
10 happens from a high to a low concentration region.

11 Okay?

12 And all that we glean from Ramappa is
13 that iron has a high enough diffusivity through
14 oxides at these temperatures. That's all that we
15 need to glean from Ramappa. Okay? And then you
16 put that in the context of Li '315, and
17 immediately one sees that there must be gettering
18 in the doped polysilicon.

19 Q Let me posit something to you, and you
20 can tell me if I am still backwards.

21 Under your theory, Ramappa would be
22 relevant if we erased all of the iron that is

1 shown in the oxide layer in Figure 5, and we
2 started with iron concentrations let's say on the
3 neighborhood of 10 to the 13. I believe you say
4 that's a number that would be expected. Is that
5 so far so good? So we'll take Figure 5, we'll
6 keep all the iron concentrations where they are,
7 and we will remove all the iron from the oxide
8 layer.

9 I believe under your theory that would be
10 the starting point of Li, or something close to
11 it.

12 Is that fair?

13 A Right. Right. And there will be no iron
14 on the left-hand side of the oxide layer. There
15 will only be iron, say, in the single-crystal
16 silicon.

17 Q And we won't put anything on top of the
18 oxide layer for now, because we're just dealing
19 with the Ramappa as it is. We're just making one
20 change at a time. We are going to take the iron
21 out of the oxide layer.

22 Would you expect there to be a step

1 down -- after a thermal process, 900 degrees, 5,
2 15 minutes, whatever, would you expect there to be
3 iron in the oxide layer?

4 MS. BÖLL: Object to form.

5 A So if there was no doped polysilicon on
6 top of the oxide, yes, there will be iron
7 segregating into the oxide as shown by Figure 5.
8 Okay? But once you put the doped polysilicon on
9 top, that's what's creating the strain fields, and
10 that's what '315, Li are talking about. Okay?

11 Q Okay. The concentration of that iron in
12 the oxide layer would not be continuous across the
13 oxide-silicon interface. Correct?

14 MS. BÖLL: Object to form.

15 A In general, not. It's dependent on
16 something called the segregation coefficient. But
17 once again, that's irrelevant. The important
18 point is the iron would be able to diffuse through
19 this thin oxides in the range of 1 to 2
20 nanometers, go into the doped polysilicon, and be
21 segregated there. Certainly it would be. And
22 that's all that's required by that claim.

1 Q Do you agree with me that the iron has to
2 be in the oxide layer before it can go through it
3 like a hot knife through butter?

4 A Sure.

5 Q Sure. Okay. I want to shift to another
6 theory of yours, the theory based on Li plus
7 Muller.

8 MS. BÖLL: Before we go there, sorry to
9 interrupt. Should we take a short break?

10 MR. SNODGRASS: Oh, sure.

11 (A recess was taken.)

12 BY MR. SNODGRASS:

13 Q So, Dr. Banerjee, I want to talk about
14 your opinions with regard to the Li/Muller
15 combination. And this begins at Page 79 of your
16 declaration. And I guess my first question is,
17 can you describe what that combination is, what
18 features of Li are retained, what features of
19 Muller are incorporated?

20 A Yes.

21 MS. BÖLL: Object to form.

22 Q Can you please do that?

1 A Yes. Both Muller and '315, and Li, the
2 challenges of '315, Li, and Muller all refer to
3 back-contact cells, so that's a commonality. They
4 all have the common goal of trying to maximize
5 cell efficiency.

6 So specifically we cited Muller to
7 address Claims 13 and 14 of '315, which talks
8 about boron being incorporated in the portion of
9 the silicon substrate. Which Muller showed us in
10 what they described as the FFE, the front floating
11 emitter.

12 So once again using Li as a base, it does
13 not have -- it does not disclose boron doping in a
14 portion of the substrate at the levels of $2E18$,
15 but Muller clearly does, so that's the
16 combination.

17 Q Am I correct to understand that you're
18 also adding certain layers of Muller to Li?

19 MS. BÖLL: Object to form.

20 A In Muller they also have this aluminum
21 oxide passivation and silicon nitride
22 anti-reflection coating.

1 Q And in your proposed combination are
2 those layers present?

3 A They are present in Muller. But what you
4 really need from Muller is the boron at a doping
5 level of $2E18$ in a portion of the substrate.

6 That's what's missing in Li.

7 Q And there I see a couple of -- or a
8 figure with a couple of different graphs on Page
9 82 of your declaration. This is in the middle of
10 Paragraph 190.

11 Is this where you're relying on Muller to
12 get the dopant concentration?

13 A Yes.

14 Q And I see reference to the orange
15 curves -- oh, yeah. The sentence right above the
16 figure, the orange dotted -- excuse me, the orange
17 dotted lines in Figure 1 of Muller reproduced
18 below showed the dopant profiles of the two
19 back-contact solar cells constructed and compared
20 by Muller.

21 Is that right?

22 A Yes.

1 Q So are you proposing that the two orange
2 lines are taken from Muller over into Li?

3 MS. BÖLL: Object to form.

4 A I'm not sure what you mean by "two orange
5 lines." I am using the orange line for the
6 left-hand figure for the boron. Right? That's a
7 front floating emitter.

8 Q The orange dotted lines that you
9 reference. I assumed that you were referring to
10 the two curves, maybe better than lines. But the
11 one on the left would start at, I don't know what,
12 3 times 10 to the 18 and then curve down to 3
13 times 10 to the 16th at approximately .7 microns,
14 and the one on the right, it starts off at 5 times
15 10 to the 17th, goes up, and then cascades down
16 again to 5 times 10 to the 16th at .6 microns,
17 those two dotted lines?

18 MS. BÖLL: Object to form.

19 A The boron starts at approximately 2 times
20 10 to the 18. And yeah, Muller compares the
21 phosphorous doped fronts of his field with the
22 boron doped front floating emitters. And his

1 conclusion is the boron doped front floating
2 emitter is superior.

3 So from that, one would glean the
4 teaching that $2E18$ boron doping in a portion --
5 front portion of that substrate is a good thing to
6 add to Li, which is also back-contact IBC cell.

7 Q Are you proposing that one of skill in
8 the art would have been motivated to use the
9 dopant profiles that are shown in orange in Figure
10 1 of Muller in Li?

11 MS. BÖLL: Object to form.

12 A It doesn't necessarily have to have the
13 same doping shape. What this teaches us is you
14 want the doping concentration at around, starting
15 at around 2×10^{18} sloping downward.
16 So it has to slope downward, that's a key point.
17 Because that's what's going to create the relevant
18 fields.

19 Q All right. A doping profile will behave
20 differently, though. Correct?

21 MS. BÖLL: Object to form.

22 A Depending, doping will be different

1 magnitudes of electric fields, so there will be
2 some differences in that sense.

3 Q Is the boron doping concentration greater
4 than 2 times 10 to the 18th, at least at certain
5 depths?

6 MS. BÖLL: Object to form.

7 A It's approximately 2 times 10 to the 18.
8 It's definitely less than 4 times 10 to the 18,
9 which is discussed in the '315 patent.

10 So this goes back to the ambiguity that I
11 was mentioning this morning. Yeah, and '315 did
12 not specify 2E18 plus or minus a certain
13 percentage. But clearly according to the '315,
14 4E18 is out of bounds, and this concentration is
15 definitely significantly lower than 4E18. It's
16 approximately 2E18. So I think it's applicable.

17 Q It appears to me to be closer to 3 times
18 10 to the 18th than 2 times 10 to the 18th.

19 Do you agree with that?

20 MS. BÖLL: Object to form.

21 Q Especially since this is logarithmic?

22 MS. BÖLL: Same objection.

1 A Yeah, log scapes are hard to read.

2 Q I mean, even if it was linear, the orange
3 line is closer to the third tick than the second
4 tick. Right?

5 A So if you expanded this to a linear
6 scale, it will actually be closer to the 2E18.
7 Remember, as you go up it gets compressed. Right?
8 So it is actually closer to the 2E18 concentration
9 than 3E18 on the log scale.

10 Q I get it. Thank you. Yes. I had it
11 backwards.

12 But isn't it still closer to 3? It is
13 logarithmic, so it is closer to 3. Right?

14 MS. BÖLL: Object to form.

15 A I think it is closer to 2, but what is a
16 few dopants among friends?

17 Q So one skilled in the art, if I am
18 understanding you correctly -- we'll look at
19 Muller and think 2 times 10 to the 18th is a good
20 doping concentration. They'll look at King and
21 Swanson and Marvin and think 1 times 10 to the
22 18th is a good concentration.

1 Would a person of ordinary skill in the
2 art be kind of unsure which route to take? Why
3 choose one over the other, or would both be
4 equally attractive?

5 MS. BÖLL: Object to form.

6 A So as I mentioned before, you know, what
7 you do is look at ranges. Right? I mean, the
8 patent itself talks about approximately 2E18.
9 Whether it's 2E18 or 1E18 could depend on the
10 specifics of the rest of the structure.

11 But clearly '315 is disavowing use of
12 4E18-type levels. That doesn't constitute
13 approximately 2E18, that part is clear.

14 Q I want to get back to the layers,
15 aluminum oxide and the anti-reflective layer that
16 are shown in -- actually, I don't know which is
17 which, to be honest. Maybe gray and purple in the
18 figure on Page 81.

19 A Yeah.

20 Q Are those incorporated into the front
21 surface of Li in your proposed combination?

22 A Yes. Oh, pardon me, are they

1 incorporated on front of Muller? But once again,
2 the only thing that we're taking from Muller is
3 the boron FFE layer.

4 Q Okay. All right. So those layers aren't
5 in the combination.

6 MS. BÖLL: Object to form.

7 A I am looking at Paragraph 192. So we did
8 include the FFE along with this front-side
9 aluminum oxide and silicon nitride to replace the
10 phosphorous-doped portion of Li.

11 Q Yeah, so I guess that was my question.
12 Are we incorporating kind of the whole thing, or
13 are we just incorporating the FFE by bringing the
14 dopants over?

15 A Yeah, so maybe it's to skin the cat, of
16 course. So the key ingredient we need is the FFE
17 layer. I think the aluminum oxide and the nitride
18 from Muller come along for the ride. I don't
19 think it's mandatory, but it wouldn't hurt either,
20 so ...

21 Q If they do come along for the ride, that
22 is, would you agree, a significant change to Li?

1 MS. BÖLL: Object to form.

2 A I don't know if I agree. Because like I
3 said, although Li does not explicitly discuss
4 passivation layers or anti-reflection coatings on
5 top of the texture, Li does make the statement
6 that he did not describe every bell and whistle
7 connected with the invention to describe his
8 patent.

9 And that's true for most patents, right;
10 otherwise, patents become unreadable they would be
11 so long. He wanted to focus on the key aspects of
12 his invention and left other pieces that will be
13 well known in the prior art to be included
14 surreptitiously, I guess.

15 So I will grant you that Li does not
16 explicitly describe a passivation layer or an arc
17 layer, but I disagree that he disavows those
18 layers also. So that's my position.

19 Q Yeah. But would you agree that if we
20 start from the position that Li does not have any
21 layer on its front surface, and it doesn't -- and
22 it doesn't explicitly disclose a layer, it doesn't

1 inherently disclose a layer, so there is no layer
2 there in at least one embodiment of Li, and if you
3 were to go from there to adding two additional
4 layers, the ones on Muller, that would be a
5 significant change.

6 Would you agree with that?

7 MS. BÖLL: Object to form.

8 A What you are saying is, of course, a
9 hypothetical. Right? I mean, I agree with you
10 that Li does not explicitly or inherently disclose
11 those layers. But he doesn't explicitly disavow
12 those layers either. So assuming for argument's
13 sake that Li did not have those layers and then he
14 incorporated this aluminum oxide and nitride in
15 addition to Muller, yeah, those would be two
16 additional layers. But once again, the most
17 significant thing that you need is the boron FFE
18 layer, because that's what the claims talk about.
19 The claims are silent as to passivating layers or
20 anti-reflection coatings.

21 Q But would you agree with me that if you
22 wanted to add the two layers -- is it -- am I

1 using the right terminology, is that an aluminum
2 oxide and a silicon nitride layer?

3 A Yeah.

4 Q If you're going to add an aluminum oxide
5 and a silicon nitride layer to a structure that
6 doesn't otherwise have them, you're introducing
7 heating steps that's going to impact other
8 components within the system.

9 Is that fair?

10 MS. BÖLL: Object to form.

11 A So in this case as it turns out, with the
12 aluminum oxide is very often deposited by
13 technique called atomic layer deposition that I
14 use extensively in my research. And that's done
15 at a pretty low temperature, 100 degrees to 200
16 degrees.

17 But given the fact that the diffusivities
18 depend exponentially on temperature, the
19 additional heating step of the aluminum oxide is
20 going to be negligible.

21 Similarly, the silicon nitride often is
22 deposited using plasma-enhanced CVD, also at

1 relatively modest temperatures of 400, 500 degrees
2 centigrade. So in terms of the additional heating
3 step, that's also marginal in that case.

4 Q The process that you described for the
5 aluminum oxide, did you say atomic layer
6 deposition?

7 A That's a commonly used technique that's
8 used. I don't know if Muller used that, but
9 that's very often what folks use. I can look at
10 Muller to confirm it one way or the other.

11 Q Okay. Regardless of what Muller
12 disclosed, a person of ordinary skill in the art
13 could have used other methods of depositing those
14 layers. Correct?

15 A There will be some limitations. Because
16 this is being deposited on a roughened-up,
17 textured surface, and it's important that you
18 cover it up conformally. So that introduces some
19 restrictions in terms of the deposition
20 techniques.

21 This atomic deposition layer technique is
22 explicitly designed to do uniform coverage over

1 such -- conformal coverage over such structures.
2 I can take a look at -- quick look at Muller to
3 see if he discusses that.

4 Yeah, on Page 266, under Experimental, it
5 says, For passivation the samples were dipped and
6 received an alumina passivation (plasma assisted
7 atomic layer deposition, PAALD). That is right.
8 I hadn't really looked at Muller, so that's what a
9 POSITA would do.

10 Q I want to discuss the figures that you
11 have on Page 84 of your declaration. This is at
12 the bottom of Paragraph 192.

13 You've inverted Figure 5E of Li, and I
14 see that you have the red up top where 520 is,
15 which I think is the dopant. But you have 520 on
16 the -- what used to be the top side, now the
17 bottom side, is filled in with blue.

18 Do you see that?

19 A Are you looking at 5E from Li?

20 Q I am looking at 5E on Page 84 of your
21 declaration.

22 A Yes.

1 Q And I guess, you know, comparing that
2 with your other reproductions of 5E, you have the
3 red on both the top and the bottom. For example,
4 on Pages 39 and 40 of your declaration. I guess
5 my question is, is there any import to you having
6 filled in the 520 on the -- in the trench in that
7 instance?

8 MS. BÖLL: Object to form.

9 A So the red regions, if you do the doping
10 of the front surface field or if the trench is
11 also exposed to dope the trench, in this case with
12 phosphorous, if you dope it front and back, if you
13 use something like POCl doping, for example,
14 phosphorous oxychloride, but there's other doping
15 techniques which would not do that.

16 So, for example, if you had a
17 phosphosilicate glass that is deposited only on
18 the front surface, that would dope only the front,
19 not the back.

20 Or if like Muller, one used iron
21 implantation to do the doping, and you had the
22 front surface of the wafer facing the implanter,

1 would only dope the bottom of 5E that's shown in
2 Figure 40 and in figure -- on Page 40, sorry. And
3 then Figure 5E flipped. So now the red region,
4 the front surface field could be iron implanted
5 only from the top, and there would be no doping in
6 the trench.

7 So there is, once again, many ways you
8 can skin this cat.

9 Q So that would be another change to Li in
10 your proposal is now we do not have dopant in the
11 trench.

12 Is that right?

13 A Usually not in that region, so ...

14 Q Do I understand the process of ion
15 implementation correctly to be that you would only
16 get dopant on one side, the side that's facing the
17 emitter?

18 A Right. So in (indiscernible) you have a
19 linear actuator. You shoot ions in a vacuum at
20 the surface, so it will only implant the surface
21 that's exposed to the ion beam. It doesn't go all
22 around way at the back, unlike in thermal

1 diffusion.

2 Q So if one wanted to similarly dope the
3 trench region, they would -- they would have to
4 flip it over, flip over the --

5 A In ion condition, yes.

6 Q And are you suggesting -- trying not to
7 read too much into this figure, but are you
8 suggesting that that isn't necessary under your
9 proposal, to just leave it undoped and that's why
10 it's all blue, including --

11 MS. BÖLL: Object to form.

12 A Yeah, it's not critical, in my opinion,
13 for the following reason. The reason you'd want
14 to dope it will be to sort of act as a back
15 surface field. But one should keep in mind that
16 the lateral extent of these trenches are very,
17 very -- these figures are not to scale. So the
18 lateral extent of the trenches are going to be
19 much smaller than the lateral extent of these
20 emitter regions.

21 So when it comes to surface
22 recombination, A, it matters. Right? So it's a

1 recombination velocity times the exposed area. So
2 this trench area being so small, yeah, you get
3 some -- if you didn't implant it or dope it, you'd
4 get some enhanced recombination. But that's over
5 such a small area, I think it will not be a
6 significant impact. You could -- you could dope
7 it, or you could leave it undoped if you chose to.

8 Q If one wanted to, for whatever reason,
9 dope it the same way that Li had doped it, you
10 would need to add a mask over the new,
11 quote/unquote, front surface which is the top
12 in -- as it's presented on Page 84, to make sure
13 that that aluminum oxide/silicon nitride layers
14 did not get doped.

15 Is that right?

16 A Not necessarily. Because silicon nitride
17 itself is a good diffusion mask for phosphorous.
18 Because I think I state that in my report. So
19 that itself could act as a mask, I mean.

20 Q Okay. I'm sorry, I'll let you finish.
21 Just tell me when you're done.

22 A If you look at Paragraph 199 on Page 89,

1 towards the top I state that, "In Luque the
2 silicon nitride layer was used as a diffusion
3 mask," and then goes on, "The use of silicon
4 nitride both as a diffusion mask and
5 anti-reflection coating and surface passivator is
6 equally applicable here."

7 So the silicon nitride by itself could
8 serve multiple functions.

9 Q Okay. I want to shift to Paragraph 197
10 of your declaration. Towards the middle of that
11 paragraph, you use the phrase "more efficient."
12 And unfortunately that's a long sentence to start
13 the paragraph where that appears.

14 So I'll let you review that. And then my
15 question is going to be, what led you to believe
16 that modifying Li as you have proposed would make
17 it more efficient?

18 A I said that because Muller did this
19 analysis and compared front surface field with
20 phosphorous doping, and boron doped front floating
21 emitter. And he concluded that the second case
22 had better long-term reliability, less UV

1 degradation.

2 So in addition to high efficiency,
3 long-term reliability is also obviously very
4 desirable for all products, including solar cells.
5 So that would have motivated a POSITA to use a
6 boron doping of $2E18$ in a portion of the substrate
7 in Li.

8 Q Would there have been any drawbacks to
9 the modification to Li that you're proposing?

10 MS. BÖLL: Object to form.

11 Q I guess let me withdraw the question.
12 I'll ask you a different question.

13 Did you consider any drawbacks that would
14 attend the modification to Li that you're
15 proposing?

16 A I mean, I always think of pros and cons
17 when I propose combinations. I did not see any
18 roadblocks, I think.

19 Q You do agree that all other things being
20 equal, increasing the number of processing steps
21 is usually disfavored.

22 Is that right?

1 MS. BÖLL: Object to form.

2 A I think "all things being equal" is sort
3 of a loaded statement.

4 Q Okay. Do you know if a person of
5 ordinary skill in the art would have been
6 motivated to reduce processing steps?

7 MS. BÖLL: Object to form.

8 A Once again, that's a pretty broad,
9 somewhat vague question. But in broad strokes,
10 yeah, simpler the better, cheaper the better, more
11 efficient the better, more reliable the better.

12 If they don't have tariffs, that's
13 better.

14 Q In Paragraph 203 you talk about better
15 stability. Let me find this phrase.

16 Do you have 203?

17 A Yes, I see that.

18 Q When do you mean by that?

19 A That means that under UV illumination
20 solar cell efficiency --

21 (Discussion off the record; technical
22 difficulty.)

1 A Solar cell efficiencies decrease over
2 time. Then I think I add a sentence, "This is
3 known as light-induced degradation."

4 Q All right. So under your proposed
5 combination, you are not heating Li as often as Li
6 was heated originally. Right? Because the doping
7 on the front side is an ion implantation.

8 Is that right?

9 A Well, that's not entirely true. Because
10 when you do ion implantation, you still have to do
11 a subsequent heating step to do two things: The
12 implant process can introduce some crystal damage,
13 and the implanted dopants do not lie on
14 substitution locations. That means they do not
15 replace the silicon host atoms. You need to do
16 both. And that does require a certain degree of
17 heating, which is known as annealing. Now, those
18 temperatures are generally lower than diffusion
19 temperatures, but there is some heating involved.

20 Q What about times; are they shorter times
21 or -- generally, do you know?

22 A Once again, you can create time versus

1 temperature. So you can do things in the furnace
2 at modest temperatures for time scales of 15
3 minutes, 30 minutes. Or there is something called
4 rapid tunnel processing, which is -- is in this?
5 I think it gets confused, that talks about that.
6 So these are at significantly higher temperatures,
7 1100 degrees C for maybe 15, 30 seconds or so. So
8 you can do a trade-off of time and temperature.

9 Q I am going to shift forward. Paragraph
10 223 of your declaration. Here we're now under a
11 different section heading. You recall,
12 Dr. Banerjee, this is the section where I believe
13 you're referring to the two prior bases. One you
14 have Li with either Marvin, King, or Swanson, and
15 the other where you have Li and Muller. And here
16 under Section 7, VII, you're discussing Hu and
17 Ramappa again.

18 Are you with me so far?

19 A Yes.

20 Q So in Paragraph 223 you say the second
21 paragraph -- excuse me, the second sentence, I
22 believe, "Combining any of the above Li

1 combinations with Hu and Ramappa as described here
2 would have been within the level of ordinary skill
3 in the art, as this would have required no
4 material changes to the process of Li."

5 Okay? Do you see that?

6 A Yes.

7 Q And then in 215, Paragraph 215, you
8 say -- I'm going to pick the second sentence up
9 about halfway. "It would have been obvious to the
10 skilled artisan that such metal impurities would
11 be present in the emitter region due to gettering
12 that occurs during Li's 950 degrees C dopant
13 diffusion step as taught by Hu and Ramappa."

14 Do you see that?

15 A Yes.

16 Q So am I correct in understanding that in
17 this section you're not proposing additional
18 heating steps; you're just contending that a
19 person of ordinary skill in the art would have
20 known it's obvious that under your view minimum
21 impurities in Li would have been transmitted up to
22 the material layer?

1 Is that correct?

2 MS. BÖLL: Object to form.

3 A Looking at Muller under the experimental
4 conditions. So it looks like after he did the
5 boron implant, they did an anneal in a furnace,
6 with a peak time of 80 minutes at 1050 degrees
7 centigrade. That's more than enough to cause
8 gettering.

9 Q I apologize, you were referencing Muller?

10 A I'm looking at the Muller reference, yes.

11 Q So I understand this section to be
12 applicable to both of your prior Li combinations,
13 the one with Muller, the one with King, Marvin, or
14 Swanson.

15 And so if I'm understanding correctly,
16 you're not proposing a new step to Li that's not
17 disclosed in Li; you're not proposing a new step
18 to Muller that's not disclosed in Muller.

19 Is that right?

20 A No, we are not introducing new steps. So
21 what you are saying is Li and Muller in view of Hu
22 and Ramappa could tell a POSITA that there would

1 be getting in the poly emitter.

2 Q Have you designed a solar cell to the
3 extent that you've been required to choose a
4 doping concentration?

5 A Yes.

6 Q Have you done so on the front side of the
7 solar cell?

8 A I have a couple of dozen papers on solar
9 cells that's listed in my CV. I describe many
10 different structures. I can't remember offhand if
11 that was one of the experiments.

12 Q Do you recall any considerations that you
13 paid attention to in deciding what the dopant
14 concentration should be?

15 A Yes.

16 MS. BÖLL: Objection.

17 Q And what were those considerations?

18 A Try to maximize cell efficiency.

19 Q I suspect that was dependent on a number
20 of other parameters.

21 Is that right?

22 MS. BÖLL: Object to form.

1 A I mean, the exact doping depends on the
2 solar cell structure that you are working on. In
3 our case we were working on silicon crystals which
4 are about 25 microns thick, with a technique that
5 was developed by a startup that I was on the
6 advisory board of, called Silicon on Metal. And
7 then my students and I did a lot of research on
8 that structure, where it involved things like
9 designing the doping level. We worked on hetero
10 structures.

11 Q Do you recall what the doping level was?

12 MS. BÖLL: Object to scope.

13 A Not offhand. I mean, but ten, 15 years
14 ago.

15 Q Is it your understanding that prior to
16 2014 the trend in the industry was to move to
17 thinner oxidation layers and higher doping
18 concentrations?

19 MS. BÖLL: Object to scope. Object to
20 form.

21 A I haven't don an exhaustive survey of
22 which way the industry was moving.

1 Q Even in the absence of an exhaustive
2 survey, do you have a sense for the way the
3 industry was moving?

4 MS. BÖLL: Object to form.

5 A You know, different companies have
6 championed different structures. So Sun Power,
7 which is not Maxeon, I know they used to talk
8 about the IBC cells. Other companies use front
9 and back contacts. So there's quite a few flavors
10 of solar cell out there on the market. So I
11 really couldn't answer you off the top of my head.

12 Q Do you know Dr. David Carroll outside of
13 this proceeding?

14 A I've never heard of him before.

15 Q You do not contend that the claims of the
16 '315 patent were found in the prior art. Right?
17 It's all obviousness, no anticipation. Right?

18 A That is correct.

19 Q Do you have an opinion as to why the
20 claims of the '315 patent were never performed or
21 embodied in a single device?

22 MS. BÖLL: Object to form. Object to

1 scope.

2 A I didn't make any anticipation arguments.
3 So I did not find any art which disclosed all the
4 claim elements.

5 Q Do you have an opinion as to why you were
6 unable to find any such art?

7 MS. BÖLL: Object to form. Object to
8 scope.

9 A No. There's -- I couldn't really answer
10 that off the top of my head. There are so many
11 bells and whistles that you can add to a solar
12 cell structure. So I guess -- I guess in the art
13 that we found. I mean, there may be art out there
14 which anticipates '315, but I didn't find any.
15 But there are certainly strong one
16 (indiscernible.)

17 Q Did you ever design a solar cell that was
18 intended for space applications?

19 A Not per se. So our cells were designed
20 for terrestrial. But I'm glad that you asked
21 that. I mean, they would be quite suited for
22 solar cell applications because the unique aspect

1 of this technology by this company called
2 AstroWatt, I am on the advisory board of the
3 company. Unfortunately they went belly up now.
4 They have a new embodiment.

5 So they came up with this very
6 interesting technology where they would flake off
7 single-crystal films of silicon, about 25 microns,
8 take back by nickel metal plating. That's called
9 silicon on metal. So that would be very
10 attractive for space applications because it's a
11 very light weight. And for space, as you know,
12 weight matters a lot.

13 They are also mechanically flexible, so
14 they could be put around curved surfaces. So
15 although we didn't specifically design it for
16 space, I think it would be a great candidate for
17 NASA.

18 Q Sitting here right now, can you recall
19 any testimony you provided today that you wish to
20 change or amend or supplement?

21 A I wish I didn't make that joke about the
22 tariffs. You never know how -- okay. No.

1 Q That won't see the light of -- that is a
2 nonevent.

3 A No. I think I'm okay.

4 Q Okay. I may have further questions if
5 counsel for petitioner asks you questions that
6 require any followup. Otherwise, I don't have
7 anything right now.

8 MS. BÖLL: Okay. I think I will have a
9 couple of questions. Maybe we can go off the
10 record for a few minutes while I check my notes.

11 (A recess was taken.)

12 EXAMINATION BY COUNSEL FOR PETITIONER

13 BY MS. BÖLL:

14 Q Dr. Banerjee, do you recall being asked
15 some questions at the beginning of the deposition
16 about your understanding of the scope of the
17 claims?

18 A Yes.

19 Q Were you asked to opine on whether any of
20 the claims of the '315 patent are indefinite?

21 A No.

22 Q Were you asked to opine on whether any of

1 the claims of the '315 patent are sufficiently
2 enabled?

3 A No.

4 Q Were you asked to opine on whether the
5 claims of the '315 patent are supported by
6 sufficient written description?

7 A No, I was not asked to.

8 Q Do you recall being asked about
9 whether -- excuse me. Do you recall being asked
10 about whether certain parameters or conditions can
11 impact diffusion?

12 A Yes.

13 Q In your opinion, would an oxide layer of
14 1- to 2-nanometer thickness as described in the Li
15 reference prevent gettering from occurring?

16 A No.

17 Q Why not?

18 A Because the other prior art that we cited
19 clearly showed that at these thicknesses, iron and
20 other impurities will very easily diffuse through
21 that, and there necessarily will be gettering in
22 doped polysilicon emitters.

1 MS. BÖLL: Nothing further.

2 MR. SNODGRASS: Okay. I have nothing
3 further.

4 (Off the record at 3:33 p.m. EDT.)
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ACKNOWLEDGMENT OF DEPONENT

I, SANJAY BANERJEE, Ph.D., do hereby
acknowledge that I have read and examined the
foregoing testimony, and the same is a true,
correct and complete transcription of the
testimony given by me, and any corrections appear
on the attached Errata sheet signed by me.

(DATE)

(SIGNATURE)

C E R T I F I C A T E

I, Debra Ann Whitehead, E-Notary Public in and for
the Commonwealth of Virginia, do hereby certify:

That SANJAY BANERJEE, Ph.D., the witness
whose deposition is hereinbefore set forth, was duly
sworn by me before the commencement of such
deposition and that such deposition was taken
virtually and is a true record of the testimony
given by such witness.

I further certify that the adverse party,
CANADIAN SOLAR INC., was represented by counsel at
the deposition.

I further certify that the deposition of
SANJAY BANERJEE, Ph.D., occurred virtually, on
Friday, March 21st, 2025, from 10 a.m. to 3:33 p.m.
EDT.

1 I further certify that I am not related to
2 any of the parties to this action by blood or
3 marriage, I am not employed by or an attorney to any
4 of the parties to this action, and that I am in no
5 way interested, financially or otherwise, in the
6 outcome of this matter.

7

8 IN WITNESS WHEREOF, I have hereunto set my
9 hand this 31st day of March, 2025.

10

11 My commission expires:

12 October 31, 2027

13

14 

15 E-NOTARY PUBLIC IN AND FOR THE
16 COMMONWEALTH OF VIRGINIA

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21

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Conducted on March 21, 2025

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Page	Line	Correction/Change and Reason
28	2	Insert "not" between "it's" and "going"
29	19	Replace "were" with "was"
31	20	Replace "relation" with "gradation"
65	18	Replace "which is" with "and"
68	9	Replace "and" with "in"
75	3	Replace "volts when" with "Boltzmann"
80	9	Should read "You can't order one species not to diffuse"
85	14	Replace "92" with "22"
98	4	Replace "on" with "with"
116	17	Replace "are" with "or" and delete "."
122	20	Replace "at" with "are"
160	21	Replace "fronts of his" with "front surface"
161	22	Insert "on profile" before/after "doping"
165	15	Replace "maybe it's" with "many ways"
172	18	Replace "(indiscernible)" with "ion implanter"
172	19	Replace "actuator" with "accelerator"
173	5	Insert "implant" after "ion"
173	17	Insert "small" after "very"
173	22	Replace "A" with "area"
179	4	Replace "tunnel" with "thermal"
184	7	Replace "not" with "now"

4/8/25
(Date)

Sanjay Banerjee
(Signature)

No. 575274

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4/8/25

(Date)

Sanyam Banerjee
(Signature)

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ACKNOWLEDGMENT OF DEPONENT

I, Sanjay Banerjee, Ph.D., do hereby
acknowledge that I have read and examined the
foregoing testimony, and the same is a true, correct
and complete transcription of the testimony given by
me and any corrections appear on the attached Errata
sheet signed by me.

4/2/25

(Date)

Sanjay Banerjee

(Signature)