

Exhibit 2023

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

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CANADIAN SOLAR INC., : Case Nos.
Petitioner, : IPR2024-01039,
v. : IPR2024-01040
MAXEON SOLAR PTE., : U.S. Patent Nos.
LTD., : 8,222,516,
Patent Owner. : 8,878,053

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Deposition of SANJAY BANERJEE, Ph.D.
Conducted Virtually
Thursday, March 20, 2025
9:59 a.m. EDT

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Pages 1 - 156
Reported by: Debra A. Whitehead

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

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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

EXAMINATION OF SANJAY BANERJEE, Ph.D.	PAGE
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By Mr. Peterson	6
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EXHIBITS MARKED IN TODAY'S SESSION

(None Marked)

EXHIBITS MARKED IN PRIOR SESSIONS

(Not Attached)

IPR2024-0104 EXHIBIT	PAGE
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Exhibit 1003	30
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Exhibit 1004	15
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Exhibit 1006	82
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Exhibit 1007	92
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Exhibit 1008	54
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Exhibit 1009	135
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IPR2024-01039 EXHIBIT	
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Exhibit 1003	115
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1 P R O C E E D I N G S

2 SANJAY BANERJEE, Ph.D. having been duly sworn,

3 testified as follows:

4 MR. PETERSON: So my name is Jeremy
5 Peterson, with PV Law, LLP, counsel for Patent
6 Owner Maxeon Solar PTE, LTD. And I will be taking
7 the deposition. With me are Jacob Snodgrass and
8 Jing Zhao.

9 Ms. Böll, do you want to identify your
10 yourself?

11 MS. BÖLL: Sure. This is Brooke Böll
12 from Sidley Austin, LLP, on behalf of Petitioner
13 Canadian Solar.

14 EXAMINATION BY COUNSEL FOR PATENT OWNER

15 BY MR. PETERSON:

16 Q Good morning, Dr. Banerjee.

17 A Good morning.

18 Q Can you state your full name, for the
19 record, please.

20 A Sanjay Kumar Banerjee.

21 Q Where are you located for this
22 deposition?

1 A Austin, Texas.

2 Q Is anyone in -- are you in your home or
3 in an office?

4 A At home, I am alone.

5 Q Are you currently in contact with
6 anybody?

7 A No. I brought my cell phone with me, but
8 I'm not accessing that.

9 Q I just ask that you don't access the
10 cellphone during the deposition.

11 A Sure.

12 Q Do you have any documents in front of
13 you?

14 A I brought unmarked copies of the two
15 patents, the '516 and '053, and my unmarked copies
16 of my two declarations with me.

17 Q Did you receive the documents that we
18 sent to you?

19 A Yes. And I just opened the box today,
20 this morning.

21 Q Those are for your use in case you'd
22 rather go through paper copies of whatever we're

1 going through. But whatever we're going through
2 will also be shown on the screen. It's up to you
3 which method you prefer.

4 I am going to go through some ground
5 rules for the deposition.

6 Is that okay?

7 A Sure.

8 Q Please only provide verbal answers. The
9 court reporter cannot record any answers that are
10 not verbal.

11 If you do not understand the question, I
12 will try to reask the question.

13 Do you understand?

14 A Yes.

15 Q If you do not ask for clarification, I
16 will assume you understood the question. If your
17 attorney objects, you still need to answer the
18 question unless your attorney instructs you not
19 to.

20 A Okay.

21 Q If you need to come back to a question,
22 just let me know, we can go back to any question.

1 If you need a break for any reason, we
2 can take a break, but not while an answer is still
3 pending.

4 Do you understand?

5 A Yes.

6 Q Is there any reason that you can think of
7 that you cannot tell the truth to any of my
8 questions today?

9 A No.

10 Q Are you going to tell the truth to the
11 questions I ask today?

12 A Yes.

13 Q Are you aware of any medical condition
14 that you have that would prevent you from
15 testifying falsely today?

16 A So I did have shoulder surgery on my left
17 arm, I am recovering. The only reason I'm -- so I
18 will be fine. But the only reason I mention that
19 is, it will take me a few more seconds to, you
20 know, review some documents, but that's okay.

21 Q That's fine. The only reason I ask that
22 question is, in the past I have deposed somebody

1 with Alzheimer's, and it did not go well.

2 Have you ever been deposed before?

3 A Yes.

4 Q About how many times?

5 A I don't recall exactly, but I think about
6 a couple of dozen times.

7 Q A couple dozen? Okay. And when was the
8 last time?

9 A Late last year.

10 Q So like December 2024, something like
11 that, or are we talking --

12 A I think -- yeah, December 2024, that's
13 right, yeah.

14 Q Have you ever testified at trial?

15 A Yes.

16 Q How many times?

17 A I believe at the ITC around four times,
18 and then once in the Northern District of
19 California.

20 Q How about, have you ever been involved
21 with IPRs before?

22 A Yes.

1 Q About how many?

2 A Probably a couple of dozen times.

3 Q Did you do anything to prepare for your
4 deposition today?

5 A I reviewed the patents and my declaration
6 and the prior art.

7 Q About how long did you prepare?

8 A Overall or yesterday?

9 Q Did you prepare any time other than
10 yesterday?

11 A Yes.

12 Q How many times?

13 A Well, I met with counsel briefly for an
14 hour yesterday and a few hours the two previous
15 days. But I have been reviewing the documents
16 quite extensively over the past week.

17 Q What counsel did you meet with?

18 A Sorry?

19 Q Which counsel did you meet with?

20 A Ms. Brooke Böll and Leif Peterson. And
21 William Neer, he was just sitting there.

22 Q Did you review your declarations for the

1 IPRs that you are here to testify on in your
2 preparation?

3 A Yes.

4 Q And did you review the prior art related
5 to these IPRs when preparing for this deposition?

6 A Yes.

7 Q And do you understand that you are here
8 to testify in regard to the declarations that you
9 wrote in IPR Numbers IPR2024-01039 and
10 IPR2024-01040?

11 A Yes.

12 Q Did you prepare your expert declaration
13 for the IPR, IPR2024-01039?

14 A Yeah, these are my declarations. Yeah.

15 Q And did you write them all by yourself?

16 A No; it was a collaborative effort with
17 counsel.

18 Q Did you write the first draft?

19 A I provided a lot of input on the
20 technical aspects. I am not a lawyer, so I
21 depended on them for the legal aspects. And then
22 we went back and forth.

1 Q How many hours do you think that you
2 worked on your expert declaration related to the
3 IPR2024-01039?

4 A Are you asking about the writing of the
5 declaration or the overall preparation?

6 Q Overall preparation.

7 A I do not recall, but I'm guessing
8 probably around a hundred hours overall.

9 Q How about for the writing?

10 A Once again I'm guessing. You know, we
11 went back and forth. Probably maybe around 40, 50
12 hours, maybe.

13 Q And just to shortcut this, do you mind if
14 I refer to the IPR2024-01039 as the 1039 IPR?

15 A Sure, that's fine.

16 Q Just to make things shorter.

17 A Yeah. Refer to them in terms of the last
18 three digits of the patent, I remember that.

19 Q Yeah, last three or four digits. Yeah.

20 And how about the 1040 IPR; did you draft
21 that IPR?

22 MS. BÖLL: Object to form.

1 A Once again, it was a collaborative
2 effort. I provided a lot of input on the
3 technical aspects.

4 Q Same answers with regard to what you just
5 said for the 1039?

6 A That's correct.

7 Q How were you retained for these matters?

8 A Sidley approached me. I had worked with
9 Sidley on prior cases.

10 Q Have you spoken to anybody, to anyone at
11 Canadian Solar?

12 A No.

13 Q When were you retained for these matters?

14 A I don't honestly recall. I'm guessing
15 something last year.

16 Q Prior to the declaration --

17 A Yeah.

18 Q -- I imagine?

19 A Yeah.

20 Q Are you being paid for your work on these
21 IPRs?

22 A Yes.

1 Q What is your rate?

2 A I believe it's 650 an hour.

3 Q Do you mind if I refer to Canadian Solar,
4 Inc., as CSI?

5 A Sure.

6 MR. PETERSON: Can we pull up Deposition
7 exhibit that's marked as IPR2024-01040, Exhibit
8 1004.

9 (IPR2024-01040 Exhibit 1004, previously
10 marked, not attached.)

11 Q And that's your CV, Dr. Banerjee.

12 A Oh, that's my CV?

13 Q Yeah.

14 A Okay.

15 Q Now, Dr. Banerjee, it's up to you; do you
16 want to take control of the document or do you
17 want to have Mr. Shankin take control over
18 scrolling the document?

19 A I think let him have it. If I change my
20 mind, I will let you know.

21 MR. PETERSON: Can you zoom this in a
22 little bit. There you go. Thank you. Can we

1 turn to Page 3 of this document, please.

2 Q Your CV says that you received a -- is
3 that a Bachelor of Tech from the Indian Institute
4 of Technology?

5 Is that correct?

6 A Yes, it is equivalent to B.S. in the U.S.

7 Q And you received a master's from the
8 University of Illinois in electrical engineering
9 in 1981.

10 Is that correct?

11 A Yes.

12 Q And a Ph.D. in electrical engineering
13 from the University of Illinois in 1983.

14 Is that correct?

15 A Yes.

16 Q And what is your current position?

17 A I am the Cockrell Family Regents Chair
18 Professor in electrical and computer engineering
19 at the University of Texas at Austin.

20 But here it also says I am the director
21 of the Microelectronics Center. I stepped down
22 from that position in January 2025.

1 Q So this Cockrell Family Regents Chair is
2 at the University of Austin?

3 A University of Texas at Austin.

4 Q University of Texas at Austin.

5 What are your responsibilities in that
6 role?

7 A I teach classes on semiconductor device
8 physics, semiconductor processing. I raise
9 research funding. I supervise graduate students
10 and postdoctoral fellows. And while I was
11 director I was also managing the clean room where
12 devices are made and managing the technicians
13 where we do the research.

14 Q Does this role involve solar panels at
15 all?

16 A It involves making solar cells with a --

17 Q You said -- do you make solar cells?

18 A Yes, we make solar cells, but we do not
19 make complete panels. It is not a manufacturing.

20 Q What would you consider the difference
21 between a solar cell and a complete panel?

22 A In a solar panel you take multiple solar

1 cells and string them together in series, in
2 parallel, to get the appropriate outputs, and then
3 encapsulate them so that they can withstand the
4 environment.

5 Q I'm just going to go through your
6 previous positions quickly.

7 It says you worked at Texas Instruments
8 from 1983 to 1987. What was your role there?

9 A I was part of the team that worked on the
10 world's first 4-megabit DRAM, D-R-A-M, that's
11 dynamic random access memory. And in that role I
12 worked on polysilicon devices.

13 Q Polysilicon chips or solar cells?

14 A No, not solar cells. These are memory
15 devices. Some of them involved polysilicon
16 thin-film transistors.

17 Q Is this the only company that you worked
18 at outside of academia?

19 A Yes, but I've consulted with many
20 companies over the years.

21 Q So then next it says University of Texas,
22 Assistant Professor, from 1987 to 1990.

1 Is that correct?

2 A Yes.

3 Q And what was your role in that position?

4 A Teaching, research, and fighting for
5 tenure.

6 Q What classes did you teach?

7 A I've been teaching basically the same two
8 classes, one on semiconductor device physics where
9 we talk about p-n junctions, solar cells.

10 And then I also teach the device
11 fabrication class, where I talk about the theory
12 of how devices such as p-n junctions can be made
13 which can be used in solar cells. But we don't
14 make solar cells per se in that class.

15 I've also in the past taught a graduate
16 course on silicon device physics, where we talk
17 about aspects such as tunneling, transport,
18 recombination, generation, and things like that.

19 Q Was that all in your role as assistant
20 professor? Are you listing classes that you have
21 taught across your career at the University of
22 Texas?

1 A I've been teaching, like I said,
2 basically those three courses all my life.

3 More recently, over the last I guess
4 decade or two, I have not been teaching the
5 graduate course on silicon data physics; I've been
6 focusing on the course on semiconductor device
7 physics and semiconductor device fabrication,
8 which is both theory and a lab.

9 Q When did you start, first start teaching
10 about solar panels?

11 MS. BÖLL: Object to form.

12 A So we don't -- so the course that I
13 started teaching in 1987 was on semiconductor
14 devices, where we cover devices such as p-n
15 junctions, transistors, and solar cells. And I've
16 been teaching that ever since.

17 Q And you said that you make solar cells in
18 the lab.

19 Is that correct?

20 A In the course of my research on solar,
21 yes.

22 Q When did you first start making solar

1 cells over the course of your research?

2 A I made solar cells I believe early two
3 thousand -- started working on them I think late
4 2000s, and then early 2010 time frame. But a lot
5 of the relevant technologies for that I started
6 working on way before that.

7 For example, I have worked on polysilicon
8 emitters, polysilicon and amorphous on oxide p-n
9 junctions from the 1990s, I believe.

10 I've also worked on physics of tunneling
11 to thin oxides. Once again I have to look at my
12 CV, but I am tempted to say from the 1990s.

13 Q And that was related to transistors.

14 Correct?

15 A The initial work for polysilicon doping
16 was for p-n junctions and poly emitter bipolar
17 transistors. And the tunneling work was also
18 related to transistors, yes.

19 Q Do you know when exactly in the late
20 2000s you started working on your first solar
21 cells?

22 A I just looked at my CV recently. I

1 believe our first publications on solar cells were
2 around 2011. But it takes a few years before --
3 when you start working on a subject, before you
4 can start publishing on it. So I don't remember
5 exactly when we started, but I am tempted to say
6 it's got to be a few years before that.

7 But as I told you a few minutes back, a
8 lot of the relevant technologies, such as making
9 p-n junctions which are used in solar cells, or
10 more specifically poly emitter p-n junctions which
11 can also be used in solar cells, those I've worked
12 on since the 1990s.

13 Q Yeah, I got that. I'm just trying to
14 figure out when the first solar cell you worked on
15 was.

16 So would you say that would be 2008,
17 2009.

18 MS. BÖLL: Object to form.

19 A I don't recall exactly when we started
20 working on it, but as I said, I think my first
21 publication on silicon solar cells is around 2011.
22 And since it takes three, four years to get

1 publishable results, probably around that time
2 frame, 2008 maybe.

3 MR. PETERSON: Can we go back to Page 1
4 of this exhibit, please.

5 Q This page lists your selected recent
6 testifying experience. Correct?

7 A A little bit outdated, I've had a few
8 more since then, but it's more or less correct.

9 Q I mean, do you know what is missing off
10 of this?

11 A So it doesn't list case that I talked
12 about that I -- the deposition that I did in 2024.
13 That's not listed over here. That's not related
14 to solar cells.

15 And then if you can scroll up, please.
16 Let's see.

17 A/V TECHNICIAN: Let me know if you want
18 me to zoom in, Doctor.

19 MR. PETERSON: No. I'm fine.

20 A I'm working on some of the cases that are
21 currently in progress that I'm not listing.

22 Q Are these cases related to solar cells?

1 A Yes.

2 Q And are they district court cases or IPRs
3 or ITC cases?

4 A They are IPRs. I think one of them may
5 also be at the district court, though I have not
6 done any work for that specifically.

7 Q Do you recall who the parties are in
8 those cases?

9 MS. BÖLL: Sanjay, I just want to caution
10 you not to reveal confidential information in your
11 response.

12 MR. PETERSON: I'm just trying to get the
13 same information that's listed on the CV here.

14 MS. BÖLL: Understood.

15 Q Can you answer the question,
16 Dr. Banerjee, without revealing confidential
17 information, of course.

18 A Yes, what I'm not sure about is for
19 ongoing cases, what's stipulated in my engagement
20 letters. So that's why I am hesitating.

21 Q I certainly do not want you to reveal
22 confidential information. If you can answer the

1 question, go ahead. If you can't, then that's
2 fine.

3 A No. I think I'll respectfully decline.

4 Q Okay. That's fine.

5 So AGST versus CanSolar, is that Canadian
6 Solar, your client for the current case?

7 A Yes.

8 Q And you testified in the ITC for them in
9 2022.

10 Is that correct?

11 A Actually, I was adverse to CanSolar in
12 that particular case. So I've underlined the
13 parties that I was representing.

14 Q Oh, okay. That helps. Thank you.

15 And then the second case -- this goes in
16 chronological order. Correct?

17 A Reverse chronological.

18 Q Right. And the second case down, do you
19 remember what technology that related to?

20 A Yes. That was a power transistor
21 technology, vertical power transistor.

22 Interestingly enough, there was polysilicon doped

1 films involved in that case also, but it wasn't
2 solar.

3 Q How about the third case down here; do
4 you recall what technology that related to?

5 A Once again polysilicon, but for thin-film
6 transistors.

7 Q Okay. And how about Solaria versus
8 CanSolar; I imagine that was probably solar cells?

9 A Yes.

10 Q Do you remember what type of solar cells?

11 A I don't.

12 Q And then the next one down is, is it
13 LONGi --

14 A Yes.

15 Q -- Solar --

16 A Yes.

17 Q -- versus Hanhwa?

18 I imagine that was a solar panel case?

19 A Yes.

20 Q How about Number 6; do you remember what
21 that technology was in that case?

22 A No. I've forgotten.

1 Q How about BitMicro versus Samsung?

2 A They all had to do with semiconductor
3 devices, such as transistors, CMOS, solar cells,
4 device physics, fabrication processing. Those are
5 my core areas of expertise.

6 Q So was the LONGi Solar versus Hanhwa, was
7 that the first solar case that you worked on?

8 A It looks like it.

9 Q And that was in 2019. Correct?

10 A Yeah, that -- that -- I think that's
11 true. Yeah.

12 Q It looks like you won at the ITC,
13 congratulations.

14 A Thank you.

15 Q Other than what we have just discussed,
16 do you have any experience with solar panels?

17 MS. BÖLL: Object to form.

18 A So a lot of the work at the University of
19 Texas that I've done has been in concert with a
20 startup whose advisory board I am on. The name of
21 the startup was called AstroWatt, but they have
22 now gone belly-up. They have evolved in another

1 form, And I am also involved with that.

2 So I help them do a lot of the basic R&D
3 in our lab, but they took some of the technology,
4 and I believe they did put them in panels to test
5 for long-term reliability. But my involvement
6 with that was very nominal.

7 Q I didn't catch the name of the company.

8 What was the name?

9 A A-S-T-R-O-W-A-T-T.

10 Q Oh, AstroWatt.

11 And when did you first start working with
12 AstroWatt?

13 A It would be prior to our first papers on
14 solar cells, so probably -- I'm guessing now -- I
15 think around 2008, 2009 time frame, perhaps.

16 Q Okay. Other than that, have you done any
17 other work with solar panels?

18 A Not personally. However, I was involved
19 in a big Department of Energy multi-university
20 program headquartered at Stanford and Berkeley.
21 This is known as the Bay Area Photovoltaic
22 Consortium Effort. It's listed in my CV under

1 research grants.

2 So there are six thrusts in that effort,
3 involving many universities across the U.S. They
4 asked me to lead the silicon thrust. So in
5 addition to my own research, there are other
6 research projects by other faculty. Some of it
7 dealt with solar panels, so I was exposed to
8 relevant research in that context as the head of
9 that thrust.

10 MR. PETERSON: Can you scroll down to
11 Page 11 of this exhibit, please.

12 Q Is that what you were just talking about
13 at the top of this page, the Bay Area PV
14 Consortium?

15 A That's correct.

16 Q So that was from 2015 to 2017.

17 Is that correct?

18 A It looks like it.

19 Q Have you done any other work on solar
20 panels other than what you've already testified
21 to?

22 A Once again, I did not work on solar

1 panels myself, as I told you. But the research
2 thrust involving multiple projects that I was sort
3 of overseeing, if you will, some of the other
4 faculty did work on solar panels.

5 Q Anything else?

6 A No.

7 MR. PETERSON: Can we pull up the exhibit
8 that's named IPR2024-01040, Exhibit 1003,
9 Declaration of Sanjay Banerjee.

10 (IPR2024-0104 Exhibit 1003, previously
11 marked, not attached.)

12 Q Dr. Banerjee, have you seen this document
13 before?

14 A Yes.

15 Q And what is this document?

16 A It is my declaration regarding the '053
17 patent.

18 Q Now, '053, that refers to the U.S. Patent
19 No. 8,878,053. Correct?

20 A That's correct.

21 Q And I take it you're okay with us
22 referring to that as the '053 patent?

1 A Yes.

2 Q At a high level, can you tell me what the
3 '053 patent relates to?

4 MS. BÖLL: Object to form.

5 A So the '053 is a method patent regarding
6 making solar cells with a back junction and front
7 contact and back contact with textured surface,
8 front surfaces.

9 Q Have you ever heard the term "1-sun solar
10 cell"?

11 A 1-sun?

12 Q Yeah.

13 A Not specifically. But I can hazard a
14 guess.

15 Q Well, have you heard of the term
16 "concentrator solar cell"?

17 A Yes.

18 Q Does the '053 patent relate to a
19 concentrator solar cell?

20 MS. BÖLL: Object to form.

21 A (No response.)

22 Q Dr. Banerjee?

1 A Yes, I'm looking at the patent.

2 Whether a solar cell is used under
3 1-sun -- people sometimes call that air mass 1.5,
4 perhaps -- or concentrator, the underlying device
5 structure of the solar cell is very similar in the
6 concept that it simply uses mirrors to concentrate
7 the sunlight over a large area and focus it onto
8 the solar cell.

9 So the '053 is, in my opinion, agnostic
10 as to whether it will be used under 1-sun or under
11 concentrated conditions.

12 Q So what is your understanding what the
13 term "1-sun" means?

14 A I have not heard of the term 1-sun
15 specifically.

16 I believe what you will be referring to
17 is what's often known as air mass 1. So when the
18 sun is traversing across the sky, it gets -- if
19 you're in outer space, there is no atmosphere to
20 absorb the sunlight, so that's called AM 0.

21 But at noon when the sun is at its
22 zenith, the sun is going through the atmosphere,

1 the sun absorption of the sunlight, I believe that
2 is called air mass 1. I think that's what you are
3 referring to as 1-sun.

4 But then the sun is not at the zenith
5 throughout the day. So very often people will
6 take the average solar output roughly at, say, the
7 sun is roughly at 45 degrees with respect to the
8 normal to the surface, and that's called air mass
9 1.5.

10 Q So what technology do you think the '053
11 patent relates to?

12 MS. BÖLL: Object to form.

13 A As I told you, I believe it's agnostic as
14 to whether you use that 1-sun. I am assuming that
15 refers to air mass 1 or air mass 1.5 without
16 concentrators, or under concentrated conditions.

17 Q Are there differences between a 1-sun
18 solar cell and a concentrator solar cell?

19 A In a concentrator solar cell you would
20 have mirrors, concave mirrors, which would focus
21 the sunlight over a large area. And you put a
22 small area solar cell at the focal point of the

1 mirror, and then you have typically motors so that
2 during the course of the day it will track the sun
3 so it will capture the maximum amount of solar
4 power while in a non -- in a 1-sun solar cell you
5 don't use mirrors, so you capture the sunlight
6 using large area solar cells.

7 Q In the solar cells themselves --
8 forgetting the mirrors and motors and the other
9 things, the solar cells themselves -- are there
10 differences between a 1-sun solar cell and a
11 concentrator solar cell?

12 A That's a pretty broad question, so you
13 would have to show me specific art to see if there
14 are any maybe differences in the details.

15 Q Do concentrator solar cells work at
16 higher temperatures?

17 A In general, yes, because the -- depending
18 on how much you concentrate the sunlight, there
19 could be heating of the substrate.

20 Q Are there differences in concentrator
21 solar cells versus 1-sun based on the heat
22 differences between the concentrator solar cell

1 and 1-sun?

2 MS. BÖLL: Object to form.

3 A What you are asking is a very broad
4 question, and you have to show me specific art to
5 answer that specifically. But in broad terms you
6 could use a 1-sun solar cell even under
7 concentrator conditions. The efficiency numbers
8 will change for the reasons I mentioned, vis-à-vis
9 the heating of the substrate.

10 Q You mean by efficiency numbers?

11 A Yeah.

12 Q No. When you say the efficiency numbers
13 may change, what do you mean by that?

14 A Oh, efficiency refers to what fraction of
15 the incident sunlight is being converted into
16 electrical energy.

17 Q And why would that be different between a
18 1-sun solar cell and a concentrator solar cell?

19 MS. BÖLL: Object to form.

20 A There can be multiple reasons.

21 So one reason is what I just mentioned,
22 which is at high concentrations the solar cell

1 would heat up, perhaps, depending on how much
2 concentrating you are doing. And that would
3 increase your so-called intrinsic carrier
4 concentration, which can then impact the reverse
5 saturation current J_0 . That will then
6 impact the open circuit voltage.

7 There can be also at very high
8 temperatures something called bandgap narrowing.
9 And then, finally, you could also have things like
10 at high -- high photon fluxes, you could get
11 effects such as Auger recombination processes.
12 Which would still be present at 1-sun, but it
13 might be present to a greater degree when you
14 concentrate the sunlight.

15 But in my opinion, '053 is agnostic as to
16 whether it's used under 1-sun or under
17 concentrator conditions. There will be
18 differences of the efficiency, but it's not as if
19 it will not work under concentrator or it will not
20 work under 1-sun.

21 Q Would a concentrator solar cell need much
22 lower resistances than a 1-sun solar cell to

1 perform well?

2 MS. BÖLL: Object to form.

3 A I think if you show me specific art that
4 you have in mind. But in general I can tell you,
5 you always want as low of a resistance as possible
6 in a solar cell because if you have a high
7 resistance you get a poor fill factor, and that
8 decreases efficiency.

9 MR. PETERSON: Can you turn to Paragraph
10 32 of this report, please.

11 Q Do you see Paragraph 32?

12 A Yes.

13 Q This paragraph describes the
14 considerations that -- strike that.

15 Have you ever heard the term or acronym
16 "POSITA," P-O-S-I-T-A?

17 A Yes.

18 Q And what is your understanding of what
19 the term "POSITA" means?

20 A Personal of ordinary skill in the art.

21 Q Paragraph 32 describes the considerations
22 that a POSITA would consider when determining

1 whether a patent is obvious. Correct?

2 A Yes.

3 Q And on the top of Page 9 do you see a
4 four-factor list?

5 A Yes.

6 Q And are these the factors a POSITA must
7 consider when determining whether a patent is
8 obvious?

9 MS. BÖLL: Object to form.

10 A As I told you, I'm not a lawyer, so this
11 is --

12 Q I'm not asking for your legal opinion.
13 I'm just trying to walk through these and ask
14 about your declaration related to these factors.

15 A Okay. What is your question? Sorry.

16 Q Are these four factors the factors that a
17 POSITA must consider when determining whether a
18 patent is obvious?

19 MS. BÖLL: Object to form.

20 A Yes.

21 Q The first factor is the scope and content
22 of the prior art. Correct?

1 A Yes.

2 Q And does your declaration cover the scope
3 and content of the prior art?

4 A I believe so.

5 Q How?

6 A You said how?

7 Q Yeah.

8 A I gave summaries of the cited prior art
9 in my declaration, and I tried to enunciate the
10 scope and the content in the relevant paragraphs.

11 Q Second factor is the differences between
12 the prior art and the claims at issue. Correct?

13 A Yes.

14 Q Does your declaration cover the
15 differences between the prior art and the claims
16 at issue?

17 A Yes.

18 Q Do you understand the term
19 "anticipation"?

20 A Yes.

21 Q What does anticipation mean to you?

22 A Sorry?

1 Q And what does the term "anticipation"
2 mean to you?

3 MS. BÖLL: Object to form.

4 A So it's described in Paragraph 22 onwards
5 of my declaration.

6 So for a claim to be anticipated by the
7 prior art, each and every requirement of the claim
8 must be found expressly or inherently in a single
9 prior art reference as recited in the claim.

10 Q Okay. In your opinion, does any of the
11 prior art cited in your declaration anticipate any
12 of the claims of the '053 patent?

13 A No; we only made obviousness arguments.

14 Q Is that the same for the '516 patent?

15 A That's correct.

16 Q And that's because none of the prior art
17 teach every single element of each claim.

18 Correct?

19 MS. BÖLL: Object to form.

20 A None of the prior art that I found show
21 that. I mean, there may be other prior art that I
22 might have missed.

1 Q Are you aware of any other prior art that
2 anticipates any of the claims of the '053 patent?

3 A No, not sitting over here.

4 Q How about the '516 patent?

5 A No.

6 Q And the third factor is the knowledge of
7 a person of ordinary skill in the art. Correct?

8 A Yes.

9 Q Actually, pertinent art, it says.

10 What would you consider the pertinent art
11 to be in this case?

12 A I describe that in Paragraph 45 of my
13 declaration. So this would be someone who would
14 have an advanced degree in electrical engineering,
15 applied physics, chemistry and field science, and
16 at least two years experience designing,
17 developing, or researching in the field of solar
18 design, solar cell design or manufacture, circa
19 2008, or he or she could have a bachelor's with at
20 least three years experience.

21 Q So what is the pertinent art? Is it
22 solar cell design and manufacturing?

1 MS. BÖLL: Object to form.

2 A It's solar cell design or manufacturing.

3 Q Are you aware of the term "priority
4 date"?

5 A Yes.

6 Q And what is it?

7 A That's the earliest date that a patent
8 can claim priority to -- that's a circular
9 statement. That can, I guess, lay claim to, if
10 you will.

11 Q So it's the date of filing of the
12 earliest patent application. Correct?

13 MS. BÖLL: Object to form.

14 A Yes, I believe that's true.

15 Q So this third factor, the knowledge of
16 person of ordinary skill in the pertinent art,
17 that's the knowledge as of the priority date.

18 Correct?

19 A I think that's true.

20 Q And you didn't find any art that
21 anticipated the claims of the '053 or the '516
22 patent as of the priority date. Correct?

1 A I did not.

2 Q Have you found any actual solar panels
3 that would anticipate the '053 or '516 patent as
4 of the priority date?

5 MS. BÖLL: Object to form. Object to
6 scope.

7 A I did not look for any, and I did not
8 find any.

9 Q Sir, do you have any evidence that a
10 POSITA would have known how to create solar cells
11 covered by the claims of the '053 or '516 patent
12 as of the priority date?

13 MS. BÖLL: Object to form.

14 A Yeah, I believe a POSITA would take
15 combinations of the cited prior art to come up
16 with the claims that are being challenged.

17 Q Other than the combinations in the prior
18 art that you suggested, do you have any evidence?

19 A Not --

20 MS. BÖLL: Object to form.

21 A Not sitting over here, no.

22 Q And the fourth factor is whatever

1 objective factors indicating obviousness or
2 nonobviousness that may be present for any
3 particular case. Correct?

4 A Yes.

5 Q And your declaration discusses two
6 objective factors that you say support
7 nonobviousness -- or obviousness. Correct?

8 A Yes.

9 Q I believe it's the last two sections of
10 your declaration.

11 A That's correct.

12 Q And you listed these factors as, No
13 commercial success attributable to the '053 patent
14 and no evidence of unexpected results.

15 Correct?

16 A That's correct.

17 Q And that's the same for the '516 patent.
18 Correct?

19 A I think so.

20 Q At this time, are you aware of any other
21 factors indicating obviousness or nonobviousness?

22 A No, not at this time.

1 Q Are you familiar with the term "high-low
2 junction"?

3 A Yes.

4 Q And what does this term mean to you?

5 A High-low junction is different from a p-n
6 junction in the sense that it is the same doping
7 type, either donors or acceptors, but at two
8 different concentrations.

9 Q Does it always have to be the same dopant
10 type?

11 A For it to qualify as a high-low junction,
12 yes.

13 Q Why?

14 A That's my understanding of that term,
15 based on my experience.

16 Q Can you turn to Paragraph 52 of your
17 declaration, please.

18 Okay. This paragraph discusses Figure 4B
19 of the '053 and '516 patents. Correct?

20 A Yes.

21 Q And just to be clear, Figure 4B is the
22 same in the '053 and '516 patents. Correct?

1 A Yes.

2 Q This paragraph says the tunnel oxides,
3 107, 402, are thermally grown on the front and
4 back surfaces, and polysilicon layers 108/401 are
5 formed on the tunnel oxide layers. Right?

6 A Yes.

7 Q So this is describing a tunnel oxide
8 layer between the silicon and polysilicon layers.
9 Correct?

10 A Yes.

11 Q Do you know what a tunneling layer is?

12 A Yes. I've been working on tunneling
13 oxides since the 1990s, perhaps.

14 Q Can you tell us what a tunneling oxide
15 layer is?

16 MS. BÖLL: Object to form.

17 Q Strike that.

18 Can you tell us what a tunnel oxide layer
19 is?

20 A Yes.

21 MS. BÖLL: Object to form.

22 Q And what is it?

1 A So a tunneling is a quantum mechanical
2 phenomenon which involves taking into account the
3 wave properties of matter, in this case electrons.

4 So when electron hits a potential energy
5 barrier, in this case presented by the tunnel
6 oxide such as silicon dioxide which has a very
7 large bandgap, classically that electron would
8 reflect back from the barrier if it did not have
9 enough kinetic energy to surmount the barrier.

10 But quantum mechanically you think of it
11 as a wave, where the tunnel barrier is like a
12 semitransparent or a translucent barrier, with the
13 finite reflection probability, but also finite
14 transmission probability.

15 So that electron with a kinetic energy
16 less than the potential barrier -- potential
17 energy in the tunneling barrier classically would
18 not be able to go through. Because that would
19 involve negative kinetic energies, which are
20 nonsensical from a classical point of view, but
21 quantum mechanically can penetrate through. And
22 that's what tunneling is.

1 Q So do tunnel oxide layers require certain
2 thickness in order to be effective at tunnelling?

3 A The published theory and experimental
4 papers on tunneling for probably 30, 40 years,
5 yes. And the answer is yes.

6 Q Do you know roughly what thickness would
7 have to be?

8 A That depends on the type of tunneling
9 barrier, specifically the height of the barrier.
10 The smaller the height, the thicker of the barrier
11 you can have.

12 So thinner the barrier, the more
13 tunneling probability. Lower the barrier, the
14 more tunneling probability. And generally there
15 is an exponential dependence of the tunneling
16 probability on the tunnel barrier thickness.

17 So you get tunneling even for thick
18 oxides. But to get significant tunneling in the
19 case of silicon dioxide on silicon, you know, you
20 need about maybe 1 to 4 nanometers, that's 10
21 angstroms or 40 angstroms.

22 But you can get tunneling even beyond

1 that, but maybe not high enough to be useful for
2 your application.

3 Q What happens if the silicon oxide layer
4 is too thin? Does that prevent tunneling?

5 A No.

6 MS. BÖLL: Objection. Form.

7 A No. The thinner the barrier, more is the
8 tunneling probability. But if you make it too
9 thin, the oxide may not grow uniformly. So that's
10 why if it's too thin, it goes through so easily
11 that it's very often not really useful.

12 Q Why wouldn't it be useful?

13 A That depends on the context of what
14 you're trying to achieve.

15 Q I'm just asking because you said it
16 wouldn't be useful. So I was just wondering what
17 you meant by that?

18 A Presumably you're putting in the tunnel
19 barrier to block the transport of one type of
20 carrier or the other. If the tunnel oxide is very
21 thin, the barrier may not form uniformly, you may
22 have pinholes or defects. And that can basically

1 lead to a short circuit between the two electrodes
2 on either side of the tunnel barrier.

3 Q So you said "pinholes or defects." What
4 do you mean by defects?

5 A Defects could be incompletely formed
6 tunnel oxides where the -- or maybe the -- maybe
7 the nominal thickness may be 10 angstroms but in
8 certain locations it may be 1 angstrom or zero
9 angstroms.

10 Q Would that also include broken tunnel
11 oxides?

12 MS. BÖLL: Object to form.

13 A I mean, if you do heat treatment of these
14 oxides as some of the cited prior art discusses,
15 you could break the oxide at certain locations.
16 And depending on the context, it may or may not
17 matter.

18 Q So let's get into that a little bit.

19 What prior art are you talking about when
20 you're talking about breaking the tunnel oxide?

21 A I believe --

22 MS. BÖLL: Object to form.

1 A I believe I cited Gan and Kwark among
2 others in that context.

3 Q And so Gan and Kwark.

4 Do Gan and Kwark both start with a tunnel
5 oxide and breaking, do you know?

6 MS. BÖLL: Object to form.

7 A Well, both of them I believe start with
8 the tunnel oxide, and then they do experiments
9 where they do heat treatments at gradually
10 increasing temperatures. And let me look at Gan
11 and Kwark as we speak.

12 So they do experiments of doing anneals
13 at different temperatures or times. And in
14 general the higher the temperature or longer the
15 anneal time, there will be a greater propensity
16 towards rupturing the oxide at certain locations
17 but retaining that in other locations.

18 Q And what is the effect of rupturing the
19 oxide?

20 A So as Gan and Kwark discuss, if you
21 rupture the oxide -- I'm looking at, for example,
22 Paragraph 95 of the '053 report, '053 declaration.

1 And there is a Figure 4 from --

2 Q I'm sorry, what paragraph is that?

3 A Paragraph 95 of the '053 declaration.

4 MR. PETERSON: Can we -- can we turn to
5 that paragraph, please, so we can all see it.

6 There is a figure below. Can you turn.

7 Q This is the figure you're discussing?

8 A No. I said Paragraph 95.

9 Q Oh, 95.

10 A Figure 4, of Kwark.

11 Q There you go. Okay.

12 A Yeah.

13 Q So what were you saying about this
14 figure?

15 A Yeah. So in this experiment they're
16 growing an oxide, a tunnel oxide. And then
17 they're doing heat treatments of the oxide.

18 And as the anneal temperature increases,
19 you see that the J nought, which is an indirect
20 measure of how much of the oxide might have been
21 broken up, indicates that as J nought increases
22 with high temperatures, it implies that it's

1 breaking up more and more of the oxide while
2 retaining that in other locations.

3 As you can see even at the highest
4 temperature of 1000 degrees centigrade, even if
5 there is some oxide breakup, it's still a lower J
6 nought than for the no chemox case without a
7 tunneling barrier, so you retain advantages of
8 having that oxide.

9 Q How do you know that Kwark is starting
10 with the tunnel oxide?

11 A When you grow an oxide SiO_2 , it's well
12 known to be an insulator with an energy bandgap of
13 around 9 electron volts. Silicon or polysilicon,
14 on the other hand, has a bandgap of around 1.1
15 electron volts.

16 So when you align the structures of
17 silicon or polysilicon on either side of the
18 (indiscernible) you get a so-called energy band
19 diagram, which I believe was shown in other places
20 in Kwark and Gan, indicating a rectangular
21 potential energy barrier. That would be the
22 tunnel barrier.

1 Q So do you know the thickness of the
2 silicon dioxide layer in Kwark?

3 A I don't recall offhand, but I'm sure it's
4 described.

5 If you put up Kwark, and I can tell you.

6 MR. PETERSON: Can we pull up Exhibit
7 IPR2024-01040, Exhibit 1008, please.

8 (IPR2024-01040 Exhibit 1008, previously
9 marked, not attached.)

10 Q Did you want to direct us to anyplace in
11 particular in this exhibit?

12 A I'm looking at a hard copy of Kwark.

13 Q I'm sorry, I couldn't hear that.

14 A I'm looking at the hard copy of Kwark
15 that you sent me.

16 I don't see any thicknesses mentioned in
17 Kwark. But the Gan prior art that I also cited
18 had a thickness of around 20 angstroms that I had
19 mentioned in ...

20 Q We'll get to Gan. I am just asking about
21 Kwark right now.

22 A Yeah, I don't see oxide thickness is

1 mentioned. But it's got to be in the range we
2 talked about earlier, which is 10, 20 angstrom is
3 angstrom range perhaps.

4 Q Why does it have to be in that range?

5 A That's based on my general knowledge of
6 the field. When you grow these chemical oxides,
7 it tends to sort of fall into roughly that range.

8 Q In order to have the tunneling
9 properties. Correct?

10 MS. BÖLL: Object to form.

11 A Yeah, it's a function of the process that
12 you are using and to be able to have proper
13 tunneling characteristics.

14 Q And what process is Kwark using, do you
15 know?

16 A Kwark uses what's called chemical oxide,
17 which often involves using so-called ozonated DI
18 water, deionized water. And the way you generate
19 the ozone is through UV exposure, ultraviolet
20 light exposure.

21 The ozone, which is O₃, is chemically
22 quite reactive and will react with the silicon to

1 form silicon dioxide.

2 Q Then how do you -- how would one of skill
3 in the art grow this chemox layer to a certain
4 thickness?

5 A I misspoke. So I am looking at -- so
6 what I told you is true in general. And other
7 prior art uses UV/ozonated chemical oxide. But in
8 this case Kwark is growing a chemical oxide.

9 Q Can you point us to what you're looking
10 at, please?

11 A Yeah, I am looking at the Kwark document
12 on Page 743. The first column.

13 MR. PETERSON: Can we turn the exhibit on
14 the screen to Page 743, please.

15 Can we zoom in, please.

16 A Yeah, so it's in the first column. If
17 you scroll up a little bit.

18 Q It's in that second paragraph.

19 A Right. Where it talks about the RCA
20 clean.

21 MR. PETERSON: Scroll up a little bit so
22 we can see the whole second paragraph, or as much

1 as of it as you can get.

2 There you go.

3 A So it's very standard procedure to clean
4 silicon wafers with this so-called RCA clean,
5 which, by the way, I've been using for 30, 40
6 years. And an outcome of that cleaning process is
7 you will end up growing this chemical oxide on the
8 surface. So that's what they are using in this
9 particular example.

10 And for the control case of no chemical
11 oxide, they are etching off this chemical oxide
12 with hydrofluoric acid, HF. But in other art they
13 use the UV ozone technique that I described a few
14 minutes earlier.

15 Q So does this describe how long they used
16 the RCA -- was it RCA?

17 A Yes.

18 Q -- RCA for or any other values that would
19 lead you to believe, or would lead you to
20 understand what the thickness is of this chemox
21 layer?

22 MS. BÖLL: Object to form.

1 MR. PETERSON: Yeah, that was a bad
2 question. Strike that.

3 Q Does Kwark list any parameters related to
4 this RCA clean step?

5 A Kwark doesn't, but RCA cleans are very
6 well known in the art. And there is a range of
7 temperatures and times and chemical recipes that
8 are used that I teach my undergrad students in my
9 class.

10 Q So would everybody in the art use the
11 exact same steps to get the exact same thicknesses
12 for this oxide layer?

13 A So there is not an exact temperature,
14 exact time. There is a range of temperatures and
15 times.

16 Q Right. And you would use different
17 temperatures and times to get different
18 thicknesses. Correct?

19 A That's correct. However, as I told you,
20 the variation of those thicknesses is not going to
21 be large. It will be sort of in the range of 10
22 to 20 angstrom range. You will not be growing a

1 thousand-angstrom oxide with this technique.

2 Q Well, that's if you want to get
3 tunneling. Correct?

4 MS. BÖLL: Object to form.

5 A If you didn't want to get tunneling, if
6 you wanted to do RCA cleans, regardless of what
7 parameters you use, you will not be able to get
8 very thick oxides. I mean, suppose you had an
9 application which wanted to inhibit tunneling.
10 This RCA clean recipe will not be able to achieve
11 that.

12 Q Okay.

13 MR. PETERSON: We've been going for over
14 an hour here. So do you want to take a break?

15 THE WITNESS: Yes, please.

16 (A recess was taken.)

17 BY MR. PETERSON:

18 Q So I just want to make sure I've got your
19 testimony correct, Dr. Banerjee.

20 Are you saying that this chemox layer
21 described by Kwark is a tunnel oxide layer?

22 A Yes.

1 Q Would any silicon dioxide layer between
2 the -- a silicon layer and a polysilicon layer act
3 as a tunnel oxide?

4 MS. BÖLL: Object to form.

5 A Yes, a silicon dioxide layer would act as
6 a tunnel oxide, provided it was thin enough. As I
7 told you, tunneling probability decreases
8 exponentially with the barrier thickness. So if
9 you made it very thick you would still get
10 tunneling, but it would not be of any practical
11 use.

12 Q So Gan and Kwark describe breaking up
13 this tunnel oxide layer. Correct?

14 MS. BÖLL: Object to form.

15 A Gan and Kwark describe processing the
16 tunnel oxide at different temperatures. At the
17 low temperature range there will not be any
18 significant breakup. But higher the temperature
19 and longer the annealing time, it will be
20 progressively more and more breakup. It's not a
21 sudden process where it's not broken at all, and
22 then all of the sudden it breaks up completely.

1 It's sort of a continuum, as Figure 4 of Kwark
2 shows you.

3 Q So as this -- as this breakup is getting
4 more progressive, is the tunnel oxide layer still
5 acting as a tunnel oxide layer?

6 A So if it breaks up, what you have are
7 regions where you have the tunnel oxide present
8 and regions where it's ruptured, maybe partially
9 or maybe completely.

10 You can then think of the overall device
11 simplistically as two parallel devices, one with
12 the tunnel oxide in parallel with regions, a small
13 region where this oxide may or may not have broken
14 up fully or partially.

15 And as it happens, as there's more and
16 more breakup, a larger and larger fraction of the
17 area would have broken up oxides. And that's
18 reflected by this J nought E in Figure 4 of Kwark
19 progressively increasing.

20 But even if it breaks up by showing the
21 comparison with no chemox, where there is no
22 tunnel oxide, but a POSA would learn from this

1 that even for broken-up oxides there is still some
2 tunnel oxide left behind, which gives you
3 advantages. Because the one with the tunnel
4 oxide, even if it's broken up, has a lower J
5 nought than the no chemox case.

6 Q So the electrons wouldn't just go through
7 the breaks in a path of least resistance?

8 MS. BÖLL: Object to form.

9 A So what ends up happening is, you know,
10 the electrons are impinging on this barrier
11 everywhere, so they do take the path of least
12 resistance.

13 But just imagine I have an oxide which
14 is, say, 95 percent intact and there are small
15 pinholes in certain locations. For that electron
16 to go through those small pinholes, you are right,
17 it would have lower tunneling barrier. But now it
18 has to traverse over a longer distance in the
19 polysilicon, which also presents resistance.

20 So some of them would go through the
21 pinholes, but a lot of them would still go through
22 the tunnel oxide.

1 And that's why the J nought increases
2 progressively with more and more annealing
3 temperature, but it doesn't all of the sudden go
4 to the values of J nought corresponding to no
5 chemox.

6 Q Is there any temperature at which point
7 the oxide would fail to be a tunnel oxide layer?

8 MS. BÖLL: Object to form.

9 A In the temperature regime explored by
10 Kwark, which is up to highest temperature of 1000
11 degrees, clearly even at the highest temperature
12 where there is the maximum breakup, there are
13 still benefits. Because the value of the J nought
14 is still about -- a factor of what? I guess
15 significantly lower than the J nought values with
16 no chemox, so there is no tunnel oxide.

17 Q What about 1100 degrees Celsius; do we
18 know anything about that?

19 MS. BÖLL: Object to form.

20 A Kwark doesn't show any data at such a
21 high temperature.

22 Q So Kwark doesn't tell us what would

1 happen at 1100 degrees?

2 A Yeah, Kwark did not do such a high
3 temperature.

4 Q What about 1200 degrees; does Kwark tell
5 us what would happen at 1200 degrees?

6 A 1000 degrees I believe is the highest
7 that Kwark went up in. And there are still
8 benefits.

9 Q Would a POSITA looking at Kwark
10 understand what would happen at 1100 degrees?

11 A A POSITA would know in general terms that
12 if you went to 1100 there will be more breakup and
13 the J nought would be increased. But whether or
14 not that would also go to the value at chemox
15 would depend on many factors, including the
16 thickness of that oxide and the annealing time.

17 We've been talking about temperature, but
18 time is also another parameter.

19 Q So at what -- strike that.

20 Do you know at what temperature the
21 chemox would start to break up at?

22 MS. BÖLL: Object to form.

1 A Well, in the case of Kwark, it only goes
2 down to 850 degree centigrade. And then -- I'm
3 talking in the poly case.

4 So let's see. I don't see any data for
5 the poly case. But in Figure 6 of Kwark --

6 Q Hold on one second.

7 MR. PETERSON: Can we turn to Figure 6,
8 please. It's at the end of this document.

9 A Figure 6 of Kwark, if you look at the
10 lowest --

11 Q Hold on.

12 MR. PETERSON: Mr. Shankin, can we turn
13 to the end of this document, Figure 6, please.

14 Q Sorry for interrupting, Dr. Banerjee. I
15 just wanted to get us all on the same page.

16 A Sure. No problem.

17 Q Okay.

18 A So Figure 6 of Kwark shows the gamma
19 equal to 0 SIPOS case. And gamma, you'll recall,
20 is the ratio of the oxidizing gas, I believe N2O,
21 or I think silane SiH4. So gamma equal to zero
22 corresponds to poly.

1 And you will see that between 850 and 900
2 there is no difference of the J nought, and only
3 after 900 it starts going up. So from that one
4 could infer that there isn't any breakup,
5 significant breakup, below 900. It starts
6 breaking up more and more above that.

7 But there are many other parameters, as I
8 told you, and one should not draw global
9 conclusions based on that. I mean, the exact
10 thickness of the oxide, the annealing time, all
11 those things matter.

12 MR. PETERSON: Could we turn back to
13 Figure 4, please.

14 Q So Figure 4 doesn't show this same flat
15 curve between 850 and 900. Correct?

16 A I'm looking at Kwark to see what the
17 differences might have been between the experiment
18 shown in Figure 4 versus Figure 6.

19 Q Yeah. I'm just asking, Figure 4 doesn't
20 show that same flat line from 850 to 900.

21 Correct?

22 A No, it doesn't.

1 Q So would that lead one skilled in the art
2 to believe that the tunneling oxide starts
3 breaking up at least as low at 850?

4 A Probably. I mean, one really needs more
5 complete information --

6 Q Okay.

7 A -- to say that definitely.

8 But I think the key point is, regardless
9 of some degree of breakup, it's still beneficial
10 to have this oxide compared to no oxide at all.
11 That's really the key message.

12 Q Well, at least at these temperatures.
13 Correct?

14 A But even up to thousand degrees it's
15 beneficial because you get a lower J nought
16 compared to the no chemox case.

17 Q Right. But we don't know what happens
18 above a thousand degrees, you said. Correct?

19 A There is no data shown in Kwark.

20 MR. PETERSON: Can we turn back to the
21 Exhibit 1003, please.

22 Q So you said you reviewed the '053 and

1 '516 patents prior to this deposition. Correct?

2 A Yes.

3 Q And we were just talking, discussing
4 tunneling oxides. Correct?

5 A Yes.

6 Q Do the '053 and '516 patents have --
7 teach tunneling oxides?

8 A Yes.

9 Q Do they teach any other oxide between the
10 silicon layer and polysilicon layer other than the
11 tunnel oxide?

12 A I don't think so. But if you point me to
13 some location I can tell you specifically.

14 Q No, I don't think so either, that's why I
15 was asking you.

16 In the context of solar cells, would a
17 silicon dioxide layer between the silicon and
18 polysilicon layer be anything other than tunnel
19 oxide?

20 A Yeah, you could. You could have a
21 passivating oxide also.

22 Q So you could have a passivating oxide in

1 between, not letting any electricity flow between
2 the silicon and polysilicon layers?

3 A If you did, you would have to open up
4 windows in that passivating oxide, and you would
5 have the polysilicon in contact with the silicon
6 in those window regions.

7 If the passivating oxide was thin enough,
8 it could also have tunneling. But in many cases
9 passivating oxides can be too thick to allow
10 tunneling. So in that case it will do H holes in
11 the passivating oxide and have what are called
12 blind contact solar cells.

13 Q So you would have direct -- in that case
14 you would have a passivating oxide that would
15 break up, and you would have direct contact
16 between silicon and polysilicon. Correct?

17 MS. BÖLL: Object to form.

18 A Yeah, you would have the H of the
19 passivating oxide, and have the polysilicon either
20 in direct contact or a thinner tunnel oxide.

21 Q Okay. So if it was thin enough, it would
22 be a tunnel oxide. Correct?

1 A That's correct.

2 MR. PETERSON: Can we turn to Paragraph
3 59 of your declaration, please.

4 Q Do you see the claim language for Claim 9
5 here?

6 A Yes.

7 MR. PETERSON: Can you scroll down a
8 little bit so we can try to get -- yeah, that's
9 good.

10 Q So Claim 9 of the '053 patent resides, "A
11 method of fabricating a solar cell comprising
12 forming a layer of polysilicon over a back surface
13 of a silicon substrate; forming a first dopant
14 source layer over the layer of polysilicon;
15 diffusing dopants from the first dopant source
16 layer to the layer of polysilicon, to form a
17 backside junction with the silicon substrate;
18 diffusing dopants into a front surface of the
19 silicon substrate, the front surface of the
20 silicon substrate facing the sun during normal
21 operation; and forming a metal contact on the
22 front surface of the silicon substrate, wherein

1 the metal contact is electrically coupled to the
2 silicon substrate."

3 Correct?

4 A Yes.

5 Q Does this claim recite whether the dopant
6 types are P-type or N-type?

7 MS. BÖLL: Object to form.

8 A The claims don't specifically. But
9 the -- if you read the claims in light of the
10 specifications -- I know you're not supposed to be
11 limited by the specifications.

12 Q I'm just asking you whether the claim
13 does?

14 A So the claims --

15 MS. BÖLL: Counsel, can you let him
16 finish his answer, please.

17 MR. PETERSON: Well, he's not answering
18 my question.

19 A So the claims don't require the dopant
20 type. But, however, if you look at the Claim
21 Element 9.D, it does require the dopants, the
22 first dopant type to have the opposite polarity

1 compared to the dopant type of the substrate;
2 otherwise it would not form a backside junction.

3 Q Do you know whether Claim 1 recites
4 whether -- what the dopant types are?

5 A I have not looked at Claim 1 recently
6 because I don't think it was challenged.

7 Q Okay. Can you -- you said you have the
8 patents with you. Correct?

9 A Yes. Yes.

10 Yes, I see Claim 1.

11 Q Does it recite what dopant types the
12 silicon layer and the polysilicon layer?

13 A Yes, it does.

14 Q Does it also recite that it's a backside
15 junction?

16 A Yes.

17 Q But Claim 9 does not recite the dopant
18 types. Correct?

19 A Claim 9 does not. However, as I told
20 you, to form a backside junction, the first dopant
21 type must be opposite to the substrate dopant.

22 So if, for argument's sake, you say that,

1 Okay, we'll start with the P-type substrate, then
2 the backside dopant must be an N-dopant.

3 Q Okay. Do you see Claim Element 9.C?

4 A Yes.

5 Q It says, "Forming a first dopant source
6 layer over the layer of polysilicon."

7 Correct?

8 A Yes.

9 Q And then 9.D says, "Diffusing dopants
10 from the first dopant source layer to the layer of
11 polysilicon, to form a backside junction with the
12 silicon substrate."

13 Correct?

14 A Yes.

15 Q And then 9.E is where you diffuse the
16 dopants into the silicon substrate. Correct?

17 A On the front side, yes.

18 Q Yeah. So 9.D, when you're forming the
19 backside junction, the silicon doesn't have --
20 hasn't been doped. Correct?

21 MS. BÖLL: Object to form.

22 A No. The starting silicon substrate

1 already has some doping.

2 Q Where does it say that?

3 A First of all, you read this in light of
4 the specs. And a POSITA would know you start with
5 the doped silicon substrate or a base. But then
6 also if you look at Claim 9.D, let's focus on the
7 term "backside junction." So based on the
8 prosecution history, the patentee disavowed things
9 like high-low junctions. And so --

10 Q So is this your legal opinion?

11 MS. BÖLL: Counsel, again, I would ask
12 that you let him finish his answer please.

13 MR. PETERSON: I just wanted, before he
14 started getting into an area that he might not
15 want to get into, he understands that I'm going to
16 be asking him whether this is his legal opinion or
17 not.

18 Q You can finish.

19 A No, I'm not a lawyer.

20 Q Yeah.

21 A So I can read the patents and the
22 prosecution history. And my nonlegal impression

1 was backside junction refers to p-n junctions.
2 Therefore, regardless of which dopant type is your
3 first dopant type, you have to have the opposite
4 dopant type in the substrate.

5 Q Okay. So you're basing this backside
6 being opposite type dopant types based on the
7 prosecution history.

8 Is that fair?

9 MS. BÖLL: Object to form.

10 A Partly based on that.

11 Also, you have to have a p-n junction
12 somewhere in a solar cell, otherwise you cannot
13 separate the charges. So you cannot have a solar
14 cell which is entirely doped N-type or entirely
15 doped P-type.

16 Q So a high-low junction wouldn't be a
17 solar cell?

18 MS. BÖLL: Object to form.

19 A A high-low junction certainly would not
20 be a decent solar cell.

21 I mean, you may get some photoactivity.
22 But in order to separate the forward-generated

1 electrons and holes, you do need a potential
2 barrier as created by a p-n junction. So high-low
3 junction, I'm not aware of anyone using high-low
4 junctions alone to make practical solar cells.

5 I mean, you get some photoactivity, but
6 not enough to be of practical use.

7 Q So you're not aware of anyone using
8 high-low junctions alone. When you say "alone,"
9 do you mean without an oxide layer?

10 A No; without a p-n junction also.

11 Q Oh, so you're not aware of anyone that's
12 using just a high-low junction without a p-n
13 junction effectively in a solar cell.

14 Is that what you're saying?

15 MS. BÖLL: Object to form.

16 A You could have -- I haven't reviewed art
17 like that that is in the context of this
18 deposition. But you could have other types of
19 heterojunctions which would serve a similar role.

20 Q What do you mean by heterojunction?

21 A Heterojunction is two different types of
22 materials, such as two semiconductors with two

1 different bandgaps, or metal in contact with a
2 semiconductor not giving rise to an ohmic contact,
3 but a Schottky barrier. So those could be used,
4 in principle. But I'm not aware of any prior art,
5 sitting here, where those have been used.

6 Q So as you're sitting here today, you
7 think that an effective -- any effective solar
8 cell is going to have a p-n -- or a backside
9 junction. Correct?

10 MS. BÖLL: Object to form.

11 A No. Effective solar cell will have a p-n
12 junction; it could be at the front side also.

13 Q So it is going to have a p-n junction
14 either at the front side or the back side.

15 Correct?

16 A Practical solar cells with decent
17 efficiencies, I believe that's true.

18 Q So if it was on the back side, it would
19 be a backside junction. Correct?

20 MS. BÖLL: Object to form.

21 A If the p-n junction is on the back side
22 it will be a backside junction.

1 Q So when you were reading the prosecution
2 history, do you recall if the statements you're
3 referring to were referring to what's now Claim 1
4 or whether they were referring to what's now Claim
5 9?

6 A I don't recall specifically.

7 Q You don't recall?

8 A I have to look at the prosecution
9 history. But I am tempted to say it's the both,
10 but I really need to look at the prosecution
11 history.

12 Q But you don't know?

13 A I don't recall offhand, sitting here.

14 Q Do you know why Claim 1 would have the
15 types of dopants recited but not Claim 9?

16 MS. BÖLL: Object to form.

17 A So Claim 9 is going to be more flexible.
18 It's not restricted to a P-type substrate --
19 sorry, an N-type substrate or an N-type base. It
20 could also be applicable to a P-type base. But if
21 you did that, you'd also have to flip the dopant
22 type of the first dopant type, go from P-type to

1 N-type.

2 Q But couldn't this also be an N-type
3 silicon N-type polysilicon since it's not recited
4 which one is which?

5 MS. BÖLL: Objection to form.

6 A Based on what I recall from the
7 prosecution history, it could not.

8 Q But you don't know if the prosecution
9 history was based off of -- what you read was
10 related to this claim. Correct?

11 A I should look at the prosecution history.
12 But what I recall is, the disavowed high-low
13 junctions, when they're talking about the backside
14 junction they're talking about p-n junctions or
15 n-p junctions.

16 Q But my question was, you don't know
17 whether it was related to Claim 1 or Claim 9, what
18 you read in the prosecution history. Correct?

19 A I don't recall specifically, but I'm
20 tempted to say it relates to both.

21 Q You're tempted to say that what?

22 A That a backside junction has to be a p-n

1 junction.

2 Q Outside of the context of what you read
3 in the prosecution history, do you have any reason
4 to believe that?

5 A Well, as I told you, a practical p-n
6 junction with reasonable efficiencies has p-n
7 junctions somewhere, either at the front or at the
8 back.

9 MR. PETERSON: Can we turn to Page 86 of
10 this exhibit please. Paragraph 86, I'm sorry.

11 Q This paragraph relates to the prior art
12 Froitzheim reference. Correct?

13 A Yes.

14 Q And Froitzheim is the reference you used
15 as a base reference for grounds in the '053 patent
16 declaration. Correct?

17 A Some of the grounds, yes.

18 Q And the '053 declaration, did you use a
19 different reference as a base?

20 A No; I guess for it's all the grounds.

21 Okay.

22 Q And for the '516 patent you used

1 Froitzheim for some of the grounds, correct, as a
2 base?

3 A That's correct.

4 Q And the '516 patent you also used a
5 couple other references as the base. Correct?

6 A Yes.

7 Q Okay.

8 A Meier, I believe.

9 Q Yeah. And for all of those where you
10 used Froitzheim as a base in the '053 and '516,
11 you used Froitzheim for the silicon layer and the
12 doping types. Correct?

13 MS. BÖLL: Object to form.

14 Q Dr. Banerjee, are you reviewing it?

15 A We certainly used it for that.
16 Froitzheim also talks about texturizing the front
17 surface. I am just trying to see --

18 Q I am just talking about for the
19 independent claims.

20 A Okay. Yeah. Yeah, then the answer is
21 yes.

22 Q Sorry I wasn't more clear there.

1 Now, Froitzheim just uses one silicon
2 layer. Right. It doesn't have a layer of silicon
3 and polysilicon?

4 A That's correct.

5 Q Your proposal was to bring in the oxide
6 layer and polysilicon from Gan, Kwark, and Borden.
7 Correct?

8 A As alternatives, yes.

9 Q As alternatives, correct.

10 And then after you brought in the oxide
11 layer and the polysilicon layer from either Gan,
12 Kwark, or Borden, you would use Froitzheim to
13 continue the doping into the polysilicon.

14 Correct?

15 A Yes.

16 MR. PETERSON: Can we turn to Paragraph
17 39 please. I'm sorry. I'm sorry. Let's bring up
18 the exhibit 1040, Exhibit 1006, please.

19 (IPR2024-1040 Exhibit 1006, previously
20 marked, not attached.)

21 Q Have you seen this exhibit before,
22 Dr. Banerjee?

1 A Yes.

2 Q And what is this exhibit?

3 A It's the Froitzheim patent.

4 MR. PETERSON: Can you turn to Paragraph
5 39 of this exhibit please.

6 Q This paragraph teaches starting with an
7 N-type silicon layer doped with a phosphorus
8 crystal. Correct?

9 A Doped with -- yes.

10 Q Do you know if that's an amorphous
11 silicon or a crystal silicon?

12 A Crystalline.

13 Q And Paragraph 40 and 42 discuss using
14 boron to dope the back of the silicon layer with a
15 P-type dopant. Correct?

16 A That's correct.

17 Q And it discusses using diffusion.
18 Correct?

19 A Yes.

20 Q What does diffusion mean?

21 A Diffusion is a statistical process given
22 by random Brownian motion of particles at a

1 high-enough temperature so that you have enough
2 random Brownian motion from a high-concentration
3 region to a low-concentration region.

4 Q And so is it using heat to drive the
5 dopants into the silicon?

6 A You need heat, but you also need a
7 concentration gradient.

8 Q And what is creating that gradient?

9 A What's creating the gradient is, what you
10 are depositing is a boron dope source material,
11 which has a high boron concentration -- and
12 Froitzheim talks about different types of
13 sources -- while the single-crystal N-type
14 substrate has a low boron doping to begin with.

15 So when you heat it up, the boron dope
16 source is a high boron concentration that will
17 drive it down the concentration gradient into the
18 substrate, forming a p-n backside junction.

19 Q And looking at Paragraph 42, this says,
20 "A suitable doping liquid is SIODOP, a trademark
21 of Merck. Then the wafer is treated in an
22 atmosphere that contains oxygen at a temperature

1 of 900 to 1200 degrees centigrade, preferably
2 between 1000 and 1100 degrees centigrade, to
3 generate an oxide layer and to drive in the
4 dopant."

5 Do you see that?

6 A Yes.

7 Q Why would they prefer to use 1000 to 1100
8 degrees, do you know?

9 A That's because the higher the
10 temperature, the higher is the diffusion
11 coefficient which has a so-called Arrhenius
12 dependency.

13 So diffusion coefficient is equal to a
14 prefactored D nought, times exponential, minus
15 what's called an activation energy for the doping
16 diffusion, divided by KT -- K being the volts when
17 constant, T being temperature in kelvin. So
18 higher the temperature, more will be the
19 diffusivity. And that will determine the junction
20 depth. But it also depends on the diffusion time.

21 So these are the parameters that are
22 there.

1 Q So they're trying to achieve a higher
2 diffusion?

3 Is that correct?

4 A So you could -- I mean, these are
5 problems that I give to my undergrad students,
6 this type of problem.

7 So you are trying to achieve a certain
8 junction depth and a certain doping concentration.
9 And the two main parameters, the diffusion
10 temperature and the diffusion time. Longer the
11 diffusion time, higher the temperature.
12 Everything else being the same, you'd get a deeper
13 junction and the higher concentration of the
14 surface. Shorter the temperature -- or diffusion
15 time and lower the temperature, you get a shallow
16 junction. So those are the norms that a POSITA
17 would use.

18 Q Why would it be preferable to have a
19 deeper junction?

20 A It depends on the device design
21 parameters. You'd want a junction of the
22 appropriate depth to achieve the maximum

1 efficiency in your solar cell.

2 MR. PETERSON: Can we turn back to
3 Exhibit 1003, please.

4 Can you turn to Paragraph 106, please.

5 Q Paragraph 106 in Exhibit 1003 is
6 discussing why you would combine Froitzheim and
7 Gan. Correct?

8 A Yes.

9 Q And as we discussed earlier, you would
10 take the silicon from Froitzheim and add in the
11 oxide layer and polysilicon from Gan. Correct?

12 A In this case, yes.

13 Q And that's the same thing for Kwark and
14 Borden. Correct?

15 A Basically. But there will be other
16 differences that I don't recall.

17 Q Yeah, for the independent claims I'm
18 talking about.

19 A Yes.

20 Q Now, looking at Paragraph 107, in this
21 paragraph you describe the combination. Correct,
22 and why you would perform the combination?

1 A Yes.

2 Q And you say, "Before introducing the
3 boron dopant by diffusion at the rear side of the
4 substrate (for example, as described in Paragraphs
5 40 to 41 of Froitzheim), the skilled artisan would
6 perform Gan's steps of growing thin thermal oxide
7 to form an interfacial oxide layer followed by
8 polysilicon deposition to form the polysilicon on
9 an oxide layer on the back side of the wafer,
10 after which the polysilicon would be doped instead
11 of the substrate to form the polysilicon emitter."

12 Right?

13 A Yes.

14 Q So you're following steps of Froitzheim
15 up until the silicon is doped, before the silicon
16 doping. And then you would follow the steps in
17 Gan to add the oxide layer in the polysilicon to
18 form Gan's silicon layer. Correct?

19 MS. BÖLL: Object to form.

20 A You're following all the relevant steps
21 from Gan at the right location of the process flow
22 in Froitzheim.

1 Q What am I omitting?

2 A I'm not sure. What do you mean?

3 Q I thought you said I was omitting some
4 process steps from Gan?

5 A No. I said relevant process steps.

6 Q Oh. Then after you add the oxide in the
7 polysilicon layer from Gan, then you would follow
8 Froitzheim steps to add the dopant. Correct?

9 A Yes.

10 Q And would that be the same with Kwark and
11 Borden?

12 A Well, this part, essentially, yes.

13 Q Can you turn to Paragraph 91 please.

14 So in this paragraph you discuss the
15 oxide layer and polysilicon layer of Gan that you
16 proposed adding to Froitzheim. Correct?

17 A Yes.

18 Q And it also discusses an interfacial
19 oxide layer. Correct?

20 A Yes.

21 Q What is an interfacial oxide layer?

22 A In this case it's the oxide that always

1 exists between the deposited polysilicon and the
2 single-crystal silicon substrate.

3 Q Is that a tunneling oxide layer?

4 A Depending on how thick it is, it could
5 serve as a tunneling oxide.

6 MR. PETERSON: Can you turn to Paragraph
7 92, please.

8 Q Okay. So do you see the sentence that
9 starts on the last line of Page 38?

10 A Yes.

11 Q It says "both J" -- is that J nought?

12 A Yes.

13 Q And P sub C. What --

14 A It's actually rho sub C, the Greek letter
15 rho.

16 Q Rho sub C? That's how people in the know
17 refer to it?

18 So it says, Both J nought and rho sub C
19 are thus tied to indicators that improve solar
20 cell performance.

21 Correct?

22 A Yes.

1 Q Then it says, then it reads, "Gan noted
2 that J nought was lower due to the use of thermal
3 oxide as the interfacial layer in our samples."

4 Correct?

5 A Yes.

6 Q Can you explain what J nought and ρ sub
7 C are?

8 A Yes. J nought is a so-called reverse
9 saturation current in a junction under reverse
10 bias. And that's a nice metric for the quality of
11 the junction vis-à-vis recombination processes.
12 ρ sub C is known as the specific contact
13 resistance. So that's the resistance between,
14 say, a metal contact and a semiconductor. And you
15 end up getting the contact resistance by dividing
16 ρ sub C by the contact area. The lower the
17 value, the better.

18 Q Is it beneficial to have both J nought
19 and ρ sub C be lower?

20 A Repeat that, please?

21 Q I'm sorry, strike that.

22 Is it beneficial to have J nought and ρ

1 sub C be lower values, and you're trying to drive
2 down the value of J nought and rho sub C?

3 A Yes.

4 Q Why?

5 A Because as I told you earlier, I think, J
6 nought will determine ultimately the open circuit
7 voltage of a solar cell, while rho sub C will
8 determine the internal series resistance of the
9 solar cell, which in turn determines what's known
10 as the fill factor of the value characteristics of
11 the solar cell. And both of these pertain to the
12 maximum efficiency of a solar cell. If you drive
13 these parameters low, you can increase efficiency.

14 MR. PETERSON: Can we pull up
15 IPR2024-01040, Exhibit 1007, please.

16 (IPR2024-1040 Exhibit 1007, previously
17 marked, not attached.)

18 Q Have you seen this exhibit before?

19 A That's the Gan reference. Right?

20 Q Yes.

21 A Yes, I have.

22 Q And this is the Gan reference that you

1 recite in both of your declarations. Correct?

2 A Yes.

3 MR. PETERSON: So if you would turn to
4 Page 245, please. Can you scroll up a little bit
5 more.

6 Q Now, the title of this document is
7 Polysilicon Emitters For Silicon Concentrator
8 Solar Cells. Correct?

9 A Yes.

10 Q So this article is related to silicon
11 concentrator solar cells?

12 A It says silicon concentrator solar cells,
13 but I believe Gan stated correctly that the
14 results are also applicable to what he called
15 sun-1 solar cells, it's more generally applicable.

16 Q Now, the abstract states that J nought
17 less than equal to 5×10^{-14}
18 and ρ_{sc} around 1×10^{-5} are
19 obtained for both N- and P-type polysilicon
20 emitters.

21 Correct?

22 A Yes.

1 Q And so is the object of Gan to get these
2 levels, or these values, as low as possible?

3 A Yes.

4 MR. PETERSON: Now can we scroll down so
5 we can see the introduction, please.

6 Q This introduction tells us that there is
7 an oxide layer between the polysilicon and
8 substrate. Correct?

9 A Yes.

10 Q And it also tells us that the oxide is
11 not thermally stable. Correct?

12 A At very high temperatures.

13 Q Right. And then it says that, The
14 breakup of the interfacial oxide has direct impact
15 on both majority and minority characters in the
16 polysilicon emitter. Correct?

17 A Yes.

18 Q It says, This can be seen from the
19 dependence on the specific contact resistivity ρ_{sc}
20 and the emitter saturation current density J_0
21 nought, upon either anneal condition or the oxide
22 integrity.

1 Correct?

2 A Yes.

3 Q So that basically means ρ sub C and J
4 nought are dependent on how much the oxide is
5 broken up. Correct?

6 MS. BÖLL: Object to form.

7 A Yeah, they depend on oxide breakup, among
8 other parameters.

9 Q Then it says, When the effect of the
10 interfacial oxide is negligible, such as when the
11 interfacial oxide loses its integrity in high
12 temperature anneals, ρ sub C is low, around 2
13 times 10 to the minus 7 ohm centimeter squared?

14 A It's ohm centimeter squared.

15 Q Oh, ohm. Okay. And the J nought is
16 high, around 1 times 10 to the negative 12.

17 Correct?

18 A Yes.

19 Q And then Gan says, Conversely, when both
20 carriers are mostly blocked by the interfacial
21 oxide like for an intact chemical oxide, around 15
22 angstroms, the ρ sub C is high and the J nought

1 is low.

2 Correct?

3 A Yes.

4 Q Can you explain what this means?

5 A Can I explain what this means?

6 Q Yeah.

7 A Yeah. So you have this trade-off between
8 ρ_{sc} which will impact your fill factor, and
9 J_{sc} which will impact your open circuit
10 voltage. So trying to see what the oxide breakup
11 progressively at higher temperatures has on these
12 two parameters.

13 Q So you are effectively trying to thread a
14 needle, right, between having the oxide being
15 broken up but not having it being broken up too
16 much. Correct?

17 MS. BÖLL: Object to form.

18 A Yeah. You're trying to -- you're trying
19 to optimize the overall efficiency of the solar
20 cell by optimizing these two parameters, J_{sc}
21 and ρ_{sc} .

22 Q But Gan suggests that the more you break

1 up the interfacial oxide, the worst J nought is.

2 Correct?

3 A Yes.

4 Q And why is it bad to break up the oxide
5 too much?

6 MS. BÖLL: Object to form.

7 A So if you break it up too much, your J
8 nought will increase, which will hurt you in terms
9 of VOC, the open circuit voltage. But you also
10 gain, however, with lower values of rho sub C,
11 which helps the fill factor and the efficiency.
12 So like you were saying very elegantly, you are
13 trying to thread the needle.

14 MR. PETERSON: Can we turn to Page 249,
15 please. And can we scroll down a little bit.

16 Okay. That's good.

17 Q On the left hand paragraph about halfway
18 down you see where Gan reads, "On the other hand,
19 the drastic change in the rho sub C can be
20 attributed to the transition of the majority
21 carrier transport from tunneling to channel
22 resistance. When the interfacial oxide is intact,

1 tunneling is the only process available for the
2 majority carriers to pass through the interfacial
3 oxide. This usually results in a high contact
4 resistance because of low tunneling probability."

5 Do you see that?

6 A Yes.

7 Q So Gan was starting off with a tunnel
8 oxide. Correct?

9 A Yes.

10 Q And when the interfacial oxide is intact,
11 then we wait for the majority carriers to pass
12 through its tunneling. Correct?

13 A Yes.

14 Q But this creates a high contact
15 resistance. Right?

16 A That's correct.

17 Q Then why would there be low tunneling
18 probability?

19 A So tunneling probability depends on the
20 oxide thickness and the height of the tunneling
21 barrier. Now if you stick to silicon, silicon
22 dioxide, the height of the tunneling barrier is

1 fixed. So then the variable is the tunnel oxide
2 thickness. With oxide, tunnel oxide is thin, you
3 would have a relatively high tunneling
4 probability. If it's thick, the tunneling
5 probability will go the down and rho sub C will go
6 up.

7 MR. PETERSON: Could we turn to Table 1
8 on the previous page.

9 Q Do you see table 1 there at the bottom?

10 A Yes.

11 Q And this describes what happens to J
12 nought and rho sub C under different temperature
13 and time anneal steps. Right?

14 A Yes.

15 Q And this is the second anneal step.
16 Correct?

17 A I forget what the first anneal step is in
18 Gan. It's the second anneal step, but I am not
19 sure what the first anneal step was.

20 Q Okay. Do you want to take a look to see
21 if you can ...

22 A Maybe I will, if it's relevant.

1 Q I was going to ask do you know what the
2 second anneal step is, so ...

3 A Oh, I see Gan, so it is shown in Figures
4 4 and 5. The first anneal step refers to what's
5 called an FGA. FGA stands for forming gas anneal.

6 Q And that's the first anneal step?

7 A Yeah, that's what Gan is calling the
8 first anneal step.

9 Q And what would that anneal step be?

10 A So a forming gas is typically nitrogen
11 with a few percent of hydrogen mixed in it. And
12 you anneal it at temperatures typically around 450
13 or so, 450 degrees centigrade.

14 And the idea is to diffuse in some
15 hydrogen, which ties up what are called fast
16 interface states between the oxide and the
17 silicon. And that helps with reduction of J
18 nought also.

19 Q And what is the second anneal step for?

20 A So the second anneal step is at a much
21 higher temperature, and that's when the
22 interfacial oxide is breaking up partially. And

1 let me see.

2 In this case the second anneal step is
3 this high-temperature annealing process where Gan
4 is trying to progressively break down the
5 interfacial tunnel oxide and study the trade-off
6 between J nought and ρ sub C.

7 Q Is this also the drive-in step?

8 A It could be.

9 Q Can you see -- you see --

10 MR. PETERSON: Can we scroll up just a
11 little bit. Sorry. The other way. Okay.

12 Q Do you see the paragraph that starts,
13 "The effect of the," on the right side, towards
14 the top?

15 A Uh-huh. Yes.

16 Q What does that say the second step anneal
17 step is for?

18 A It's been used for the dopant drive-in.

19 Q Yeah. Okay. Can we scroll back --
20 sorry. The end of that paragraph it says,
21 "Considering the significant increase of J nought
22 caused by increasing the drive-in temperature from

1 900 to 1,000 degrees Celsius, it is beneficial to
2 use the two-step anneal to optimize J nought."

3 Correct?

4 A I see that.

5 Q And what does that mean to you?

6 A I think it -- Gan is proposing using the
7 first forming gas anneal process that's shown in
8 Figures 4 and 5 to help reduce the interface state
9 density. And then restricting the second anneal
10 temperature to 900 degrees C so that the J
11 nought -- or row temperature, so the J nought is
12 reasonably low.

13 Q Because it describes a significant
14 increase of J nought caused by increasing the
15 drive-in temperature from 900 to 1,000. Correct?

16 A Yeah, it says that.

17 MR. PETERSON: And can we scroll down to
18 Table 1, please.

19 Q And that's kind of what's being described
20 here in Table 1. Correct? The increase of J
21 nought as you go from 900 to 1,000?

22 A Yeah, J nought is increasing with higher

1 temperatures or longer anneal times. But it's not
2 a digital totally bad versus totally good. It is
3 a continuum.

4 Q Right. But Gan describes it as a
5 significant increase of J nought. Right?

6 MS. BÖLL: Object to form.

7 A Yeah, Gan calls it significant. So as J
8 nought increases, your ρ sub C will gradually
9 degrees, but your ρ C would gradually improve.
10 So it's -- a POSITA would be able to, you know,
11 thread the needle, as you're saying.

12 Q Okay.

13 MR. PETERSON: So we've been going about
14 an hour. Do you want to take a break?

15 THE WITNESS: Yes, please. Yeah.

16 MR. PETERSON: Let's go off the record,
17 please.

18 (A recess was taken.)

19 MR. PETERSON: Can we bring up, what was
20 it, the last exhibit, Exhibit 1007.

21 Can we scroll down so we can see the
22 Figure 6 on the next page. And kind of zoom in.

1 There you go.

2 BY MR. PETERSON:

3 Q And do you see Figure 6 on this page?

4 A Yes.

5 Q And do you see the box up in the top
6 right-hand corner?

7 A Yes.

8 Q Do you understand that this is referring
9 to N and P layers, which are labeled as N and P,
10 followed by a temperature which is first step
11 anneal time, and then followed by another number,
12 which would be the time that it was at that
13 temperature, and then a dash, and then two more
14 numbers, which would be temperature and anneal
15 time for the second step anneal?

16 Is that correct?

17 A Yeah, that's what it looks like.

18 Q And is this -- is this showing kind of
19 the same thing as Table 1, where the long -- the
20 higher the temperature and the longer the anneal
21 increases the J nought?

22 A Yes, it does. So the only reason I was

1 hesitating was, you know, before the break we
2 talked about first step anneal and second step
3 anneal.

4 So looking at Figures 4 and 5, it looks
5 like the first step anneal was the forming gas
6 anneals, which are done at much lower
7 temperatures. But over here I think the two
8 different temperatures and times may be different
9 from the first step anneal, second step anneal
10 like we were talking about earlier. It is using
11 slightly different language.

12 But the overall story is the same. The
13 higher the temperature, the longer the time. The
14 more the breakup, the lower -- the higher the J
15 nought and the lower the rho C.

16 MR. PETERSON: Can we turn back to
17 Exhibit 1003, please. And turn to Paragraph 95,
18 please.

19 Q So this paragraph relates to Kwark now.
20 Right?

21 A Yes.

22 Q And in this paragraph you discuss what

1 Kwark found using polysilicon and chemox in the J
2 nought of a polysilicon emitter. Correct?

3 A Yeah.

4 Q Do you know if Kwark is related to
5 concentrator solar cells?

6 A I think essentially Kwark is focusing on
7 these poly emitters. I don't recall if they mean
8 concentrator cells or not. But as I stated
9 earlier, and in fact Gan also mentions, that the
10 teachings of the solar cell design are applicable
11 to both concentrator and 1-sun solar cells.

12 MR. PETERSON: So can we scroll down just
13 a little bit. Not too much. Go -- just -- yeah.
14 That's good.

15 Q And the last sentence here says, And the
16 lower the J nought E. How would you say that?

17 A I mean, that's fine. It's a reverse
18 saturation current density.

19 Q The lower the reverse saturation or J
20 nought number, the better because it tends to
21 increase the V sub OC and therefore solar cell
22 efficiency.

1 What does this mean?

2 A $V_{sub OC}$ is the so-called open circuit
3 voltage.

4 So when you find some lag in the solar
5 cell, you can put up a voltmeter so that there is
6 no current flowing to the structure. So V_{oc} is
7 the maximum voltage that would be output from the
8 solar cell.

9 Conversely, you can short-circuit the
10 terminals, and that gives you the so-called
11 short-circuit current. And the two of them
12 together will determine how much maximum power
13 output you can get out of it, depending on the
14 so-called fill factor.

15 They all relate to the efficiency of the
16 solar cell.

17 Q What is the $J_{sub OE}$? What is that?

18 A I think they are using it
19 interchangeably.

20 Q Interchangeably, J_{nought} and $J_{sub OE}$?

21 A Yeah, so when they use the subscript E,
22 it refers to emitter. Because in all of these

1 structures we usually design for poly emitter
2 bipolar transistors. But the teachings carry over
3 to p-n junctions and solar cells in general.

4 Q That's helpful. Thank you.

5 MR. PETERSON: Can we turn to the next
6 page, which shows Figure 4 of Kwark.

7 Q So we already covered this figure, so I
8 am not going to go into much more than what we
9 already did. But this figure shows that the best
10 J nought is at 850 degrees Celsius. Correct?

11 MS. BÖLL: Object to form.

12 A But they don't have data at 800. The
13 lowest is 850.

14 Q I'm sorry. I thought I said 850.

15 Now, do you know what anneal step this
16 temperature is referring to?

17 A So this is after the polysilicon has been
18 deposited on the interfacial oxide. Now, you
19 could use that to thermal process step to also
20 drive in dopants if need be. But it's agnostic as
21 to whether you have done the diffusion at the same
22 time or earlier.

1 MR. PETERSON: Can we pull up Exhibit
2 IPR2024-01040, Exhibit 1008, please.

3 Q And we've already pulled this up. This
4 is the KwarK exhibit. Right, Exhibit 1008?

5 A Yes.

6 MR. PETERSON: Can we turn to Page 745
7 please. Sorry. 743 please. And can we scroll in
8 so we can see the second paragraph on the left
9 side.

10 Q Do you see the paragraph that starts, "In
11 order to establish unambiguous results"?

12 A Yeah.

13 Q This is the paragraph that relates to
14 Figure 4. Correct?

15 A Yes.

16 Q And I know we've already discussed some
17 of this, so I'm going to skip through that.

18 Do you see about three-quarters of the
19 way through this paragraph it starts, "Prediffused
20 emitter B"?

21 Do you see that?

22 A Yes.

1 Q Then it says, Displays a baseline of J
2 sub OE 5 times 10 to the negative 14 A over cm, or
3 centimeter squared, due to recombination in the
4 bulk of the emitter.

5 A Yes.

6 Q Do you see that?

7 A Yes.

8 Q And then it continues. "To this is added
9 a component due to outdiffusion from the heavily
10 doped poly, which becomes increasingly significant
11 for annealing temperatures over 900 degrees
12 Celsius. This is apparent if one notes that the
13 increase in J sub OE for emitter B can be
14 accounted for by the J sub OE of emitter C at the
15 same temperature. At 1000 degrees Celsius, this
16 outdiffusion is severe enough to dominate the J
17 sub OE which accounted for the lack of difference
18 between the emitters B and C."

19 Correct?

20 A Yes.

21 Q So what does that part that I just read
22 to you mean to you?

1 A By prediffused emitter, what Kwark is
2 talking about is making up backside p-n
3 junction -- well, in this case it's just the
4 junction -- so making the p-n junction by
5 diffusing boron directly into the single-crystal N
6 dope silicon substrate. So that's his control
7 sample.

8 And then the -- what he calls the
9 outdiffused emitter KC is where you don't form the
10 p-n junction begin with; you form the interfacial
11 tunnel oxide, deposit the poly dopant P-type. And
12 then as you heat it up, the dopants will be driven
13 in from the high concentration region in the poly,
14 through the tunnel oxide, into the substrate.

15 Now, oxides in general are diffusion
16 barriers, but it doesn't stay a barrier forever.
17 Once again, it depends on the diffusion
18 temperature and the time and the thickness of the
19 oxide. Tunnel oxides are typically not thick
20 enough to block dopant diffusion, that's why you
21 cannot use them as masking oxides, diffusion
22 masking oxides.

1 So what ends up happening is -- I've
2 worked on, published many papers on this topic, by
3 the way. So the dopants will diffuse very rapidly
4 along the grain boundaries in the poly, kind of
5 hit a roadblock, and then it will leak through
6 the -- through the interfacial oxide more and more
7 as you diffuse it at a higher and higher
8 temperature, longer and longer in time.

9 At some point the diffusion from --
10 outdiffusion from the doped poly, through the
11 interfacial tunnel oxide into the silicon, becomes
12 so large that there is no distinction between
13 prediffusing and post-diffusion. That's what he's
14 talking.

15 Q So at 1000 degrees Celsius, that's what
16 it is talking about, the outdiffusion severe
17 enough to dominate the J sub OE. Correct?

18 A Yes.

19 Q So what this is saying is, you don't want
20 to go above 1000. Correct?

21 MS. BÖLL: Object to form.

22 A But there's no data above 1000. But I

1 may point out, as I told you before, even at 1000,
2 there is improvement compared to that no chemox
3 case. So having an oxide helps even at 1000
4 degrees centigrade.

5 Q Do you know why it's calling the
6 outdiffusion severe?

7 MS. BÖLL: Object to form.

8 A It's calling it severe because it
9 asymptotes to the value for case B, but it is not
10 so severe as to match the no chemox case.

11 You want it to be as low as possible to
12 maximize Voc. But it is a continual degradation;
13 not a digital hundred percent good, hundred
14 percent bad.

15 Q We're going to switch over to the '516
16 patent declaration now.

17 So what we've just discussed for
18 Froitzheim, Gan, and Kwark, that also applies to
19 your analysis for the '516 patent. Correct?

20 MS. BÖLL: Object to form.

21 A Yeah, some of our analysis we do look at
22 combinations of Froitzheim with Gan, Kwark,

1 Borden.

2 Q Right. I'm just talking about
3 Froitzheim, Gan, and Kwark.

4 A Okay.

5 Q For the '053 and the '516, it's the same
6 combination. Right? Taking Froitzheim's silicon,
7 Gan and Froitzheim's oxide and polysilicon.

8 Correct? Same analysis?

9 MS. BÖLL: Object to form.

10 A I remember that '516 is a structure
11 patent and '053 that we talked about was a method.

12 Q Yeah. No. I understand that. But
13 you're still applying the silicon from Froitzheim
14 and the dopants with the oxide and polysilicon
15 from Gan and Kwark. Correct?

16 A Yes.

17 Q So what we've just discussed would
18 equally apply to the '516 patent. Correct?

19 A I have to look at the -- compare the two
20 declarations. In a general sense, yes. Subject
21 to the caveat that, you know, there may be aspects
22 that I am focusing on in the '516 regarding

1 structure where '053 I might have been focusing
2 more on the --

3 Q I'm just trying to determine whether we
4 need to go through all that again --

5 A Oh, okay.

6 Q -- for the '516 patent, or whether you
7 get out of here earlier.

8 A Okay. Yeah, in that case, yes, it is
9 acceptable.

10 Q Obviously if you applied something
11 differently in the '516, then you applied it
12 differently. But okay.

13 MR. PETERSON: Can we pull up the exhibit
14 IPR2024-01039, Exhibit 1003, please.

15 (IPR2024-01039 Exhibit 1003, previously
16 marked, not attached.)

17 MR. PETERSON: So from here on in we're
18 going to be discussing the '516 patent. So if I
19 say pull up the 1003 exhibit, this will be the one I
20 will be talking about.

21 Q Dr. Banerjee, have you seen this document
22 before?

1 A Yes.

2 Q What is this document?

3 A It's my declaration.

4 Q It's your declaration for IPR2024-0139.

5 Correct?

6 A Yes.

7 Q And this declaration relates to U.S.

8 Patent Number 8,222,516. Correct?

9 A Yes.

10 Q And is it okay if I'm calling this the
11 '516 patent?

12 A Yes.

13 MR. PETERSON: Can you turn to Paragraph
14 51 of this declaration, please. Actually, hold
15 on. Turn to Paragraph 49, please. Yeah. Okay.
16 That's good.

17 Q The second sentence of Paragraph 49 says,
18 "According to the '516 patent, a backside junction
19 is formed by the N-type substrate 101 and the P
20 doped polysilicon emitter 108 formed at the solar
21 cell's backside."

22 Correct?

1 A Yes.

2 Q Is the term "emitter" a term of art?

3 A Yes.

4 Q And what does it mean?

5 A So depends on what type of structure. So
6 I'm assuming you're talking about solar cells?

7 Q Yes.

8 A So in solar cells it's the doping type,
9 highly doped region within opposite doping type to
10 the substrate, which is also known as a base. And
11 this terminology is actually carried over from
12 bipolar junction transistors.

13 Q So the emitter always has the opposite
14 type doping as the base?

15 A In general, yes. But I guess this is
16 regarding the '315 that we'll talk about tomorrow.
17 There they use the term "emitter" in a slightly
18 different context, both P-tag and N-tag doped.
19 But here it's opposite type.

20 Q But Claim 9 doesn't discuss the types of
21 the doping. Correct?

22 MS. BÖLL: Object to form.

1 A If you look at the element which says an
2 emitter formed over a back surface of the
3 substrate, the emitter layer forming a backside
4 junction, and tell from the phrase "backside
5 junction" that it has to be the opposite type.

6 Q And what are you basing that off of?

7 A This relates to the discussion we had
8 before the break, that when I looked at the
9 prosecution history, it defined -- the patentee
10 defined backside junctions as oppositely doping
11 types -- opposite doping types, so p-n or n-p
12 junctions. And that's consistent with the fact
13 that a decent solar cell, "decent" meaning
14 reasonably high efficiency solar cell, needs to
15 have a p-n junction so that it will create a
16 potential barrier to physically separate the
17 photogenerated electron hole pairs.

18 Q Is the term "polysilicon emitter" a term
19 of art?

20 A Yes.

21 Q And what does that mean?

22 A Polysilicon are -- polysilicon emitter is

1 synonymous with poly emitters. And once again,
2 that terminology came from the literature on BJTs,
3 or bipolar junction transistors, and then they
4 applied that to solar cells.

5 Polysilicon is a film of silicon which
6 has single-crystal grains, which are misoriented
7 with respect to each other, separated by what are
8 called grain boundaries. And then you can dope it
9 highly.

10 Q Do you know the chemical composition of a
11 polysilicon emitter?

12 A Chemically silicon. You may have trace
13 impurities, but the bulk of it is silicon.

14 Q I'm sorry, I couldn't hear what you just
15 said.

16 A So chemically it is silicon. There may
17 be trace impurities, but most of it is silicon.

18 Q Are there different types of polysilicon
19 layers?

20 A It can have polysilicon. So polysilicon,
21 as I said, consists of single-crystal grains which
22 are misoriented with respect to each other.

1 Now, the grain sizes can be different.
2 In general, the higher the annealing temperature
3 or the processing temperature, the grain sizes
4 tend to become larger and larger, until it
5 asymptotes at an average grain size of the film
6 thickness.

7 And you can, of course, dope it at
8 different levels. You can dope it P- and N-type,
9 and you can deposit them by different techniques.

10 Q Do you know how the polysilicon emitters
11 are formed in the '053 and '516 patents?

12 A The claims are agnostic as to that. I
13 can look at the specs.

14 This discloses multiple techniques.

15 If you look at Column 2, Lines 59 and
16 next few lines, it talks about chemical vapor
17 deposition, CVD; such as low-pressure chemical
18 deposition, LPCVD; or plasma-enhanced CVD, PECVD.

19 Q Are you talking about the '516 patent?

20 Is that what you're looking at?

21 A Well, yeah. The specs are the same.

22 Q The only reason I ask is because you gave

1 a page and line -- or column and line numbers, and
2 I wanted to make sure they matched up.

3 A Okay.

4 Q Is this consistent with how polysilicon
5 emitters are generally formed on solar cells?

6 MS. BÖLL: Object to form.

7 A I'm not sure what you mean by
8 "generally." But it's certainly one of the ways
9 that's commonly used.

10 Q So in part of Paragraph 49 here that's on
11 Page 16, you state, "Between the polysilicon
12 emitter 108 and the substrate 101 is a tunnel
13 oxide layer 107, which may comprise silicon oxide
14 thermally grown on the substrate's surface."

15 Do you see that?

16 A Yes.

17 Q And you cite to the '516 patent.

18 Correct?

19 A Yes.

20 Q And if you look at Column 263 to 67 of
21 the '516 patent, it says, "The tunnel oxide layer
22 107 may comprise silicon dioxide thermally grown

1 to a thickness of about 10 to 15 angstroms on the
2 back surface of the substrate 101."

3 Is that correct?

4 A Yes.

5 Q Is this the sentence you were quoting in
6 your declaration at Paragraph 49?

7 A Yes.

8 Q So in the quote you say, "which may
9 comprise silicon oxide thermally grown."

10 Was silicon oxide a typo?

11 A Yeah, silicon dioxide.

12 Q Would a POSITA understand the tunnel
13 oxide layer to comprise silicon dioxide?

14 A That could be one type of tunnel oxide.

15 Q Are you aware of other tunnel oxides?

16 A Yeah, there's many.

17 Q And can you give me some?

18 A The Meier patent talks about use of
19 alumina, for example, Al_2O_3 , that could be used as
20 the tunnel oxide. I've worked with hafnium
21 dioxide, HfO_2 . Zirconium dioxide, ZrO_2 , in my
22 research. Those can be used as tunnel oxides.

1 Basically any dielectric or insulator
2 that's thin enough could be used as a tunnel
3 oxide.

4 MR. PETERSON: Can we turn to Paragraph
5 58, please.

6 Q On the bottom of Page 19 you state that
7 "Interfacial oxide layer refers to a layer of
8 silicon dioxide between the substrate and the
9 polysilicon emitter."

10 Correct?

11 A Yes.

12 Q What does the term "interfacial oxide
13 layer" here mean?

14 A It's a silicon dioxide layer which is at
15 the interface of the poly emitter and the silicon
16 substrate.

17 Q So that's specifically for this case.
18 Generally what does the term "interfacial oxide
19 layer" mean?

20 MS. BÖLL: Object to form.

21 Q Yeah, strike that.

22 Is what you just said, is that specific

1 to the case of the '516 patent?

2 MS. BÖLL: Object to form.

3 A No; it would be applicable to the '053
4 also.

5 Q So more generally what does the term
6 "interfacial oxide layer" mean?

7 MS. BÖLL: Object to form.

8 A "More generally" is pretty extensive,
9 so ...

10 I mean, in the broadest universe, it will
11 be any oxide that's between two materials. But
12 here it's talking about silicon dioxide between
13 the silicon substrate and the polysilicon dope
14 emitter.

15 Q And what does an interfacial oxide layer
16 do?

17 A It can do multiple things. So if it's of
18 the appropriate thickness, that could serve as
19 your tunneling oxide. But in addition to that,
20 oxides on silicon give you benefits in terms of
21 passivation by reducing what are called interface
22 state defect density, which also reduces J nought.

1 MR. PETERSON: Can we scroll down so we
2 can see the bottom of Page 20 and the top of Page
3 21, please. Okay.

4 Q And here you state, "Kwark, et al., did
5 not just report on work with SIPOS, but the
6 authors also reported surprising good results with
7 pure silicon emitters which they referred to as
8 poly."

9 Do you see that?

10 A We call it SIPOS, but anyway.

11 Q SIPOS. Sorry.

12 A So what is your question? Sorry.

13 Q Do you see that?

14 A I see that, yes.

15 Q Is "pure polysilicon emitters" a term of
16 art?

17 A I've heard of polysilicon emitters. I
18 haven't seen the adjective "pure" connected to
19 that. But I presume it's one without too many
20 contaminants.

21 Q Too many or without any contaminants?

22 A Well, it's -- in this business it's hard

1 to get rid of all contaminants in general. The
2 issue is is it low enough to get the job done. So
3 that's what I define as pure. You're never going
4 to get zero contaminants.

5 Q So pure doesn't mean 100 percent
6 polysilicon to you?

7 A Yeah, it does not.

8 Q How are pure poly emitters formed in
9 Kwark, do you know?

10 A Let me look up Kwark. Just a second.
11 APCVD. Hot wall APCVD. APCVD stands for
12 atmospheric pressure chemical vapor deposition.

13 Q I'm sorry, Dr. Banerjee. We can't hear
14 you because you're not speaking into the mic.

15 A So Kwark is using hot wall APCVD. APCVD
16 stands for atmospheric pressure chemical vapor
17 deposition.

18 Q And how are they getting pure polysilicon
19 emitters from that?

20 A In this case the study relates to SIPOS,
21 where they are -- just in this parameter gamma,
22 which is defined as this ratio of flow between

1 N2O, which is the oxidizing species, and silane,
2 which is the silicon-containing species.

3 So if you have gamma equal to zero, that
4 means they are not flowing any of the oxidizing
5 gas N2O. And that's when they are getting,
6 quote/unquote, pure polysilicon. But as I was
7 telling you, pure -- even pure polysilicon will
8 not be 100 percent pure; there will always be
9 trace amounts of impurities.

10 MR. PETERSON: Can we turn to Paragraph
11 185, please. Page 84.

12 Let's scroll down so we can see Figure 4,
13 please.

14 Q So this shows a prediffused Emitter B and
15 an outdiffused Emitter C. Correct?

16 A Yes.

17 Q What does "prediffuse" mean?

18 A As I told you before, prediffused I
19 believe means the diffusing in the boron P-type
20 dopant with an N-type substrate prior to the
21 deposition of this polysilicon layer. So the p-n
22 junction is in the bulk single-crystal silicon.

1 Q And "outdiffuse," what does that mean?

2 A That means they are depositing the doped
3 polysilicon on top of this interfacial oxide, and
4 then heat-treating the polysilicon.

5 The dopants in the polysilicon will
6 diffuse rapidly along these grain boundary
7 defects, sort of hit a road block at this thin
8 interfacial oxide, but it's not thick enough to
9 block diffusion.

10 So if you do the heat treatment at a
11 high-enough temperature or long-enough time, the
12 dopants in the poly will gradually leach into the
13 underlying substrate. And at some point that
14 outdiffusion coincides to the prediffused
15 diffusion of the single-crystal substrate, and
16 that's why the two results converge in Figure 4.

17 Q And so do you have Kwark there in front
18 of you?

19 A Yes.

20 Q That's Exhibit 1008.

21 Can you look at Page 743.

22 A Okay.

1 Q In the left column, the first full
2 paragraph, it says, The prediffused emitter B
3 displays a baseline $J_{sub OE}$ of 5 times 10^{-14} to the
4 negative 14 due to recombination of bulk emitter.

5 Do you see that?

6 A Yes.

7 Q Do you know how this baseline measure is
8 calculated?

9 A Yeah. So what you do is, a p-n junction
10 diode has asymmetry IV characteristics. So in
11 forward bias, the current goes up exponentially
12 with forward bias. So the current in the diode is
13 given by current density. J refers to current
14 density. It's current. So J will be given by J_0
15 $\exp(qV/kT)$ -- q being
16 the charge of the electron, V being the applied
17 voltage, k is the Boltzmann constant
18 B-O-L-T-Z-M-A-N-N, and T is temperature in kelvin.
19 So $J_0 \exp(qV/kT)$, minus 1.

20 So if you apply a reverse bias, the first
21 term basically zero, so the current would saturate
22 on reverse bias at J_0 . Alternatively, you

1 could also look at forward bias, where the current
2 goes up exponentially and you can get a curve fit
3 to extract the J nought.

4 Q Can we tell from Kwark what emitter C's
5 baseline is?

6 A It depends on how you -- how they're
7 defining reference as a p-n junction that's formed
8 in the bulk without this additional complications
9 of polysilicon grain boundary defects, et cetera,
10 et cetera. So I'm not sure what the baseline
11 would be in that sense.

12 But perhaps if you look at the 850
13 degrees result where there is not much out
14 diffusion as the baseline in that sense.

15 Q Do you know if it would be, the baseline
16 for emitter C would be higher or lower than the
17 baseline for emitter B?

18 A Are we using the term "baseline" as your
19 reference point with respect to which you're
20 measuring changes. So as shown here for C, the
21 baseline is a lower value than for B. Right? At
22 850.

1 Q Okay. And can you tell whether emitter B
2 or emitter C is the P-type polysilicon or N-type
3 polysilicon?

4 MS. BÖLL: Object to form.

5 A I believe it's P-type.

6 Q So that's emitter B is the P-type?

7 A Both of them are P-type.

8 Q Both of them are P-type?

9 A Yeah.

10 The P-type diffusing and then N-type
11 substrate, so you are forming p-n junctions.

12 Q Right. I guess I'm confused. I thought
13 when you kind of bled into the silicon -- so
14 emitter -- I'm just trying to get this straight.
15 I'm sorry, the question is going to be terrible.

16 But you're saying Emitter B and Emitter C
17 are both P-type?

18 MS. BÖLL: Objection. Form.

19 A So a p-n junction will have higher P-type
20 doping on one side and higher N-type doping on the
21 other side. And the junction is defined at the
22 point where the two doping -- where the two

1 concentrations match, so that the net
2 concentration is zero. Okay?

3 So assuming you're starting with an
4 N-type substrate, which I believe what they are
5 starting with, from one surface you are diffusing
6 in P-type dopants. So the junction will form
7 where the diffusing P-type dopants usually
8 gradually go down as a function of depth. But
9 that concentration matches the starting N-type
10 substrate concentration. Okay?

11 So at the junction the net concentration
12 has to be zero, that's how a junction is defined.

13 Q So if they're both emitter -- strike
14 that.

15 If Emitter B and Emitter C are both
16 P-type emitters, what's the difference between
17 them?

18 A They are both being diffused into a
19 starting N-type substrate. Okay?

20 Q Uh-huh.

21 A The P-type emitters for Cases B and C in
22 this case will have higher P-type doping typically

1 than the starting N-type substrate doping in this
2 case. Okay?

3 So when we talk about diffusion happening
4 from a high-concentration region to a
5 low-concentration region at high-enough
6 temperatures, so in this case the boron is
7 diffusing into the substrate. Substrate is
8 N-type. Okay? So in both B and C it's a P-type
9 dopant so that diffusing in. And wherever that
10 boron concentration equals the N-type substrate
11 doping is where the junction will form.

12 If you do the diffusion at a higher
13 temperature or a longer time, the boron will
14 diffuse in more and more, and the junction will
15 become deeper and deeper.

16 Q I understand that. But what's -- I'm
17 having a hard time understanding the difference
18 between prediffused Emitter B and outdiffused
19 Emitter C. Is prediffused Emitter B before it
20 reaches the boundaries and --

21 A No. No. Prediffuse, they are doing the
22 experiment of diffusing the boron from the

1 furnace, not from boron doped polysilicon. And
2 without any oxide on the surface, or negligible
3 oxide on the surface. Okay?

4 So they will bring an experiment where in
5 the furnace they have some other source of boron
6 dopant, could be a gaseous source, that's just
7 boron tribromide or whatever. I'm not sure if it
8 specifically describes that. But this will be
9 well known to a POSITA. Let me see boron -- Kwark
10 describes the prediffusion explicit here.

11 When I look at the relevant paragraph in
12 Kwark, which we were discussing earlier, when it
13 talks about forming Emitter B, it says, which had
14 a Gaussian surface concentration 1 micron D into a
15 5 times 10 to the 16 background. I'm looking at
16 Kwark. So if you want to we can pull up Kwark.

17 So the 5 times 10 to the 16 background
18 would be the N-type doping in the substrate.
19 Okay? That's what they are calling the
20 background.

21 And the fact that the shape of the
22 profile is Gaussian, you know, a POSITA would know

1 very well what they're doing is they are
2 introducing boron on the surface, in a furnace
3 where there is a supply of boron dopants. And
4 there's multiple ways you can introduce that.

5 That creates a boron diffusion profile
6 which is known as an erfc profile, complimentary
7 error function. Erfc is defined as E-R-F-C. And
8 then you put it in another furnace, where there's
9 no other boron available in the ambient. You
10 drive it in, and that gives you a Gaussian shape.

11 So all that's been done in the
12 prediffused case, without having the polysilicon
13 on the surface. Okay? And then they're comparing
14 with KC, where you have the polysilicon on top of
15 the interfacial oxide. And the boron is being
16 outdiffused from the polysilicon, through the
17 interfacial oxide, into the substrate.

18 Q Thank you. That's very helpful. Okay.
19 Let's turn to Borden.

20 MR. PETERSON: Can you pull up
21 IPR2024-01040 Exhibit 1009, please.

22 (IPR2024-0104 Exhibit 1009, previously

1 marked, not attached.)

2 Q Have you seen this document before?

3 A Yes.

4 Q And what is this document?

5 A This is the Borden patent.

6 MR. PETERSON: Can we turn to Paragraph
7 0018 please.

8 Q And, Dr. Banerjee, this is going to be a
9 little confusing, but I think if you -- while
10 we're looking at Paragraph 18, if you compare it
11 to Figure 2A it might be a little easier. Because
12 Paragraph 18 isn't really --

13 A So in the hard copy that you sent me,
14 that ends at Paragraph 15. It might have been an
15 oversight. Anyway, I will look at the screen.

16 Q So Paragraph 18 discusses the structure
17 of Borden's invention. Correct?

18 And I know where you're going to go with
19 this. First we're going to cover the amorphous
20 silicon part of the invention, and then we'll go
21 over and we'll talk about the polysilicon first --
22 or second. Okay?

1 A Okay.

2 Q Okay. So I just don't want you to cut me
3 off and say, yeah, but then the polysilicon and
4 all that.

5 So the question is, Paragraph 18
6 discusses Borden's invention related to its
7 amorphous silicon embodiment. Correct?

8 A Yeah.

9 Q And this teaches from front to back an
10 N-type substrate 206, a tunnel oxide layer 228, an
11 amorphous silicon layer 226, and then another
12 amorphous silicon layer 224, and then a layer of
13 TCO or transparent conductive oxide 222. Correct?

14 A Yes.

15 Q And then if we turn to Paragraph 16, I
16 believe this is, you know, what you were saying
17 should be combined with Froitzheim. Right? This
18 teaches that you can replace the two amorphous
19 silicon layers and the TCL layer with polysilicon
20 to get a silicon layer 206, a silicon dioxide
21 layer 228, and a polysilicon layer. Correct?

22 MS. BÖLL: Object to form.

1 A The numbers that you mentioned don't
2 match with my Figure 2A. And the two polysilicon
3 layers are labeled 226 and 224, not 206.

4 Q Oh, I'm sorry. I thought -- okay. I'm
5 sorry.

6 A Yeah.

7 Q A crystal silicon layer 206?

8 A Yes.

9 Q A silicon dioxide layer 228, and then
10 you're replacing amorphous silicon layer 226 and
11 amorphous silicon layer 224 and TCL layer 222 with
12 a polysilicon layer. Correct?

13 A Right.

14 Q Yeah.

15 A Except that the TCO is not really
16 relevant.

17 Q No. No. Yes, I agree. But you're
18 getting rid of that layer. You don't need that
19 layer. Correct?

20 A Yes.

21 Q Right. So the third sentence of this
22 Paragraph 16 reads, "The present inventors further

1 recognize that the tunnel oxides can be used
2 between a heavily doped or insulating layer of
3 polysilicon and/or a crystal silicon substrate,
4 forming a polysilicon emitter cell."

5 And then the next sentence reads, "Such a
6 solar cell has a similar band structure to a HIT
7 cell, essentially replacing the TCO and the
8 amorphous silicon layers with polysilicon."

9 Correct?

10 A Yes.

11 Q And that's what gets us to the silicon
12 layer, silicon dioxide layer, polysilicon layer.

13 Correct?

14 A Yes.

15 Q And it's the tunneling oxide layer, the
16 silicon dioxide layer, and the polysilicon
17 structure that you propose adding to Froitzheim
18 from Borden. Correct?

19 MS. BÖLL: Objection. Form.

20 A Yes.

21 Q The last sentence of Paragraph 16 reads,
22 "However, such cells do not provide the

1 heterojunction and its benefit of a higher cell
2 voltage due to the higher bandgap of amorphous
3 silicon."

4 Is that correct?

5 A Yes.

6 Q Would that sentence lead to you believe
7 that Borden is saying you should not make the
8 substitution or you lose the benefits of what
9 Borden is trying to teach?

10 A No. When I read Borden, I think Borden
11 recognizes the possibility of using polysilicon.
12 If instead of polysilicon one uses amorphous
13 silicon, there is additional benefits. But that
14 does not preclude you from using the benefits of
15 polysilicon on the silicon dioxide.

16 Q Yeah, but Borden is saying if you do
17 that, you lose the benefits of the higher cell
18 voltage due to the higher bandgap of amorphous
19 silicon. Right?

20 A I read this as saying that polysilicon on
21 oxide is good, but amorphous silicon on oxide is
22 even better because of this higher bandgap.

1 And, of course, you know, getting ahead
2 of myself maybe, you know, we do cite other prior
3 art also for bringing polysilicon.

4 MR. PETERSON: Can you turn to Paragraph
5 8, please, 0008.

6 Q So this paragraph also discusses a
7 masking layer. Correct?

8 A Yes.

9 Q And then that layer is patterned out, and
10 the polysilicon junction is only found where the
11 holes in the masking oxide layer are. Correct?

12 A Yes.

13 Q So in your combination with Froitzheim
14 and Borden, are you proposing that this masking
15 layer is being put into the invention of
16 Froitzheim's silicon and doping and Borden's oxide
17 layer in polysilicon?

18 A These are sort of additional bells and
19 whistles. So masking oxides are going to be
20 thicker than the interfacial oxides. So if you
21 open up small windows in the masking oxide and
22 then grow the thin tunnel oxide in the windows and

1 then deposit polysilicon, you get what they call
2 point contact cells. You could do that with
3 Froitzheim. But alternatively, you could dispense
4 with the masking layer and then have the
5 interfacial oxide everywhere, and then deposit the
6 Borden polysilicon.

7 So, I mean, as we are discussing, Borden
8 does prefer amorphous silicon, but I don't think
9 he is disavowing polysilicon completely, as you
10 can see.

11 Q My question was more specific to your
12 combination of Borden and Froitzheim.

13 Does your combination include this
14 masking layer?

15 A So in my combination you are not in the
16 masking layer.

17 Q And that's what I thought. I just wanted
18 to make sure.

19 Give me one second. I am actually
20 getting close to done here, so I'm trying to
21 move -- do you want to take a break or do you want
22 to just plow on?

1 A It depends how long more you feel you
2 will take.

3 Q Hard for me to tell.

4 MS. BÖLL: Let's take a short break.

5 MR. PETERSON: Okay.

6 (A recess was taken.)

7 MR. PETERSON: Can we pull back up that
8 last exhibit, which is Exhibit 1009.

9 BY MR. PETERSON:

10 Q So the second-to-last sentence in
11 Paragraph 0008 starts with the word "benefits."

12 Do you see that sentence?

13 A Yes.

14 Q It reads, "Benefits of the invention
15 include that it provides a controlled interface
16 for the HIT cell through insertion of a thin
17 tunnel oxide; moreover, the tunnel oxide prevents
18 epitaxial growth of amorphous silicon, allowing it
19 to remain amorphous for the optimum band
20 structure."

21 Do you see that?

22 A Yes.

1 Q Now, in your substitution of the
2 amorphous silicon for polysilicon, would the
3 tunnel oxide be preventing epitaxial growth of
4 amorphous silicon?

5 A You mean amorphous or polysilicon?

6 Q Amorphous. So you substitute out the
7 amorphous silicon and the TCO layers for a
8 polysilicon layer. Correct?

9 A Yes.

10 Q So you have a silicon layer, a tunnel
11 oxide, and a polysilicon. Correct?

12 A Yes.

13 Q In that embodiment, would the tunnel
14 oxide prevent epitaxial growth of amorphous
15 silicon?

16 A No; because there's no amorphous silicon
17 in our posit.

18 Q And so you also wouldn't get this optimal
19 band structure that it talks about. Right?

20 MS. BÖLL: Object to form.

21 A As I was telling you before the break,
22 whether you use amorphous silicon or polysilicon,

1 I mean, these are sort of additional bells and
2 whistles.

3 So even if you were to use polysilicon,
4 although you do not get the benefit of the higher
5 bandgap and the HIT junction, you still benefit
6 from the use of this interfacial oxide. And even
7 in the case of polysilicon on interfacial oxide,
8 it will help it preventing epitaxial realignment
9 of the polysilicon. This is also beneficial.

10 So a lot of the benefits transfer from
11 amorphous silicon to polysilicon. The use of
12 amorphous silicon gives you additional benefits.

13 Q Where does Borden tell us that?

14 A Well, Borden, if you look at the
15 abstract, which is right at the beginning, it
16 says -- yeah. It's right here. 008. Present
17 invention relates to improved HIT type -- HIT type
18 is an amorphous silicon -- or polysilicon emitter
19 solar cells.

20 So Borden himself recognizes the
21 possibility of getting benefits from polysilicon
22 emitters. So the replacement of polysilicon with

1 amorphous silicon would be an additional bell or
2 whistle. But it's not as if if you stuck with
3 polysilicon there's no benefits at all.

4 Q But the tunnel oxide in your substitution
5 does not prevent epitaxial growth on amorphous
6 silicon. Right?

7 MS. BÖLL: Object to form.

8 A Yeah, if you didn't have amorphous
9 silicon on the tunnel oxide instead you had
10 polysilicon, you know, there is no amorphous
11 silicon in the structure.

12 MR. PETERSON: Can we scroll down just a
13 little bit more. Actually, no, this is fine.

14 Q Then the next sentence says, "Still
15 further, it provides a layer to protect the
16 surface from plasma damage during deposition of
17 the amorphous silicon layer."

18 Correct?

19 A Yes.

20 Q Would the tunnel oxide layer in your
21 substitution provide a layer to protect the
22 surface from plasma damage during deposition of

1 that amorphous silicon layer?

2 MS. BÖLL: Object to form.

3 A So if you did not deposit amorphous
4 silicon, but instead deposited polysilicon with
5 plasma-enhanced CVD, it will help minimize plasma
6 damage during the PCV deposition of polysilicon,
7 had we made that substitution.

8 Q But it doesn't protect the surface from
9 plasma damage during deposition of the amorphous
10 silicon layer. Correct?

11 A Yes, I just told you, I mean, if you are
12 not depositing amorphous silicon, that's not
13 applicable. However, the teachings described for
14 amorphous silicon, many of those carry over to
15 polysilicon except that the polysilicon doesn't
16 give you the additional benefits of the higher
17 bandgap of the amorphous silicon, but a lot of the
18 other benefits carry over.

19 And I think Borden himself recognizes
20 that in the first sentence of 08 where he says,
21 "The present invention relates to an improved HIT
22 type or polysilicon emitter solar cell."

1 I mean, if what I said wasn't true, he
2 wouldn't have added that last phrase.

3 MR. PETERSON: Can we bring back up
4 Exhibit 1003, please.

5 Okay. Can we turn to Paragraph 198. And
6 I want to see the last sentence of that paragraph,
7 please.

8 Q The last sentence says, "As I discussed
9 in Paragraphs 144 through 151, the teachings of
10 Gan, Foglietti, Kwark, and Borden would similarly
11 have motivated the skilled artisan to integrate a
12 polysilicon emitter with an interfacial oxide
13 layer."

14 Do you see that?

15 A Yes.

16 Q Okay. Can you look through Paragraphs
17 144 through 151 and tell me where you discuss that
18 Borden's teachings would have motivated the
19 skilled artisan.

20 A Okay. These paragraphs specifically
21 primarily talk about Gan. But I can point you to
22 a couple of places. For example --

1 Q Hold on. Before you say it, can you tell
2 us the paragraph numbers so we know where you are?

3 A That is what I was about to do.

4 Okay. I would like to draw your
5 attention to Paragraph 144, towards end of Page
6 61.

7 MR. PETERSON: Can we turn there, please.

8 A Okay, I'm reading. Gan also noted that,
9 quote, the J nought, which is indicative of the
10 surface recombination of the P-type polysilicon
11 emitter (Figure 5) -- parenthetically that's our
12 insertion I guess -- appears to be much lower than
13 what has been previously reported, unquote.

14 And he goes on to say that this, quote,
15 may have to do with the use of the thermal oxide
16 as the interfacial layer in our samples. And then
17 he goes on to say that, quote, Because the
18 dominant recombination is likely at the oxide
19 interface, et cetera, et cetera.

20 So Gan clearly recognizes that that
21 interfacial oxide helps reduce surface
22 recombination with concomitant methods of J nought

1 being reduced, which then will lead to an increase
2 of the Voc. And that's discussed furthermore
3 in --

4 Q Before you go on, the question was
5 specifically related to Borden.

6 A Yes, I was going to make the connection.
7 The connection will be Borden talks about the
8 benefits of using this oxide in preventing plasma
9 damage. So plasma damage would create defects of
10 the surface, which then increases the surface
11 recombination with deleterious effects on Voc.

12 And that aspect, if you go to Paragraph
13 147, towards the end, we're citing quotes from Dr.
14 Martin Green who is an expert in the --

15 MR. PETERSON: Move to Paragraph 147,
16 please.

17 A So on Page 65, near the top. Yeah.
18 That's a quote from Dr. Green.

19 So I'm reading. "The high surface
20 recombination at the boron-infused top surface
21 limits the open-circuit voltage in front" -- this
22 is a front junction solar cell, but it's really

1 applicable to back junction cells. "By using a
2 rear junction structure, the top surface becomes
3 phosphorus-diffused and has relatively low surface
4 recombination, which increases the Voc."

5 So the point of this paragraph is you
6 want to minimize surface recombination. Defects
7 increase -- plasmas can increase surface defects,
8 as discussed by Borden. So if you go minimize
9 those plasma-enhanced damage at the surface by
10 having an interfacial oxide as disclosed by Gan,
11 Kwark, et al., that's going to be helpful.

12 Q But this isn't a quote from Borden.

13 Right?

14 A No. This is a quote from Green.

15 Q Okay. I'm asking where in these
16 paragraphs you're getting support from Borden.

17 A We're not quoting Borden over here, but
18 we're taking the teachings disclosed in Gan and
19 Green, and we see the application to the Borden
20 discussion.

21 Q But we had a discussion where with your
22 combination, taking out the amorphous silicon and

1 the TOC and replacing it with polysilicon, since
2 there is no more amorphous silicon, you're not
3 protecting epitaxial growth, and you're not
4 getting plasma damage. Correct?

5 MS. BÖLL: Object to form.

6 A I think the key teaching in Borden is
7 that use of interfacial oxide. If you had put
8 amorphous silicon on top, it would prevent
9 epitaxial regrowth of amorphous silicon. If you
10 didn't have amorphous silicon, instead have
11 polysilicon, you would help minimize the epitaxial
12 growth of the polysilicon. And the presence of
13 the interfacial oxide would help minimize any
14 plasma damage, if you're doing plasma-enhanced
15 deposition.

16 And that, as Gan and Green discuss, and
17 as I cite in Paragraphs 144 to 151, those
18 teachings carry over.

19 Q Where does Borden say this? Where is
20 your support for -- the question is, where is your
21 support from Borden?

22 MS. BÖLL: Object to form.

1 A The support for -- from Borden is,
2 although it's primarily focused on the use of
3 amorphous silicon in Paragraph 8 of Borden -- we
4 just talked about it a few minutes earlier --
5 Borden says that it's the invention relates also
6 to use of poly emitter cells. So these amorphous
7 silicon would give you additional benefits over
8 poly emitter cells. But he is not disavowing
9 Borden -- he is not disavowing use of poly emitter
10 cells.

11 MR. PETERSON: I don't have any further
12 questions at this time.

13 MS. BÖLL: Nothing from me.

14 MR. PETERSON: Let's go off the record.

15 (Off the record at 2:24 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)

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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
Thursday, March 20th, 2025, from 9:59 a.m. to 2:24
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 30th day of March, 2025.

10
11 My commission expires:

12 October 31, 2027

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a-s-t-r-o-w-a-t-t	abstract	add	al
28:9	93:16, 145:15	87:10, 88:17,	125:4, 151:11
able	academia	89:6, 89:8	al2o3
47:18, 55:12,	18:18	added	122:19
59:7, 59:10,	acceptable	110:8, 148:2	align
103:10	115:9	adding	53:16
about	acceptors	89:16, 139:17	all
10:4, 10:5,	45:7	addition	12:15, 17:15,
10:20, 11:1,	access	29:5, 124:19	19:19, 20:2,
11:7, 13:4,	7:9, 18:11	additional	27:2, 52:5,
13:9, 13:20,	accessing	130:8, 140:13,	60:21, 60:22,
19:9, 19:11,	7:8	141:18, 145:1,	63:3, 65:15,
19:17, 20:10,	according	145:12, 146:1,	66:10, 67:10,
23:12, 24:18,	116:18	147:16, 153:7	74:3, 80:20,
26:3, 26:7,	account	adjective	81:9, 88:20,
26:20, 27:1,	47:2	125:18	107:15, 107:22,
29:12, 38:14,	accounted	advanced	115:4, 126:1,
41:4, 48:20,	110:14, 110:17	41:14	135:11, 137:4,
50:19, 50:20,	achieve	advantages	146:3
52:13, 54:20,	49:14, 59:10,	53:7, 62:3	allow
55:2, 56:19,	86:1, 86:7,	adverse	69:9
63:14, 63:17,	86:22	25:11, 155:12	allowing
63:18, 64:4,	acid	advisory	143:18
64:17, 79:13,	57:12	27:20	alone
79:14, 81:16,	acknowledge	after	7:4, 76:4, 76:8
81:18, 84:12,	154:3	66:3, 82:10,	along
87:18, 97:17,	acknowledgment	88:10, 89:6,	112:4, 128:6
103:13, 105:2,	154:1	108:17	already
105:10, 109:18,	acronym	again	29:20, 74:1,
111:2, 112:16,	37:15	13:10, 14:1,	108:7, 108:9,
114:2, 114:11,	across	21:11, 26:5,	109:3, 109:16
115:20, 117:6,	19:21, 29:3,	29:22, 74:11,	also
117:16, 120:16,	32:18	111:17, 115:4,	4:13, 8:2,
120:19, 122:1,	act	119:1	16:20, 17:11,
122:18, 124:12,	60:2, 60:5	agnostic	19:10, 19:15,
133:3, 134:13,	acting	32:9, 33:13,	21:10, 21:17,
136:21, 144:19,	61:5	36:15, 108:20,	22:11, 24:5,
148:21, 149:3,	action	120:12	26:1, 28:1,
150:7, 153:4	156:2, 156:4	agree	36:7, 36:9,
above	activation	138:17	47:13, 50:10,
66:6, 67:18,	85:15	agst	54:17, 62:19,
112:20, 112:22	actual	25:5	64:14, 64:18,
absorb	43:2	ahead	68:21, 69:8,
32:20	actually	25:1, 141:1	72:14, 74:6,
absorption	25:11, 41:9,	air	75:11, 76:10,
33:1	90:14, 116:14,	32:3, 32:17,	77:12, 78:20,
	117:11, 142:19,	33:2, 33:8,	78:21, 79:2,
	146:13	33:15	81:4, 81:16,

84:6, 85:20, 89:18, 93:14, 94:10, 97:9, 100:18, 101:7, 106:9, 108:19, 113:18, 117:10, 124:4, 124:22, 125:6, 130:1, 141:3, 141:6, 144:18, 145:9, 149:8, 153:5 alternatively 129:22, 142:3 alternatives 82:8, 82:9 although 145:4, 153:2 alumina 122:19 always 37:5, 45:9, 89:22, 117:13, 127:8 alzheimer's 10:1 ambient 135:9 among 51:1, 95:7 amorphous 21:8, 83:10, 136:19, 137:7, 137:11, 137:12, 137:18, 138:10, 138:11, 139:8, 140:2, 140:12, 140:18, 140:21, 142:8, 143:18, 143:19, 144:2, 144:4, 144:5, 144:6, 144:7, 144:14, 144:16, 144:22, 145:11, 145:12, 145:18, 146:1, 146:5, 146:8, 146:10, 146:17, 147:1, 147:3, 147:9,	147:12, 147:14, 147:17, 151:22, 152:2, 152:8, 152:9, 152:10, 153:3, 153:6 amount 34:3 amounts 127:9 analysis 113:19, 113:21, 114:8 angeles 3:6 angstrom 50:8, 55:2, 55:3, 58:22 angstroms 48:21, 50:7, 50:9, 54:18, 95:22, 122:1 ann 2:5, 155:2 anneal 51:15, 52:18, 94:21, 99:13, 99:15, 99:17, 99:18, 99:19, 100:2, 100:4, 100:5, 100:6, 100:8, 100:9, 100:12, 100:19, 100:20, 101:2, 101:16, 102:2, 102:7, 102:9, 103:1, 104:11, 104:14, 104:15, 104:20, 105:2, 105:3, 105:5, 105:9, 108:15 annealing 60:19, 63:2, 64:16, 66:10, 101:3, 110:11, 120:2 anneals 51:12, 95:12, 105:6	another 27:22, 64:18, 104:11, 135:8, 137:11 answer 8:17, 9:2, 24:15, 24:22, 35:5, 48:5, 71:16, 74:12, 81:20 answering 71:17 answers 8:8, 8:9, 14:4 anticipate 40:11, 43:3 anticipated 40:6, 42:21 anticipates 41:2 anticipation 39:19, 39:21, 40:1 any 7:12, 8:9, 8:22, 9:1, 9:6, 9:7, 9:13, 11:9, 24:6, 27:16, 28:16, 29:19, 34:14, 40:10, 40:11, 41:1, 41:2, 42:20, 43:2, 43:7, 43:8, 43:9, 43:18, 44:2, 44:20, 54:16, 57:18, 58:3, 60:1, 60:10, 60:17, 63:6, 63:20, 65:4, 66:4, 68:9, 69:1, 77:4, 77:7, 80:3, 123:1, 124:11, 125:21, 127:4, 134:2, 152:13, 153:11, 154:6, 156:2, 156:3	anybody 7:6, 14:10 anyone 7:2, 14:10, 76:3, 76:7, 76:11 anyplace 54:10 anything 11:3, 30:5, 63:18, 68:18 anyway 125:10, 136:15 apcvd 126:11, 126:15 apparent 110:12 appeal 1:2 appear 154:6 appears 149:12 applicable 78:20, 93:14, 93:15, 106:10, 124:3, 147:13, 151:1 application 42:12, 49:2, 59:9, 151:19 applied 41:15, 115:10, 115:11, 119:4, 129:16 applies 113:18 apply 114:18, 129:20 applying 114:13 approached 14:8 appropriate 18:2, 86:22, 124:18 area 28:21, 29:13,
---	---	---	---

<p>32:7, 33:21, 33:22, 34:6, 61:17, 74:14, 91:16 areas 27:5 argument's 72:22 arguments 40:13 arm 9:17 around 10:17, 13:8, 13:11, 22:2, 22:21, 23:1, 28:15, 53:13, 53:14, 54:18, 93:18, 95:12, 95:16, 95:21, 100:12 arrhenius 85:11 art 11:6, 12:4, 34:13, 35:4, 37:3, 37:20, 38:22, 39:3, 39:8, 39:12, 39:15, 40:7, 40:9, 40:11, 40:16, 40:20, 40:21, 41:1, 41:7, 41:9, 41:10, 41:21, 42:16, 42:20, 43:15, 43:18, 50:14, 50:19, 54:17, 56:3, 56:7, 57:12, 58:6, 58:10, 67:1, 76:16, 77:4, 80:11, 117:2, 118:19, 125:16, 141:3 article 93:10 artisan 88:5, 148:11,</p>	<p>148:19 asked 29:4 asking 13:4, 35:3, 38:12, 49:15, 54:20, 66:19, 68:15, 71:12, 74:16, 151:15 aspect 150:12 aspects 12:20, 12:21, 14:3, 19:17, 114:21 assistant 18:22, 19:19 assume 8:16 assuming 33:14, 117:6, 132:3 astrowatt 27:21, 28:10, 28:12 asymmetry 129:10 asymptotes 113:9, 120:5 atmosphere 32:19, 32:22, 84:22 atmospheric 126:12, 126:16 attached 5:9, 15:10, 30:11, 54:9, 82:20, 92:17, 115:16, 136:1, 154:7 attention 149:5 attorney 8:17, 8:18, 156:3 attributable 44:13 attributed 97:20</p>	<p>auger 36:11 austin 3:4, 6:12, 7:1, 16:19, 17:2, 17:3, 17:4 authors 125:6 available 98:1, 135:9 avenue 3:5, 3:12, 4:7 average 33:6, 120:5 aware 9:13, 41:1, 42:3, 44:20, 76:3, 76:7, 76:11, 77:4, 122:15</p> <hr/> <p>B</p> <hr/> <p>b 109:20 b-o-l-t-z-m-a-n-n 129:18 bachelor 16:3 bachelor's 41:19 back 8:21, 8:22, 12:22, 13:11, 22:7, 23:3, 31:6, 31:7, 46:4, 47:8, 66:12, 67:20, 70:12, 77:14, 77:18, 77:21, 80:8, 83:14, 87:2, 88:9, 101:19, 105:16, 118:2, 122:2, 137:9, 143:7, 148:3, 151:1 background 134:15, 134:17, 134:20</p>	<p>backside 70:17, 72:2, 72:14, 72:20, 73:2, 73:11, 73:19, 74:7, 75:1, 75:5, 77:8, 77:19, 77:22, 79:13, 79:22, 84:18, 111:2, 116:18, 116:21, 118:3, 118:4, 118:10 bad 58:1, 97:4, 103:2, 113:14 band 53:18, 139:6, 143:19, 144:19 bandgap 36:8, 47:7, 53:12, 53:14, 140:2, 140:18, 140:22, 145:5, 147:17 bandgaps 77:1 banerjee 1:12, 2:1, 5:2, 6:2, 6:16, 6:20, 15:11, 15:15, 24:16, 30:9, 30:12, 31:22, 59:19, 65:14, 81:14, 82:22, 115:21, 126:13, 136:8, 154:2, 155:5, 155:17 barrier 47:5, 47:8, 47:9, 47:11, 47:12, 47:16, 47:17, 48:9, 48:10, 48:12, 48:13, 48:16, 49:7, 49:19, 49:21, 50:2, 53:7, 53:21, 53:22, 60:8,</p>
--	---	--	--

62:10, 62:17, 76:2, 77:3, 98:21, 98:22, 111:16, 118:16 barriers 111:16 base 74:5, 78:19, 78:20, 80:15, 80:19, 81:2, 81:5, 81:10, 117:10, 117:14 based 34:21, 45:15, 55:5, 66:9, 74:7, 75:6, 75:10, 79:6, 79:9 baseline 110:1, 129:3, 129:7, 130:5, 130:10, 130:14, 130:15, 130:17, 130:18, 130:21 basic 28:2 basically 19:7, 20:2, 49:22, 87:15, 95:3, 123:1, 129:21 basing 75:5, 118:6 bay 28:21, 29:13 because 34:17, 37:6, 40:16, 47:18, 49:15, 62:3, 63:13, 67:15, 72:6, 85:9, 92:5, 98:4, 102:13, 106:20, 107:22, 113:8, 120:22, 126:14, 136:11, 140:22, 144:16, 149:17 become 120:4, 133:15	becomes 110:10, 112:11, 151:2 been 6:2, 10:2, 10:20, 11:15, 19:7, 20:1, 20:4, 20:5, 20:16, 27:19, 46:12, 52:20, 57:5, 59:13, 64:17, 66:17, 73:20, 77:5, 101:18, 103:13, 108:17, 115:1, 135:11, 136:14, 149:13 before 1:2, 2:5, 10:2, 10:21, 21:6, 22:2, 22:3, 22:6, 30:13, 74:13, 82:21, 88:2, 88:15, 92:18, 105:1, 113:1, 115:22, 118:8, 127:18, 133:19, 136:2, 144:21, 149:1, 150:4, 155:7 begin 84:14, 111:10 beginning 145:15 behalf 3:2, 4:2, 6:12 behind 62:2 being 14:20, 35:15, 43:16, 75:6, 85:16, 85:17, 86:12, 96:14, 96:15, 102:19, 129:15, 129:16, 132:18, 135:15, 141:15, 150:1 believe 10:17, 15:2,	21:2, 21:9, 22:1, 28:4, 32:16, 33:1, 33:13, 39:4, 42:14, 43:14, 44:9, 50:21, 51:1, 51:7, 53:19, 57:19, 64:6, 65:20, 67:2, 77:17, 80:4, 81:8, 93:13, 127:19, 131:5, 132:4, 137:16, 140:6 bell 146:1 bells 141:18, 145:1 belly-up 27:22 below 52:6, 66:5 beneficial 67:9, 67:15, 91:18, 91:22, 102:1, 145:9 benefit 140:1, 145:4, 145:5 benefits 63:13, 64:8, 124:20, 140:8, 140:13, 140:14, 140:17, 143:11, 143:14, 145:10, 145:12, 145:21, 146:3, 147:16, 147:18, 150:8, 153:7 berkeley 28:20 best 108:9 better 91:17, 106:20, 140:22 between 17:21, 33:17,	34:10, 34:22, 35:17, 39:11, 39:15, 46:8, 50:1, 60:1, 66:1, 66:15, 66:17, 68:9, 68:17, 69:1, 69:16, 85:2, 90:1, 91:13, 94:7, 96:7, 96:14, 100:16, 101:6, 110:18, 112:12, 121:11, 123:8, 124:11, 124:12, 126:22, 132:16, 133:18, 139:2 beyond 48:22 bias 91:10, 129:11, 129:12, 129:20, 129:22, 130:1 big 28:19 bipolar 21:16, 108:2, 117:12, 119:3 bit 15:22, 23:7, 50:18, 56:17, 56:21, 70:8, 93:4, 97:15, 101:11, 106:13, 146:13 bitmicro 27:1 bjts 119:2 bled 131:13 blind 69:12 block 49:19, 111:20, 128:7, 128:9 blocked 95:20
---	---	---	--

blood 156:2 board 1:2, 27:20 boltzmann 129:17 borden 82:6, 82:12, 87:14, 89:11, 114:1, 135:19, 136:5, 139:18, 140:7, 140:9, 140:10, 140:16, 141:14, 142:6, 142:7, 142:12, 145:13, 145:14, 145:20, 147:19, 148:10, 150:5, 150:7, 151:8, 151:12, 151:16, 151:17, 151:19, 152:6, 152:19, 152:21, 153:1, 153:3, 153:5, 153:9 borden's 136:17, 137:6, 141:16, 148:18 boron 83:14, 84:10, 84:11, 84:14, 84:15, 84:16, 88:3, 111:5, 127:19, 133:6, 133:10, 133:13, 133:22, 134:1, 134:5, 134:7, 134:9, 135:2, 135:3, 135:5, 135:9, 135:15 boron-infused 150:20 both 20:8, 51:4, 51:7, 78:9, 79:20, 90:11, 90:18, 91:18, 92:11, 93:1,	93:19, 94:15, 95:19, 106:11, 117:18, 131:7, 131:8, 131:17, 132:13, 132:15, 132:18, 133:8 bottom 99:9, 123:6, 125:2 boundaries 112:4, 119:8, 133:20 boundary 128:6, 130:9 box 7:19, 104:5 break 9:1, 9:2, 50:15, 59:14, 64:21, 69:15, 96:22, 97:4, 97:7, 101:4, 103:14, 105:1, 118:8, 142:21, 143:4, 144:21 breaking 50:20, 51:5, 53:1, 60:12, 66:6, 67:3, 100:22 breaks 60:22, 61:6, 61:20, 62:7 breakup 53:5, 60:18, 60:20, 61:3, 61:16, 63:12, 64:12, 66:4, 66:5, 67:9, 94:14, 95:7, 96:10, 105:14 briefly 11:13 bring 82:5, 82:17, 103:19, 134:4, 148:3 bringing 141:3	broad 34:12, 35:3, 35:5 broadest 124:10 broken 50:10, 52:21, 60:21, 61:13, 61:17, 62:4, 95:5, 96:15 broken-up 62:1 brooke 3:3, 6:11, 11:20 brought 7:7, 7:14, 82:10 brownian 83:22, 84:2 bulk 110:4, 119:13, 127:22, 129:4, 130:8 business 125:22 böll 3:3, 6:9, 6:11, 11:20, 13:22, 20:11, 22:18, 24:9, 24:14, 27:17, 31:4, 31:20, 33:12, 35:2, 35:19, 37:2, 38:9, 38:19, 40:3, 40:19, 42:1, 42:13, 43:5, 43:13, 43:20, 46:16, 46:21, 49:6, 50:12, 50:22, 51:6, 55:10, 57:22, 59:4, 60:4, 60:14, 62:8, 63:8, 63:19, 64:22, 69:17, 71:7, 71:15,	73:21, 74:11, 75:9, 75:18, 76:15, 77:10, 77:20, 78:16, 79:5, 81:13, 88:19, 95:6, 96:17, 97:6, 103:6, 108:11, 112:21, 113:7, 113:20, 114:9, 117:22, 121:6, 123:20, 124:2, 124:7, 131:4, 131:18, 137:22, 139:19, 143:4, 144:20, 146:7, 147:2, 152:5, 152:22, 153:13 <hr/> C <hr/> c's 130:4 calculated 129:8 california 3:6, 10:19 call 32:3, 125:10, 142:1 called 27:21, 32:20, 33:2, 33:8, 36:8, 55:16, 69:11, 85:15, 93:14, 100:5, 100:15, 119:8, 124:21 calling 100:7, 113:5, 113:8, 116:10, 134:19 calls 103:7, 111:8 came 119:2 can't 25:1, 126:13 canadian 1:4, 6:13,
--	--	--	--

14:11, 15:3, 25:5, 155:13 cannot 8:9, 9:7, 75:12, 75:13, 111:21 cansolar 25:5, 25:11, 26:8 capture 34:3, 34:5 career 19:21 carried 117:11 carrier 36:3, 49:20, 97:21 carriers 95:20, 98:2, 98:11 carry 108:2, 147:14, 147:18, 152:18 case 1:4, 7:21, 23:11, 25:6, 25:12, 25:15, 25:18, 26:1, 26:3, 26:18, 26:21, 27:7, 41:11, 44:3, 47:3, 47:5, 48:19, 53:6, 56:8, 57:10, 62:5, 65:1, 65:3, 65:5, 65:19, 67:16, 69:10, 69:13, 87:12, 89:22, 101:2, 111:3, 113:3, 113:9, 113:10, 115:8, 123:17, 124:1, 126:20, 132:22, 133:2, 133:6, 135:12, 145:7 cases 14:9, 23:20,	23:22, 24:2, 24:3, 24:8, 24:19, 69:8, 132:21 catch 28:7 caused 101:22, 102:14 caution 24:9 caveat 114:21 cell 7:7, 17:21, 22:14, 31:10, 31:16, 31:19, 32:2, 32:5, 32:8, 33:18, 33:19, 33:22, 34:4, 34:10, 34:11, 34:22, 35:6, 35:18, 35:22, 36:21, 36:22, 37:6, 41:18, 41:22, 42:2, 70:11, 75:12, 75:14, 75:17, 75:20, 76:13, 77:8, 77:11, 87:1, 90:20, 92:7, 92:9, 92:11, 92:12, 96:20, 106:10, 106:21, 107:5, 107:8, 107:16, 118:13, 118:14, 139:4, 139:6, 139:7, 140:1, 140:17, 143:16, 147:22, 150:22 cell's 116:21 cellphone 7:10 cells 17:16, 17:17, 17:18, 18:1,	18:13, 18:14, 19:9, 19:13, 19:14, 20:15, 20:17, 21:1, 21:2, 21:21, 22:1, 22:9, 22:11, 22:21, 23:14, 23:22, 26:8, 26:10, 27:3, 28:14, 31:6, 34:6, 34:7, 34:9, 34:15, 34:21, 43:10, 68:16, 69:12, 76:4, 77:16, 93:8, 93:11, 93:12, 93:15, 106:5, 106:8, 106:11, 108:3, 117:6, 117:8, 119:4, 121:5, 139:22, 142:2, 145:19, 151:1, 153:6, 153:8, 153:10 celsius 63:17, 102:1, 108:10, 110:12, 110:15, 112:15 center 16:21 centigrade 53:4, 65:2, 85:1, 85:2, 100:13, 113:4 centimeter 95:13, 95:14, 110:3 certain 48:1, 50:8, 50:15, 51:16, 56:3, 62:15, 86:7, 86:8 certainly 24:21, 75:19, 81:15, 121:8 certify 155:3, 155:12,	155:16, 156:1 cetera 130:9, 130:10, 149:19 chair 16:17, 17:1 challenged 43:16, 72:6 change 15:19, 35:8, 35:13, 97:19 changes 130:20 channel 97:21 characteristics 55:13, 92:10, 129:10 characters 94:15 charge 129:16 charges 75:13 chemical 55:6, 55:16, 56:7, 56:8, 57:7, 57:10, 57:11, 58:7, 95:21, 119:10, 120:16, 120:17, 126:12, 126:16 chemically 55:21, 119:12, 119:16 chemistry 41:15 chemox 53:6, 56:3, 57:20, 59:20, 61:21, 62:5, 63:5, 63:16, 64:14, 64:21, 67:16, 106:1, 113:2, 113:10 chips 18:13 chronological 25:16, 25:17
--	--	---	--

circa 41:18 circuit 36:6, 50:1, 92:6, 96:9, 97:9, 107:2 circular 42:8 cite 121:17, 141:2, 152:17 cited 39:8, 40:11, 43:15, 50:14, 51:1, 54:17 citing 150:13 claim 40:6, 40:7, 40:9, 40:17, 42:8, 42:9, 70:4, 70:10, 71:5, 71:12, 71:20, 72:3, 72:5, 72:10, 72:17, 72:19, 73:3, 74:6, 78:3, 78:4, 78:14, 78:15, 78:17, 79:10, 79:17, 117:20 claims 39:12, 39:15, 40:12, 41:2, 42:21, 43:11, 43:16, 71:8, 71:9, 71:14, 71:19, 81:19, 87:17, 120:12 clarification 8:15 class 19:11, 19:14, 58:9 classes 17:7, 19:6, 19:8, 19:20 classical 47:20	classically 47:7, 47:17 clean 17:11, 56:20, 57:3, 57:4, 58:4, 59:10 cleaning 57:6 cleans 58:5, 59:6 clear 45:21, 81:22 clearly 63:11, 149:20 client 25:6 close 142:20 cm 110:2 cmos 27:3 cockrell 16:17, 17:1 coefficient 85:11, 85:13 coincides 128:14 collaborative 12:16, 14:1 column 56:12, 56:16, 120:15, 121:1, 121:20, 129:1 combination 87:21, 87:22, 114:6, 141:13, 142:12, 142:13, 142:15, 151:22 combinations 43:15, 43:17, 113:22 combine 87:6 combined 137:17 come 8:21, 43:15	commencement 155:7 commercial 44:13 commission 156:11 commonly 121:9 commonwealth 2:6, 155:3, 156:16 companies 18:20 company 18:17, 28:7 compare 114:19, 136:10 compared 67:10, 67:16, 72:1, 113:2 comparing 135:13 comparison 61:21 complete 17:19, 17:21, 67:5, 154:5 completely 60:22, 61:9, 142:9 complications 130:8 complimentary 135:6 component 110:9 composition 119:10 comprise 121:13, 121:22, 122:9, 122:13 comprising 70:11 computer 16:18 concave 33:20 concentrate 32:6, 34:18,	36:14 concentrated 32:11, 33:16 concentrating 36:2 concentration 36:4, 84:7, 84:11, 84:16, 84:17, 86:8, 86:13, 111:13, 132:2, 132:9, 132:10, 132:11, 133:10, 134:14 concentrations 35:22, 45:8, 132:1 concentrator 31:16, 31:19, 32:4, 33:18, 33:19, 34:11, 34:15, 34:20, 34:22, 35:7, 35:18, 36:17, 36:19, 36:21, 93:7, 93:11, 93:12, 106:5, 106:8, 106:11 concentrators 33:16 concept 32:6 concert 27:19 conclusions 66:9 concomitant 149:22 condition 9:13, 94:21 conditions 32:11, 33:16, 35:7, 36:17 conducted 1:13, 2:1 conductive 137:13 confidential 24:10, 24:16,
--	--	--	--

24:22 confused 131:12 confusing 136:9 congratulations 27:13 connected 125:18 connection 150:6, 150:7 consider 17:20, 37:22, 38:7, 38:17, 41:10 considerations 37:14, 37:21 considering 101:21 consistent 118:12, 121:4 consists 119:21 consortium 28:22, 29:14 constant 85:17, 129:17 consulted 18:19 contact 7:5, 31:7, 69:5, 69:12, 69:15, 69:20, 70:21, 71:1, 77:1, 77:2, 91:12, 91:14, 91:15, 91:16, 94:19, 98:3, 98:14, 142:2 contains 84:22 contaminants 125:20, 125:21, 126:1, 126:4 content 38:21, 39:3, 39:10 context 29:8, 49:13,	50:16, 51:2, 68:16, 76:17, 80:2, 117:18 continual 113:12 continue 82:13 continues 110:8 continuum 61:1, 103:3 control 15:16, 15:17, 57:10, 111:6 controlled 143:15 converge 128:16 conversely 95:19, 107:9 converted 35:15 copies 7:14, 7:15, 7:22 copy 54:12, 54:14, 136:13 core 27:5 corner 104:6 corrections 154:6 correctly 93:13 corresponding 63:4 corresponds 65:22 could 34:19, 35:6, 36:9, 36:10, 41:19, 50:5, 50:15, 66:4, 66:12, 68:20, 68:22, 69:8, 76:16, 76:18,	77:3, 77:12, 78:20, 79:7, 86:4, 90:4, 99:7, 101:8, 108:19, 122:14, 122:19, 123:2, 124:18, 130:1, 134:6, 142:2, 142:3 couldn't 54:13, 79:2, 119:14 counsel 6:5, 6:14, 11:13, 11:17, 11:19, 12:17, 71:15, 74:11, 155:13 couple 10:6, 10:7, 11:2, 81:5, 148:22 coupled 71:1 course 19:16, 20:5, 20:6, 20:12, 20:20, 21:1, 24:17, 34:2, 120:7, 141:1 courses 20:2 court 8:9, 24:2, 24:5 cover 20:14, 39:2, 39:14, 136:19 covered 43:11, 108:7 create 43:10, 118:15, 150:9 created 76:2 creates 98:14, 135:5 creating 84:8, 84:9	crystal 83:8, 83:11, 138:7, 139:3 crystalline 83:12 csi 15:4 current 16:16, 25:6, 36:5, 91:9, 94:20, 106:18, 107:6, 107:11, 129:11, 129:12, 129:13, 129:14, 129:21, 130:1 currently 7:5, 23:21 curve 66:15, 130:2 cut 137:2 cv 15:11, 15:12, 16:2, 21:12, 21:22, 24:13, 28:22 cvd 120:17, 120:18, 147:5
D			
d-r-a-m 18:10 damage 146:16, 146:22, 147:6, 147:9, 150:9, 151:9, 152:4, 152:14 dash 104:13 data 20:5, 63:20, 65:4, 67:19, 108:12, 112:22 date 42:4, 42:7, 42:11, 42:17, 42:22, 43:4,			

<p>43:12, 154:10</p> <p>day</p> <p>33:5, 34:2,</p> <p>156:9</p> <p>days</p> <p>11:15</p> <p>dc</p> <p>3:13, 4:9</p> <p>dealt</p> <p>29:7</p> <p>debra</p> <p>1:22, 2:5,</p> <p>155:2</p> <p>decade</p> <p>20:4</p> <p>december</p> <p>10:10, 10:12</p> <p>decent</p> <p>75:20, 77:16,</p> <p>118:13</p> <p>declaration</p> <p>11:5, 12:12,</p> <p>13:2, 13:5,</p> <p>14:16, 30:9,</p> <p>30:16, 38:14,</p> <p>39:2, 39:9,</p> <p>39:14, 40:5,</p> <p>40:11, 41:13,</p> <p>44:5, 44:10,</p> <p>45:17, 51:22,</p> <p>52:3, 70:3,</p> <p>80:16, 80:18,</p> <p>113:16, 116:3,</p> <p>116:4, 116:7,</p> <p>116:14, 122:6</p> <p>declarations</p> <p>7:16, 11:22,</p> <p>12:8, 12:14,</p> <p>93:1, 114:20</p> <p>decline</p> <p>25:3</p> <p>decreases</p> <p>37:8, 60:7</p> <p>deeper</p> <p>86:12, 86:19,</p> <p>133:15</p> <p>defect</p> <p>124:22</p>	<p>defects</p> <p>49:22, 50:3,</p> <p>50:4, 50:5,</p> <p>128:7, 130:9,</p> <p>150:9, 151:6,</p> <p>151:7</p> <p>define</p> <p>126:3</p> <p>defined</p> <p>118:9, 118:10,</p> <p>126:22, 131:21,</p> <p>132:12, 135:7</p> <p>defining</p> <p>130:7</p> <p>definitely</p> <p>67:7</p> <p>degradation</p> <p>113:12</p> <p>degree</p> <p>36:13, 41:14,</p> <p>65:2, 67:9</p> <p>degrees</p> <p>33:7, 53:4,</p> <p>63:11, 63:17,</p> <p>64:1, 64:4,</p> <p>64:5, 64:6,</p> <p>64:10, 67:14,</p> <p>67:18, 85:1,</p> <p>85:2, 85:8,</p> <p>100:13, 102:1,</p> <p>102:10, 103:9,</p> <p>108:10, 110:11,</p> <p>110:15, 112:15,</p> <p>113:4, 130:13</p> <p>deionized</p> <p>55:18</p> <p>deleterious</p> <p>150:11</p> <p>density</p> <p>94:20, 102:9,</p> <p>106:18, 124:22,</p> <p>129:13, 129:14</p> <p>department</p> <p>28:19</p> <p>depend</p> <p>64:15, 95:7</p> <p>depended</p> <p>12:21</p>	<p>dependence</p> <p>48:15, 94:19</p> <p>dependency</p> <p>85:12</p> <p>dependent</p> <p>95:4</p> <p>depending</p> <p>34:17, 36:1,</p> <p>50:16, 90:4,</p> <p>107:13</p> <p>depends</p> <p>48:8, 49:13,</p> <p>85:20, 86:20,</p> <p>98:19, 111:17,</p> <p>117:5, 130:6,</p> <p>143:1</p> <p>deponent</p> <p>154:1</p> <p>deposed</p> <p>9:22, 10:2</p> <p>deposit</p> <p>111:11, 120:9,</p> <p>142:1, 142:5,</p> <p>147:3</p> <p>deposited</p> <p>90:1, 108:18,</p> <p>147:4</p> <p>depositing</p> <p>84:10, 128:2,</p> <p>147:12</p> <p>deposition</p> <p>1:12, 2:1, 6:7,</p> <p>6:22, 7:10, 8:5,</p> <p>11:4, 12:5,</p> <p>15:6, 23:12,</p> <p>68:1, 76:18,</p> <p>88:8, 120:17,</p> <p>120:18, 126:12,</p> <p>126:17, 127:21,</p> <p>146:16, 146:22,</p> <p>147:6, 147:9,</p> <p>152:15, 155:6,</p> <p>155:8, 155:14,</p> <p>155:16</p> <p>depth</p> <p>85:20, 86:8,</p> <p>86:22, 132:8</p> <p>describe</p> <p>41:12, 57:15,</p>	<p>60:12, 60:15,</p> <p>87:21</p> <p>described</p> <p>40:4, 54:4,</p> <p>57:13, 59:21,</p> <p>88:4, 102:19,</p> <p>147:13</p> <p>describes</p> <p>37:13, 37:21,</p> <p>99:11, 102:13,</p> <p>103:4, 134:8,</p> <p>134:10</p> <p>describing</p> <p>46:7</p> <p>design</p> <p>41:18, 41:22,</p> <p>42:2, 86:20,</p> <p>106:10, 108:1</p> <p>designing</p> <p>41:16</p> <p>details</p> <p>34:14</p> <p>determine</p> <p>85:19, 92:6,</p> <p>92:8, 107:12,</p> <p>115:3</p> <p>determines</p> <p>92:9</p> <p>determining</p> <p>37:22, 38:7,</p> <p>38:17</p> <p>developing</p> <p>41:17</p> <p>device</p> <p>17:7, 19:8,</p> <p>19:10, 19:16,</p> <p>20:6, 20:7,</p> <p>27:4, 32:4,</p> <p>61:10, 86:20</p> <p>devices</p> <p>17:12, 18:12,</p> <p>18:15, 19:12,</p> <p>20:14, 27:3,</p> <p>61:11</p> <p>di</p> <p>55:17</p> <p>diagram</p> <p>53:19</p>
--	--	---	---

dielectric 123:1 difference 17:20, 66:2, 110:17, 132:16, 133:17 differences 33:17, 34:10, 34:14, 34:20, 34:22, 36:18, 39:11, 39:15, 66:17, 87:16 different 35:17, 45:5, 45:8, 51:13, 58:16, 58:17, 60:16, 76:21, 77:1, 80:19, 84:12, 99:12, 105:8, 105:11, 117:18, 119:18, 120:1, 120:8, 120:9 differently 115:11, 115:12 diffuse 73:15, 100:14, 112:3, 112:7, 128:6, 133:14 diffused 132:18 diffusing 70:15, 70:18, 73:9, 111:5, 127:19, 131:10, 132:5, 132:7, 133:7, 133:9, 133:22 diffusion 83:17, 83:20, 83:21, 85:10, 85:13, 85:16, 85:20, 86:2, 86:9, 86:10, 86:11, 86:14, 88:3, 108:21, 111:15, 111:17, 111:20, 111:21,	112:9, 128:9, 128:15, 130:14, 133:3, 133:12, 135:5 diffusivity 85:19 digital 103:2, 113:13 digits 13:18, 13:19 diode 129:10, 129:12 dioxide 47:6, 48:19, 54:2, 56:1, 60:1, 60:5, 68:17, 98:22, 121:22, 122:11, 122:13, 122:21, 123:8, 123:14, 124:12, 137:20, 138:9, 139:12, 139:16, 140:15 direct 54:10, 69:13, 69:15, 69:20, 94:14 directly 111:5 director 16:20, 17:11 disavowed 74:8, 79:12 disavowing 142:9, 153:8, 153:9 disclosed 151:10, 151:18 discloses 120:14 discuss 51:20, 83:13, 89:14, 105:22, 117:20, 148:17, 152:16 discussed 27:15, 87:9, 109:16, 113:17,	114:17, 148:8, 150:2, 151:8 discusses 44:5, 45:18, 50:14, 83:17, 89:18, 136:16, 137:6, 141:6 discussing 52:7, 68:3, 87:6, 115:18, 134:12, 142:7 discussion 118:7, 151:20, 151:21 dispense 142:3 displays 110:1, 129:3 distance 62:18 distinction 112:12 district 10:18, 24:2, 24:5 divided 85:16 dividing 91:15 doctor 23:18 document 15:16, 15:18, 16:1, 30:12, 30:15, 56:11, 65:8, 65:13, 93:6, 115:21, 116:2, 136:2, 136:4 documents 7:12, 7:17, 9:20, 11:15 doing 36:2, 51:12, 52:17, 133:21, 135:1, 152:14 dominant 149:18	dominate 110:16, 112:17 done 24:6, 27:19, 28:16, 29:19, 105:6, 108:21, 126:2, 135:11, 142:20 donors 45:7 dopant 45:9, 70:13, 70:15, 71:5, 71:19, 71:22, 72:1, 72:4, 72:11, 72:17, 72:20, 72:21, 73:2, 73:5, 73:10, 75:2, 75:3, 75:4, 75:6, 78:21, 78:22, 83:15, 85:4, 88:3, 89:8, 101:18, 111:11, 111:20, 127:20, 133:9, 134:6 dopants 70:15, 70:18, 71:21, 73:9, 73:16, 78:15, 84:5, 108:20, 111:12, 112:3, 114:14, 128:5, 128:12, 132:6, 132:7, 135:3 dope 83:14, 84:10, 84:15, 111:6, 119:8, 120:7, 120:8, 124:13 doped 25:22, 73:20, 74:5, 75:14, 75:15, 83:7, 83:9, 88:10, 88:15, 110:10, 112:10, 116:20,
--	--	---	--

117:9, 117:18, 128:2, 134:1, 139:2 doping 21:15, 45:6, 74:1, 81:12, 82:13, 84:14, 84:20, 85:15, 86:8, 88:16, 117:8, 117:9, 117:14, 117:21, 118:10, 118:11, 131:20, 131:22, 132:22, 133:1, 133:11, 134:18, 141:16 down 16:21, 25:18, 26:3, 26:12, 29:10, 65:2, 70:7, 84:17, 92:2, 94:4, 97:15, 97:18, 99:5, 101:4, 102:17, 103:21, 106:12, 125:1, 127:12, 132:8, 146:12 dozen 10:6, 10:7, 11:2 dr 6:16, 15:11, 15:15, 24:16, 30:12, 31:22, 59:19, 65:14, 81:14, 82:22, 115:21, 126:13, 136:8, 150:13, 150:18 draft 12:18, 13:20 dram 18:10 drastic 97:19 draw 66:8, 149:4	drive 84:4, 84:17, 85:3, 92:1, 92:12, 108:20, 135:10 drive-in 101:7, 101:18, 101:22, 102:15 driven 111:12 due 91:2, 110:3, 110:9, 129:4, 140:2, 140:18 duly 6:2, 155:6 dunner 3:11 during 7:10, 34:2, 70:20, 146:16, 146:22, 147:6, 147:9 dynamic 18:11 <hr/> E <hr/> e-notary 2:6, 155:2, 156:15 e-r-f-c 135:7 each 40:7, 40:17, 119:7, 119:22 earlier 55:2, 57:14, 87:9, 92:5, 105:10, 106:9, 108:22, 115:7, 134:12, 153:4 earliest 42:7, 42:12 early 21:2, 21:4 easier 136:11 easily 49:10	edt 1:15, 153:15, 155:19 effect 51:18, 95:9, 101:13 effective 48:2, 77:7, 77:11 effectively 76:13, 96:13 effects 36:11, 150:11 efficiencies 77:17, 80:6 efficiency 35:7, 35:10, 35:12, 35:14, 36:18, 37:8, 87:1, 92:12, 92:13, 96:19, 97:11, 106:22, 107:15, 118:14 effort 12:16, 14:2, 28:22, 29:2 either 45:7, 50:2, 53:17, 68:14, 69:19, 77:14, 80:7, 82:11, 94:21 electrical 16:8, 16:12, 16:18, 35:16, 41:14 electrically 71:1 electricity 69:1 electrodes 50:1 electron 47:4, 47:7, 47:15, 53:13, 53:15, 62:15, 118:17, 129:16 electrons 47:3, 62:6,	62:10, 76:1 elegantly 97:12 element 40:17, 71:21, 73:3, 118:1 else 30:5, 86:12 embodiment 137:7, 144:13 emitter 21:16, 22:10, 88:11, 94:16, 94:20, 106:2, 107:22, 108:1, 109:20, 110:4, 110:13, 110:14, 111:1, 111:9, 116:20, 117:2, 117:13, 117:17, 118:2, 118:3, 118:18, 118:22, 119:11, 121:12, 123:9, 123:15, 124:14, 127:14, 127:15, 129:2, 129:4, 130:4, 130:16, 130:17, 131:1, 131:2, 131:6, 131:14, 131:16, 132:13, 132:15, 133:18, 133:19, 134:13, 139:4, 145:18, 147:22, 148:12, 149:11, 153:6, 153:8, 153:9 emitters 21:8, 93:7, 93:20, 106:7, 110:18, 119:1, 120:10, 121:5, 125:7, 125:15, 125:17, 126:8, 126:19, 132:16, 132:21, 145:22 employed 156:3
---	--	---	---

encapsulate 18:3 end 57:7, 65:8, 65:13, 91:15, 101:20, 149:5, 150:13 ends 62:9, 112:1, 136:14 energies 47:19 energy 28:19, 35:16, 47:4, 47:9, 47:15, 47:17, 53:12, 53:18, 53:21, 85:15 engagement 24:19 engineering 16:8, 16:12, 16:18, 41:14 enough 25:22, 47:9, 49:1, 60:6, 69:7, 69:21, 76:6, 84:1, 110:16, 111:20, 112:17, 123:2, 126:2, 128:8 entirely 75:14 enunciate 39:9 environment 18:4 epitaxial 143:18, 144:3, 144:14, 145:8, 146:5, 152:3, 152:9, 152:11 equal 65:19, 65:21, 85:13, 93:17, 127:3 equally 114:18	equals 133:10 equivalent 16:6 erfc 135:6, 135:7 errata 154:7 error 135:7 esquire 3:3, 3:9, 4:3, 4:4, 4:5 essentially 89:12, 106:6, 139:7 establish 109:11 et 125:4, 130:9, 130:10, 149:19, 151:11 etching 57:11 even 35:6, 48:17, 48:22, 53:3, 53:4, 61:20, 62:1, 62:4, 63:11, 67:14, 113:1, 113:3, 127:7, 140:22, 145:3, 145:6 ever 10:2, 10:14, 10:20, 20:16, 31:9, 37:15 every 40:7, 40:17 everybody 58:10 everything 86:12 everywhere 62:11, 142:5 evidence 43:9, 43:18, 44:14	evolved 27:22 exact 58:11, 58:13, 58:14, 66:9 exactly 10:5, 21:19, 22:5, 22:19 examination 5:2, 6:14 examined 154:3 example 21:7, 51:21, 57:9, 88:4, 122:19, 148:22 except 138:15, 147:15 exhibit 5:10, 5:11, 5:12, 5:13, 5:14, 5:15, 5:16, 5:18, 5:19, 15:7, 15:9, 23:4, 29:11, 30:7, 30:8, 30:10, 54:6, 54:7, 54:8, 54:11, 56:13, 67:21, 80:10, 82:18, 82:19, 82:21, 83:2, 83:5, 87:3, 87:5, 92:15, 92:16, 92:18, 103:20, 105:17, 109:1, 109:2, 109:4, 115:13, 115:14, 115:15, 115:19, 128:20, 135:21, 135:22, 143:8, 148:4 exhibits 5:5, 5:8 exists 90:1 experience 23:6, 27:16,	41:16, 41:20, 45:15 experiment 52:15, 66:17, 133:22, 134:4 experimental 48:3 experiments 51:8, 51:12 expert 12:12, 13:2, 150:14 expertise 27:5 expires 156:11 explain 91:6, 96:4, 96:5 explicit 134:10 explored 63:9 exponential 48:15, 85:14, 129:15 exponentially 60:8, 129:11, 130:2 exposed 29:7 exposure 55:19, 55:20 expressly 40:8 extensive 124:8 extensively 11:16 extract 130:3 <hr/> F <hr/> fabricating 70:11 fabrication 19:11, 20:7, 27:4
---	--	--	---

facing 70:20 fact 106:9, 118:12, 134:21 factor 37:7, 38:21, 39:11, 41:6, 42:15, 43:22, 63:14, 92:10, 96:8, 97:11, 107:14 factors 38:6, 38:14, 38:16, 44:1, 44:6, 44:12, 44:21, 64:15 faculty 29:6, 30:4 fail 63:7 fair 75:8 fall 55:7 falsely 9:15 familiar 45:1 family 16:17, 17:1 farabow 3:10 fast 100:15 feel 143:1 fellows 17:10 few 9:19, 11:14, 22:2, 22:6, 22:7, 23:7, 57:13, 100:11, 120:16, 153:4 fga 100:5 field 41:15, 41:17,	55:6 fighting 19:4 figure 22:14, 45:18, 45:21, 52:1, 52:6, 52:7, 52:10, 52:14, 61:1, 61:18, 65:5, 65:7, 65:9, 65:13, 65:18, 66:13, 66:14, 66:18, 66:19, 103:22, 104:3, 108:6, 108:7, 108:9, 109:14, 127:12, 128:16, 136:11, 138:2, 149:11 figures 100:3, 102:8, 105:4 filing 42:11 fill 37:7, 92:10, 96:8, 97:11, 107:14 film 119:5, 120:5 films 26:1 finally 36:9 financially 156:5 find 42:20, 43:8, 107:4 fine 9:18, 9:21, 13:15, 23:19, 25:2, 25:4, 106:17, 146:13 finish 71:16, 74:12, 74:18 finite 47:13	finnegan 3:10 first 12:18, 18:10, 20:9, 20:22, 21:20, 22:1, 22:14, 22:20, 27:7, 28:11, 28:13, 38:21, 56:12, 56:16, 70:13, 70:15, 71:22, 72:20, 73:5, 73:10, 74:3, 75:3, 78:22, 99:17, 99:19, 100:4, 100:6, 100:8, 102:7, 104:10, 105:2, 105:5, 105:9, 129:1, 129:20, 136:19, 136:21, 147:20 fit 130:2 fixed 99:1 flat 66:14, 66:20 flexible 78:17 flip 78:21 flow 69:1, 88:21, 126:22 flowing 107:6, 127:4 fluxes 36:10 focal 33:22 focus 32:7, 33:20, 74:6 focused 153:2 focusing 20:6, 106:6,	114:22, 115:1 foglietti 148:10 follow 88:16, 89:7 followed 88:7, 104:10, 104:11 following 88:14, 88:20 follows 6:3 foregoing 154:4 forever 111:16 forget 99:17 forgetting 34:8 forgotten 26:22 form 13:22, 20:11, 22:18, 27:17, 28:1, 31:4, 31:20, 33:12, 35:2, 35:19, 37:2, 38:9, 38:19, 40:3, 40:19, 42:1, 42:13, 43:5, 43:13, 43:20, 46:16, 46:21, 49:6, 49:21, 50:12, 50:22, 51:6, 55:10, 56:1, 57:22, 59:4, 60:4, 60:14, 62:8, 63:8, 63:19, 64:22, 69:17, 70:16, 71:7, 72:2, 72:20, 73:11, 73:21, 75:9, 75:18, 76:15, 77:10, 77:20, 78:16,
---	---	--	---

79:5, 81:13, 88:7, 88:8, 88:11, 88:18, 88:19, 95:6, 96:17, 97:6, 103:6, 108:11, 111:9, 111:10, 112:21, 113:7, 113:20, 114:9, 117:22, 121:6, 123:20, 124:2, 124:7, 131:4, 131:18, 132:6, 133:11, 137:22, 139:19, 144:20, 146:7, 147:2, 152:5, 152:22 formed 46:5, 50:5, 116:19, 116:20, 118:2, 120:11, 121:5, 126:8, 130:7 forming 70:12, 70:13, 70:21, 73:5, 73:18, 84:18, 100:5, 100:10, 102:7, 105:5, 118:3, 131:11, 134:13, 139:4 forth 12:22, 13:11, 155:6 forward 129:11, 129:12, 130:1 forward-generated 75:22 found 40:8, 40:20, 43:2, 106:1, 141:10 four 10:17, 13:19, 22:22, 38:16 four-factor 38:4	fourth 43:22 fraction 35:14, 61:16 frame 21:4, 23:2, 28:15 froitzeim 80:12, 80:14, 81:1, 81:10, 81:11, 81:16, 82:1, 82:12, 83:3, 84:12, 87:6, 87:10, 88:5, 88:14, 88:22, 89:8, 89:16, 113:18, 113:22, 114:3, 114:13, 137:17, 139:17, 141:13, 142:3, 142:12 froitzeim's 114:6, 114:7, 141:16 front 7:12, 31:6, 31:8, 46:3, 70:18, 70:19, 70:22, 73:17, 77:12, 77:14, 80:7, 81:16, 128:17, 137:9, 150:21, 150:22 full 6:18, 129:1 fully 61:14 function 55:11, 132:8, 135:7 funding 17:9 furnace 134:1, 134:5, 135:2, 135:8 further 138:22, 146:15, 153:11, 155:12,	155:16, 156:1 furthermore 150:2 G gain 97:10 gamma 65:18, 65:19, 65:21, 126:21, 127:3 gan 51:1, 51:3, 51:4, 51:10, 51:20, 53:20, 54:17, 54:20, 60:12, 60:15, 82:6, 82:11, 87:7, 87:11, 88:17, 88:21, 89:4, 89:7, 89:15, 91:1, 92:19, 92:22, 93:13, 94:1, 95:19, 96:22, 97:18, 98:7, 99:18, 100:3, 100:7, 101:3, 102:6, 103:4, 103:7, 106:9, 113:18, 113:22, 114:3, 114:7, 114:15, 148:10, 148:21, 149:8, 149:20, 151:10, 151:18, 152:16 gan's 88:6, 88:18 garrett 3:11 gas 65:20, 100:5, 100:10, 102:7, 105:5, 127:5 gaseous 134:6 gaussian 134:14, 134:22,	135:10 gave 39:8, 120:22 general 34:17, 37:4, 51:14, 55:5, 56:6, 64:11, 108:3, 111:15, 114:20, 117:15, 120:2, 126:1 generally 48:14, 93:15, 121:5, 121:8, 123:18, 124:5, 124:8 generate 55:18, 85:3 generation 19:18 getting 61:3, 74:14, 91:15, 126:18, 127:5, 138:18, 141:1, 142:20, 145:21, 151:16, 152:4 give 86:5, 122:17, 124:20, 142:19, 147:16, 153:7 given 83:21, 129:13, 129:14, 154:6, 155:10 gives 62:2, 107:10, 135:10, 145:12 giving 77:2 global 66:8 go 7:22, 8:4, 8:22, 10:1, 15:22, 18:5, 23:3, 25:1, 47:18, 52:11, 57:2, 62:6,
---	---	---	---

62:16, 62:20, 62:21, 63:3, 64:14, 78:22, 99:5, 102:21, 103:16, 104:1, 106:13, 108:8, 112:20, 115:4, 132:8, 136:18, 136:20, 150:4, 150:12, 151:8, 153:14 goes 25:15, 49:10, 65:1, 129:11, 130:2, 149:14, 149:17 going 8:1, 8:4, 9:10, 18:5, 32:22, 58:20, 59:13, 66:3, 74:15, 77:8, 77:13, 78:17, 100:1, 103:13, 108:8, 109:17, 113:15, 115:18, 126:3, 131:15, 136:8, 136:18, 136:19, 141:19, 150:6, 151:11 gone 27:22 good 6:16, 6:17, 70:9, 97:16, 103:2, 106:14, 113:13, 116:16, 125:6, 140:21 gradient 84:7, 84:8, 84:9, 84:17 gradually 51:9, 103:8, 103:9, 128:12, 132:8 graduate 17:9, 19:15, 20:5	grain 112:4, 119:8, 120:1, 120:3, 120:5, 128:6, 130:9 grains 119:6, 119:21 grand 3:5 grants 29:1 greater 36:13, 51:15 greek 90:14 green 150:14, 150:18, 151:14, 151:19, 152:16 ground 8:4 grounds 80:15, 80:17, 80:20, 81:1 grow 49:9, 53:11, 55:6, 56:3, 141:22 growing 52:16, 56:8, 57:7, 58:22, 88:6 grown 46:3, 121:14, 121:22, 122:9 growth 143:18, 144:3, 144:14, 146:5, 152:3, 152:12 guess 20:3, 31:14, 42:9, 63:14, 80:20, 117:15, 131:12, 149:12 guessing 13:7, 13:10, 14:14, 28:14 <hr/> H <hr/> hafnium 122:20	halfway 97:17 hand 53:14, 97:17, 97:18, 156:9 hanhwa 26:17, 27:6 happen 64:1, 64:5, 64:10 happening 62:9, 112:1, 133:3 happens 49:3, 61:15, 67:17, 99:11 hard 54:12, 54:14, 125:22, 133:17, 136:13, 143:3 hazard 31:13 head 29:8 headquartered 28:20 hear 54:13, 119:14, 126:13 heard 31:9, 31:15, 32:14, 37:15, 125:17 heat 34:21, 36:1, 50:13, 51:9, 52:17, 84:4, 84:6, 84:15, 111:12, 128:10 heat-treating 128:4 heating 34:19, 35:9 heavily 110:9, 139:2 height 48:9, 48:10, 98:20, 98:22	help 28:2, 102:8, 145:8, 147:5, 152:11, 152:13 helpful 108:4, 135:18, 151:11 helps 25:14, 97:11, 100:17, 113:3, 149:21 henderson 3:10 here 12:1, 12:7, 16:20, 23:13, 24:13, 26:3, 41:3, 43:21, 59:14, 70:5, 77:5, 77:6, 78:13, 102:20, 105:7, 106:15, 115:7, 115:17, 117:19, 121:10, 123:13, 124:12, 125:4, 130:20, 134:10, 142:20, 145:16, 151:17 hereby 154:2, 155:3 hereinbefore 155:6 hereunto 156:8 hesitating 24:20, 105:1 heterojunction 76:20, 76:21, 140:1 heterojunctions 76:19 hf 57:12 hfo2 122:21 high 31:2, 35:22, 36:7, 36:10,
--	---	---	--

37:6, 49:1, 52:22, 63:21, 64:2, 84:11, 84:16, 94:12, 95:11, 95:16, 95:22, 98:3, 98:14, 99:3, 111:13, 118:14, 150:19 high-concentrati- on 84:2, 133:4 high-enough 84:1, 128:11, 133:5 high-low 45:1, 45:5, 45:11, 74:9, 75:16, 75:19, 76:2, 76:3, 76:8, 76:12, 79:12 high-temperature 101:3 higher 34:16, 51:14, 60:18, 85:9, 85:10, 85:18, 86:1, 86:11, 86:13, 96:11, 100:21, 102:22, 104:20, 105:13, 105:14, 112:7, 120:2, 130:16, 131:19, 131:20, 132:22, 133:12, 140:1, 140:2, 140:17, 140:18, 140:22, 145:4, 147:16 highest 53:3, 63:10, 63:11, 64:6 highly 117:9, 119:9 himself 145:20, 147:19 history 74:8, 74:22,	75:7, 78:2, 78:9, 78:11, 79:7, 79:9, 79:11, 79:18, 80:3, 118:9 hit 112:5, 128:7, 139:6, 143:16, 145:5, 145:17, 147:21 hits 47:4 hold 65:6, 65:11, 116:14, 149:1 hole 118:17 holes 69:10, 76:1, 141:11 home 7:2, 7:4 honestly 14:14 hot 126:11, 126:15 hour 11:14, 15:2, 59:14, 103:14 hours 11:14, 13:1, 13:8, 13:12 however 28:18, 58:19, 71:20, 72:19, 97:10, 139:22, 147:13 hundred 13:8, 113:13 hurt 97:8 hydrofluoric 57:12 hydrogen 100:11, 100:15 <hr/> I <hr/> idea 100:14	identify 6:9 illinois 16:8, 16:13 imagine 14:18, 26:8, 26:18, 62:13 impact 36:4, 36:6, 94:14, 96:8, 96:9 impinging 62:10 implies 52:22 impression 74:22 improve 90:19, 103:9 improved 145:17, 147:21 improvement 113:2 impurities 119:13, 119:17, 127:9 inc 1:4, 15:4, 155:13 incident 35:15 include 50:10, 142:13, 143:15 including 64:15 incompletely 50:5 increase 36:3, 92:13, 97:8, 101:21, 102:14, 102:20, 103:5, 106:21, 110:13, 150:1, 151:7 increased 64:13 increases 52:18, 52:21,	63:1, 103:8, 104:21, 150:10, 151:4 increasing 51:10, 61:19, 101:22, 102:14, 102:22 increasingly 110:10 independent 81:19, 87:17 indian 16:3 indicates 52:21 indicating 44:1, 44:21, 53:20 indicative 149:9 indicators 90:19 indirect 52:19 infer 66:4 information 24:10, 24:13, 24:17, 24:22, 67:5 inherently 40:8 inhibit 59:9 initial 21:15 input 12:19, 14:2 insertion 143:16, 149:12 instead 88:10, 140:12, 146:9, 147:4, 152:10 institute 16:3 instructs 8:18
--	---	---	--

instruments 18:7	introduce 135:4	25:8, 27:12	145:5, 150:22,
insulating 139:2	introducing 88:2, 135:2	iv 129:10	151:1, 151:2
insulator 53:12, 123:1	introduction 94:5, 94:6	J	junctions 19:9, 19:12,
intact 62:14, 95:21,	invention 136:17, 136:20,	j 90:11	20:15, 21:9,
97:22, 98:10	137:6, 141:15,	jacob 4:4, 6:7	21:16, 22:9,
integrate 148:11	143:14, 145:17,	january 16:22	22:10, 74:9,
integrity 94:22, 95:11	147:21, 153:5	jeremy 4:3, 6:4	75:1, 76:4,
interchangeably 107:19, 107:20	inventors 138:22	jing 4:5, 6:8	76:8, 79:13,
interested 156:5	involve 17:14, 47:19	job 1:20, 126:2	79:14, 79:15,
interestingly 25:22	involved 10:20, 18:15,	junction 31:6, 45:2,	80:7, 108:3,
interface 100:16, 102:8,	26:1, 28:1,	45:5, 45:6,	118:10, 118:12,
123:15, 124:21,	28:18	45:11, 70:17,	131:11
143:15, 149:19	involvement 28:5	72:2, 72:15,	K
interfacial 88:7, 89:18,	involves 17:16, 47:2,	72:20, 73:11,	kc 111:9, 135:14
89:21, 91:3,	55:17	73:19, 74:7,	kelvin 85:17, 129:18
94:14, 95:10,	involving 29:3, 30:2	75:1, 75:11,	key 67:8, 67:11,
95:11, 95:20,	ipr 1:5, 1:6, 5:10,	75:16, 75:19,	152:6
97:1, 97:22,	5:18, 12:9,	76:2, 76:3,	kind 102:19, 103:22,
98:2, 98:10,	12:10, 12:13,	76:10, 76:12,	104:18, 112:4,
100:22, 101:5,	13:3, 13:14,	76:13, 77:9,	131:13
108:18, 111:10,	13:20, 13:21,	77:12, 77:13,	kinetic 47:9, 47:15,
112:6, 112:11,	15:7, 15:9,	77:19, 77:21,	47:19
123:7, 123:12,	30:8, 30:10,	77:22, 79:14,	know 8:22, 9:20,
123:18, 124:6,	54:7, 54:8,	79:22, 80:1,	13:10, 15:20,
124:15, 128:3,	82:19, 92:15,	80:6, 84:18,	21:19, 23:9,
128:8, 135:15,	92:16, 109:2,	85:19, 86:8,	23:17, 46:11,
135:17, 141:20,	115:14, 115:15,	86:13, 86:16,	48:6, 48:19,
142:5, 145:6,	116:4, 135:21,	86:19, 86:21,	51:5, 53:9,
145:7, 148:12,	135:22	91:9, 91:11,	54:1, 55:15,
149:16, 149:21,	iprs 10:21, 12:1,	111:3, 111:4,	62:9, 63:18,
151:10, 152:7,	12:5, 14:21,	111:10, 116:18,	64:11, 64:20,
152:13	24:2, 24:4	117:12, 118:4,	67:17, 71:10,
internal 92:8	issue 39:12, 39:16,	118:5, 118:15,	72:3, 74:4,
interrupting 65:14	126:2	119:3, 127:22,	78:12, 78:14,
intrinsic 36:3	itc 10:17, 24:3,	129:9, 130:7,	79:8, 79:16,
		131:19, 131:21,	83:10, 85:8,
		132:6, 132:11,	90:16, 100:1,
		132:12, 133:11,	103:10, 105:1,
		133:14, 141:10,	106:4, 108:15,
			109:16, 113:5,

114:21, 119:10, 120:10, 126:9, 129:7, 130:15, 134:22, 136:18, 137:16, 141:1, 141:2, 146:10, 149:2 knowledge 41:6, 42:15, 42:17, 55:5 known 28:21, 32:17, 43:10, 53:12, 58:6, 91:12, 92:9, 117:10, 134:9, 135:6 kt 85:16, 129:15, 129:19 kumar 6:20 kwark 51:1, 51:3, 51:4, 51:11, 51:20, 52:10, 53:9, 53:20, 54:2, 54:5, 54:12, 54:14, 54:17, 54:21, 55:14, 55:16, 56:8, 56:11, 58:3, 58:5, 59:21, 60:12, 60:15, 61:1, 61:18, 63:10, 63:20, 63:22, 64:2, 64:4, 64:7, 64:9, 65:1, 65:5, 65:9, 65:18, 66:16, 67:19, 82:6, 82:12, 87:13, 89:10, 105:19, 106:1, 106:4, 106:6, 108:6, 109:4, 111:1, 113:18, 113:22, 114:3,	114:15, 125:4, 126:9, 126:10, 126:15, 128:17, 130:4, 134:9, 134:12, 134:16, 148:10, 151:11 ky 4:14 <hr/> L <hr/> lab 20:8, 20:18, 28:3 labeled 104:9, 138:3 lack 110:17 lag 107:4 language 70:4, 105:11 large 32:7, 33:21, 34:6, 47:7, 58:21, 112:12 larger 61:16, 120:4 last 10:8, 10:9, 13:17, 13:19, 14:15, 20:3, 44:9, 90:9, 103:20, 106:15, 139:21, 143:8, 148:2, 148:6, 148:8 late 10:9, 21:3, 21:19 law 4:6, 6:5 lawyer 12:20, 38:10, 74:19 lay 42:9 layer 46:8, 46:11,	46:15, 46:18, 49:3, 54:2, 56:3, 57:21, 58:12, 59:20, 59:21, 60:1, 60:2, 60:5, 60:13, 61:4, 61:5, 63:7, 68:10, 68:17, 68:18, 70:12, 70:14, 70:16, 72:12, 73:6, 73:10, 76:9, 81:11, 82:2, 82:6, 82:11, 83:7, 83:14, 85:3, 87:11, 88:7, 88:9, 88:17, 88:18, 89:7, 89:15, 89:19, 89:21, 90:3, 91:3, 94:7, 118:3, 121:13, 121:21, 122:13, 123:7, 123:13, 123:14, 123:19, 124:6, 124:15, 127:21, 137:10, 137:11, 137:12, 137:19, 137:20, 137:21, 138:7, 138:9, 138:10, 138:11, 138:12, 138:18, 138:19, 139:2, 139:12, 139:15, 139:16, 141:7, 141:9, 141:11, 141:15, 141:17, 142:4, 142:14, 142:16, 144:8, 144:10, 146:15, 146:17, 146:20, 146:21, 147:1, 147:10, 148:13, 149:16 layers 46:4, 46:5,	46:8, 48:1, 69:2, 104:9, 119:19, 137:19, 138:3, 139:8, 144:7 leach 128:12 lead 29:4, 50:1, 57:19, 67:1, 140:6, 150:1 leak 112:5 learn 61:22 least 41:16, 41:20, 62:7, 62:11, 67:3, 67:12 left 9:16, 62:2, 97:17, 109:8, 129:1 legal 12:21, 38:12, 74:10, 74:16 leif 11:20 less 23:8, 47:16, 93:17 let's 23:16, 50:18, 65:4, 74:6, 82:17, 103:16, 127:12, 135:19, 143:4, 153:14 letter 90:14 letters 24:20 letting 69:1 level 31:2 levels 94:2, 120:8 life 20:2
---	--	--	--

light 55:20, 71:9, 74:3 likely 149:18 limited 71:11 limits 150:21 line 66:20, 90:9, 121:1 lines 120:15, 120:16 liquid 84:20 list 23:11, 38:4, 58:3 listed 23:13, 24:13, 28:22, 44:12 listing 19:20, 23:21 lists 23:5 literature 119:2 little 15:22, 23:7, 50:18, 56:17, 56:21, 70:8, 93:4, 97:15, 101:11, 106:13, 136:9, 136:11, 146:13 llp 3:4, 3:11, 4:6, 6:5, 6:12 located 6:21 location 68:13, 88:21 locations 50:8, 50:15, 51:16, 51:17, 53:2, 62:15 long 11:7, 57:15,	104:19, 143:1 long-enough 128:11 long-term 28:5 longer 51:14, 60:19, 62:18, 86:10, 103:1, 104:20, 105:13, 112:8, 133:13 longi 26:13, 27:6 look 21:11, 43:7, 51:10, 65:9, 71:20, 74:6, 78:8, 78:10, 79:11, 99:20, 113:21, 114:19, 118:1, 120:13, 120:15, 121:20, 126:10, 128:21, 130:1, 130:12, 134:11, 136:15, 145:14, 148:16 looked 21:22, 72:5, 118:8 looking 32:1, 51:21, 54:12, 54:14, 56:5, 56:9, 56:11, 64:9, 66:16, 84:19, 87:20, 105:4, 120:20, 134:15, 136:10 looks 27:8, 27:12, 29:18, 104:17, 105:4 los 3:6 lose 140:8, 140:17 loses 95:11	lot 12:19, 14:2, 21:4, 22:8, 27:18, 28:2, 62:21, 145:10, 147:17 low 37:5, 60:17, 67:3, 84:14, 92:13, 94:2, 95:12, 96:1, 98:4, 98:17, 102:12, 113:11, 126:2, 151:3 low-concentration 84:3, 133:5 low-pressure 120:17 lower 36:22, 48:13, 53:5, 62:4, 62:17, 63:15, 67:15, 86:15, 91:2, 91:16, 91:19, 92:1, 97:10, 105:6, 105:14, 105:15, 106:16, 106:19, 130:16, 130:21, 149:12 lowest 65:10, 108:13 lpcvd 120:18 <hr/> M <hr/> made 17:12, 19:12, 21:2, 40:13, 60:9, 147:7 main 86:9 majority 94:15, 97:20, 98:2, 98:11 make 13:16, 17:17, 17:18, 17:19,	19:14, 20:17, 49:8, 59:18, 76:4, 121:2, 140:7, 142:18, 150:6 making 17:16, 20:22, 22:8, 31:6, 111:2, 111:4 managing 17:11, 17:12 manufacture 41:18 manufacturing 17:19, 41:22, 42:2 many 10:4, 10:16, 11:1, 11:12, 13:1, 18:19, 29:3, 64:15, 66:7, 69:8, 112:2, 122:16, 125:19, 125:21, 147:14 march 1:14, 155:18, 156:9 marked 5:5, 5:6, 5:8, 15:7, 15:10, 30:11, 54:9, 82:20, 92:17, 115:16, 136:1 marriage 156:3 martin 150:14 masking 111:21, 111:22, 141:7, 141:11, 141:14, 141:19, 141:21, 142:4, 142:14, 142:16 mass 32:3, 32:17, 33:2, 33:8, 33:15
---	---	--	--

master's 16:7 match 113:10, 132:1, 138:2 matched 121:2 matches 132:9 material 84:10 materials 76:22, 124:11 matter 47:3, 50:17, 66:11, 156:6 matters 14:7, 14:13 maxeon 1:7, 6:6 maximize 113:12 maximum 34:3, 63:12, 86:22, 92:12, 107:7, 107:12 maybe 13:11, 13:12, 23:2, 34:14, 48:20, 49:1, 50:6, 61:8, 61:9, 99:22, 141:2 mean 23:9, 35:10, 35:13, 39:21, 40:2, 40:21, 45:4, 50:4, 50:13, 59:8, 66:9, 67:4, 75:21, 76:5, 76:9, 76:20, 83:20, 86:4, 89:2, 102:5, 106:7, 106:17, 107:1, 110:22, 117:4, 118:21, 121:7, 123:13,	123:19, 124:6, 124:10, 126:5, 127:17, 128:1, 142:7, 144:5, 145:1, 147:11, 148:1 meaning 118:13 means 32:13, 37:19, 95:3, 96:4, 96:5, 127:4, 127:19, 128:2 meant 49:17 measure 52:20, 129:7 measuring 130:20 mechanical 47:1 mechanically 47:10, 47:21 medical 9:13 meet 11:17, 11:19 meier 81:8, 122:18 memory 18:11, 18:14 mention 9:18 mentioned 35:8, 35:21, 54:16, 54:19, 55:1, 138:1 mentions 106:9 merck 84:21 message 67:11 met 11:13 metal 70:21, 71:1, 77:1, 91:14	method 8:3, 31:5, 70:11, 114:11 methods 149:22 metric 91:10 mic 126:14 microelectronics 16:21 micron 134:14 might 36:13, 40:22, 52:20, 66:17, 74:14, 115:1, 136:11, 136:14 mind 13:13, 15:3, 15:20, 37:4 minimize 147:5, 151:6, 151:8, 152:11, 152:13 minority 94:15 minus 85:14, 93:18, 95:13, 129:19 minutes 22:7, 57:14, 153:4 mirror 34:1 mirrors 32:6, 33:20, 34:5, 34:8 misoriented 119:6, 119:22 missed 40:22 missing 23:9 misspoke 56:5 mixed 100:11	more 9:19, 20:3, 22:10, 23:8, 48:12, 48:14, 49:7, 53:1, 60:20, 61:4, 61:15, 61:16, 63:2, 64:12, 66:6, 67:4, 78:17, 81:22, 85:18, 93:5, 93:15, 96:22, 104:13, 105:14, 108:8, 112:6, 115:2, 124:5, 124:8, 133:14, 142:11, 143:1, 146:13, 152:2 moreover 143:17 morning 6:16, 6:17, 7:20 most 119:17 mostly 95:20 motion 83:22, 84:2 motivated 148:11, 148:18 motors 34:1, 34:8 move 142:21, 150:15 much 34:18, 36:1, 36:21, 52:20, 56:22, 95:4, 96:16, 97:5, 97:7, 100:20, 105:6, 106:13, 107:12, 108:8, 130:13, 149:12 multi-university 28:19 multiple 17:22, 30:2,
--	--	--	---

35:20, 120:14, 124:17, 135:4 must 38:6, 38:17, 40:8, 72:21, 73:2 myself 30:1, 141:2	48:20, 76:1, 78:10, 84:6, 108:20, 115:4, 138:18 needle 96:14, 97:13, 103:11 needs 67:4, 118:14 neer 3:9, 11:21 negative 47:19, 93:17, 95:16, 110:2, 129:4 negligible 95:10, 134:2 net 132:1, 132:11 never 126:3 new 3:12 next 18:21, 26:12, 103:22, 108:5, 120:16, 139:5, 146:14 nice 91:10 nitrogen 100:10 nominal 28:6, 50:7 non 34:4 none 5:6, 40:16, 40:20 nonlegal 74:22 nonobviousness 44:2, 44:7, 44:21 nonsensical 47:20 noon 32:21	normal 33:8, 70:20 norms 86:16 northern 10:18 nos 1:4, 1:7 noted 91:1, 149:8 notes 110:12 nothing 153:13 notice 2:5 nought 36:5, 52:19, 52:21, 53:6, 61:18, 62:5, 63:1, 63:4, 63:13, 63:15, 64:13, 66:2, 67:15, 85:14, 90:11, 90:18, 91:2, 91:6, 91:8, 91:18, 91:22, 92:2, 92:6, 93:16, 94:21, 95:4, 95:15, 95:22, 96:9, 96:20, 97:1, 97:8, 99:12, 100:18, 101:6, 101:21, 102:2, 102:11, 102:14, 102:21, 102:22, 103:5, 103:8, 104:21, 105:15, 106:2, 106:16, 106:20, 107:20, 108:10, 124:22, 129:15, 129:22, 130:3, 149:9, 149:22 number 26:20, 104:11, 106:20, 116:8	numbers 12:9, 35:7, 35:10, 35:12, 104:14, 121:1, 138:1, 149:2 nw 3:12, 4:7 <hr/> o <hr/> o3 55:21 object 13:22, 20:11, 22:18, 27:17, 31:4, 31:20, 33:12, 35:2, 35:19, 37:2, 38:9, 38:19, 40:3, 40:19, 42:1, 42:13, 43:5, 43:13, 43:20, 46:16, 46:21, 50:12, 50:22, 51:6, 55:10, 57:22, 59:4, 60:4, 60:14, 62:8, 63:8, 63:19, 64:22, 69:17, 71:7, 73:21, 75:9, 75:18, 76:15, 77:10, 77:20, 78:16, 81:13, 88:19, 94:1, 95:6, 96:17, 97:6, 103:6, 108:11, 112:21, 113:7, 113:20, 114:9, 117:22, 121:6, 123:20, 124:2, 124:7, 131:4, 137:22, 144:20, 146:7, 147:2, 152:5, 152:22 objection 49:6, 79:5, 131:18, 139:19
--	--	---	---

objective 44:1, 44:6 objects 8:17 obtained 93:19 obvious 38:1, 38:8, 38:18 obviously 115:10 obviousness 40:13, 44:1, 44:7, 44:21 oc 106:21, 107:2 occurred 155:17 october 156:12 oe 107:17, 107:20, 110:2, 110:13, 110:14, 110:17, 112:17, 129:3 offhand 54:3, 78:13 office 1:1, 7:3 often 32:17, 33:5, 49:11, 55:17 oh 15:12, 25:14, 28:10, 35:14, 52:9, 76:11, 89:6, 95:15, 100:3, 115:5, 138:4 ohm 95:14, 95:15 ohmic 77:2 okay 8:6, 8:20, 9:20, 10:7, 15:14, 25:4, 25:14, 26:7,	28:16, 30:21, 38:15, 40:10, 45:18, 52:11, 59:12, 65:17, 67:6, 69:21, 72:7, 73:1, 73:3, 75:5, 80:21, 81:7, 81:20, 90:8, 95:15, 97:16, 99:20, 101:11, 101:19, 103:12, 114:4, 115:5, 115:8, 115:12, 116:10, 116:15, 121:3, 125:3, 128:22, 131:1, 132:2, 132:10, 132:19, 133:2, 133:8, 134:3, 134:19, 135:13, 135:18, 136:22, 137:1, 137:2, 138:4, 143:5, 148:5, 148:16, 148:20, 149:4, 149:8, 151:15 omega 95:13 omitting 89:1, 89:3 once 10:18, 13:10, 14:1, 21:11, 26:5, 29:22, 111:17, 119:1 one 19:8, 24:4, 26:12, 35:21, 49:19, 56:2, 61:11, 62:3, 65:6, 66:3, 66:8, 67:1, 67:4, 79:4, 82:1, 110:12, 115:19, 121:8, 122:14, 125:19, 131:20, 132:5,	140:12, 142:19 ongoing 24:19 only 8:8, 9:17, 9:18, 9:21, 18:17, 40:13, 65:1, 66:2, 98:1, 104:22, 120:22, 141:10 onwards 40:4 open 36:6, 69:3, 92:6, 96:9, 97:9, 107:2, 141:21 open-circuit 150:21 opened 7:19 operation 70:21 opinion 32:9, 36:15, 38:12, 40:10, 74:10, 74:16 opposite 71:22, 72:21, 75:3, 75:6, 117:9, 117:13, 117:19, 118:5, 118:11 oppositely 118:10 optimal 144:18 optimize 96:19, 102:2 optimizing 96:20 optimum 143:19 order 25:16, 48:2, 55:8, 75:22, 109:11 ordinary 37:20, 41:7,	42:16 other 11:9, 27:15, 28:16, 28:17, 29:5, 29:6, 29:19, 29:20, 30:3, 34:8, 40:21, 41:1, 43:17, 44:20, 49:20, 51:17, 53:2, 53:14, 53:19, 56:6, 57:12, 57:18, 66:7, 68:9, 68:10, 68:18, 76:18, 81:5, 87:15, 95:8, 97:18, 101:11, 119:7, 119:22, 122:15, 131:21, 134:5, 135:9, 141:2, 147:18 others 51:2 otherwise 72:2, 75:12, 156:5 out 22:14, 107:13, 113:1, 115:7, 130:13, 141:9, 144:6, 151:22 outcome 57:6, 156:6 outdated 23:7 outdiffuse 128:1 outdiffused 111:9, 127:15, 133:18, 135:16 outdiffusion 110:9, 110:16, 112:10, 112:16, 113:6, 128:14 outer 32:19 output 33:6, 107:7,
---	---	---	--

107:13 outputs 18:2 outside 18:18, 80:2 over 11:16, 15:17, 18:20, 20:3, 21:1, 23:13, 32:7, 33:21, 41:3, 43:21, 59:13, 62:18, 70:12, 70:14, 73:6, 105:7, 108:2, 110:2, 110:11, 113:15, 117:11, 118:2, 129:15, 129:19, 136:21, 147:14, 147:18, 151:17, 152:18, 153:7 overall 11:8, 13:5, 13:6, 13:8, 61:10, 96:19, 105:12 overseeing 30:3 oversight 136:15 own 29:5 owner 1:9, 4:2, 6:6, 6:14 oxides 21:11, 46:2, 46:13, 48:18, 50:6, 50:11, 50:14, 55:6, 59:8, 61:17, 62:1, 68:4, 68:7, 69:9, 111:15, 111:19, 111:21, 111:22, 122:15, 122:22, 124:20, 139:1, 141:19, 141:20	oxidizing 65:20, 127:1, 127:4 oxygen 84:22 ozonated 55:17, 56:7 ozone 55:19, 55:21, 57:13 <hr/> P <hr/> p 120:8 p-n 19:9, 19:12, 20:14, 21:8, 21:16, 22:9, 22:10, 45:5, 75:1, 75:11, 76:2, 76:10, 76:12, 77:8, 77:11, 77:13, 77:21, 79:14, 79:22, 80:5, 80:6, 84:18, 108:3, 111:2, 111:4, 111:10, 118:11, 118:15, 127:21, 129:9, 130:7, 131:11, 131:19 p-o-s-i-t-a 37:16 p-tag 117:18 p-type 71:6, 73:1, 75:15, 78:18, 78:20, 78:22, 83:15, 93:19, 111:11, 127:19, 131:2, 131:5, 131:6, 131:7, 131:8, 131:10, 131:17, 131:19, 132:6, 132:7, 132:16, 132:21,	132:22, 133:8, 149:10 page 5:2, 5:10, 16:1, 23:3, 23:5, 29:11, 29:13, 38:3, 56:12, 56:14, 65:15, 80:9, 90:9, 93:4, 97:14, 99:8, 103:22, 104:3, 108:6, 109:6, 121:1, 121:11, 123:6, 125:2, 127:11, 128:21, 149:5, 150:17 pages 1:21 paid 14:20 pairs 118:17 panel 17:21, 17:22, 26:18 panels 17:14, 17:19, 20:10, 27:16, 28:4, 28:17, 29:7, 29:20, 30:1, 30:4, 43:2 paper 7:22 papers 28:13, 48:4, 112:2 paragraph 37:9, 37:11, 37:13, 37:21, 40:4, 41:12, 45:16, 45:18, 46:2, 51:22, 52:2, 52:3, 52:5, 52:8, 56:18, 56:22, 70:2, 80:10, 80:11, 82:16,	83:4, 83:6, 83:13, 84:19, 87:4, 87:5, 87:20, 87:21, 89:13, 89:14, 90:6, 97:17, 101:12, 101:20, 105:17, 105:19, 105:22, 109:8, 109:10, 109:13, 109:19, 116:13, 116:15, 116:17, 121:10, 122:6, 123:4, 127:10, 129:2, 134:11, 136:6, 136:10, 136:12, 136:14, 136:16, 137:5, 137:15, 138:22, 139:21, 141:4, 141:6, 143:11, 148:5, 148:6, 149:2, 149:5, 150:12, 150:15, 151:5, 153:3 paragraphs 39:10, 88:4, 148:9, 148:16, 148:20, 151:16, 152:17 parallel 18:2, 61:11, 61:12 parameter 64:18, 126:21 parameters 58:3, 59:7, 66:7, 85:21, 86:9, 86:21, 92:13, 95:8, 96:12, 96:20 parenthetically 149:11 part 18:9, 89:12, 110:21, 121:10, 136:20 partially 61:8, 61:14,
--	--	---	--

100:22 particles 83:22 particular 25:12, 44:3, 54:11, 57:9 parties 24:7, 25:13, 156:2, 156:4 partly 75:10 party 155:12 pass 98:2, 98:11 passivating 68:21, 68:22, 69:4, 69:7, 69:9, 69:11, 69:14, 69:19 passivation 124:21 past 9:22, 11:16, 19:15 patent 1:1, 1:2, 1:7, 1:9, 4:2, 6:5, 6:14, 13:18, 30:17, 30:18, 30:22, 31:3, 31:5, 31:18, 32:1, 33:11, 38:1, 38:7, 38:18, 40:12, 40:14, 41:2, 41:4, 42:7, 42:12, 42:22, 43:3, 43:11, 44:13, 44:17, 70:10, 80:15, 80:22, 81:4, 83:3, 113:16, 113:19, 114:11, 114:18, 115:6, 115:18, 116:8, 116:11, 116:18, 120:19, 121:17,	121:21, 122:18, 124:1, 136:5 patentee 74:8, 118:9 patents 7:15, 11:5, 45:19, 45:22, 68:1, 68:6, 72:8, 74:21, 120:11 path 62:7, 62:11 patterned 141:9 pcv 147:6 pecvd 120:18 pending 9:3 penetrate 47:21 people 32:3, 33:5, 90:16 percent 62:14, 100:11, 113:13, 113:14, 126:5, 127:8 perform 37:1, 87:22, 88:6 performance 90:20 perhaps 28:15, 32:4, 36:1, 46:13, 55:3, 130:12 person 41:7, 42:16 personal 37:20 personally 28:18 pertain 92:11 pertinent 41:9, 41:10,	41:21, 42:16 peterston 4:3, 5:3, 6:4, 6:5, 6:15, 11:20, 15:6, 15:21, 23:3, 23:19, 24:12, 29:10, 30:7, 37:9, 52:4, 54:6, 56:13, 56:21, 58:1, 59:13, 59:17, 65:7, 65:12, 66:12, 67:20, 70:2, 70:7, 71:17, 74:13, 80:9, 82:16, 83:4, 87:2, 90:6, 92:14, 93:3, 94:4, 97:14, 99:7, 101:10, 102:17, 103:13, 103:16, 103:19, 104:2, 105:16, 106:12, 108:5, 109:1, 109:6, 115:13, 115:17, 116:13, 123:4, 125:1, 127:10, 135:20, 136:6, 141:4, 143:5, 143:7, 143:9, 146:12, 148:3, 149:7, 150:15, 153:11, 153:14 petitioner 1:5, 3:2, 6:12 ph 1:12, 2:1, 5:2, 6:2, 16:12, 154:2, 155:5, 155:17 phenomenon 47:2 phone 7:7 phosphorus 83:7	phosphorus-diffu- sed 151:3 photoactivity 75:21, 76:5 photogenerated 118:17 photon 36:10 photovoltaic 28:21 phrase 118:4, 148:2 physically 118:16 physics 17:8, 19:8, 19:16, 20:5, 20:7, 21:10, 27:4, 41:15 pinholes 49:22, 50:3, 62:15, 62:16, 62:21 places 53:19, 148:22 plasma 146:16, 146:22, 147:5, 147:9, 150:8, 150:9, 152:4, 152:14 plasma-enhanced 120:18, 147:5, 151:9, 152:14 plasmas 151:7 please 6:19, 8:8, 16:1, 23:4, 23:15, 29:11, 37:10, 45:17, 52:5, 54:7, 56:10, 56:14, 56:15, 59:15, 65:8, 65:13, 66:13, 67:21, 70:3, 71:16, 74:12, 80:10,
---	--	---	--

82:17, 82:18, 83:5, 87:3, 87:4, 89:13, 90:7, 91:20, 92:15, 93:4, 94:5, 97:15, 102:18, 103:15, 103:17, 105:17, 105:18, 109:2, 109:7, 115:14, 116:14, 116:15, 123:5, 125:3, 127:11, 127:13, 135:21, 136:7, 141:5, 148:4, 148:7, 149:7, 150:16 plow 142:22 point 33:22, 47:20, 56:9, 63:6, 67:8, 68:12, 112:9, 113:1, 128:13, 130:19, 131:22, 142:2, 148:21, 151:5 polarity 71:22 poly 21:16, 22:10, 65:3, 65:5, 65:22, 106:7, 108:1, 110:10, 111:11, 111:13, 112:4, 112:10, 119:1, 123:15, 125:8, 126:8, 128:12, 153:6, 153:8, 153:9 poor 37:7 posa 61:22 posit 144:17 posita 37:16, 37:19,	37:22, 38:6, 38:17, 43:10, 43:14, 64:9, 64:11, 74:4, 86:16, 103:10, 122:12, 134:9, 134:22 position 16:16, 16:22, 19:3 positions 18:6 possibility 140:11, 145:21 possible 37:5, 94:2, 113:11 post-diffusion 112:13 postdoctoral 17:10 potential 47:4, 47:16, 53:21, 76:1, 118:16 power 25:20, 25:21, 34:4, 107:12, 129:19 practical 60:10, 76:4, 76:6, 77:16, 80:5 preclude 140:14 prediffuse 127:17, 133:21 prediffused 109:19, 111:1, 127:14, 127:18, 128:14, 129:2, 133:18, 133:19, 135:12 prediffusing 112:13 prediffusion 134:10 prefactored 85:14	prefer 8:3, 85:7, 142:8 preferable 86:18 preferably 85:1 preparation 12:2, 13:5, 13:6 prepare 11:3, 11:7, 11:9, 12:12 preparing 12:5 presence 152:12 present 4:13, 36:12, 36:13, 44:2, 61:7, 138:22, 145:16, 147:21 presented 47:5 presents 62:19 pressure 126:12, 126:16 presumably 49:18 presume 125:19 pretty 34:12, 124:8 prevent 9:14, 49:4, 144:14, 146:5, 152:8 preventing 144:3, 145:8, 150:8 prevents 143:17 previous 11:14, 18:6, 99:8 previously 15:9, 30:10,	54:8, 82:19, 92:16, 115:15, 135:22, 149:13 primarily 148:21, 153:2 principle 77:4 prior 5:8, 11:6, 12:4, 14:9, 14:16, 28:13, 38:22, 39:3, 39:8, 39:12, 39:15, 40:7, 40:9, 40:11, 40:16, 40:20, 40:21, 41:1, 43:15, 43:17, 50:14, 50:19, 54:17, 56:7, 68:1, 77:4, 80:11, 127:20, 141:2 priority 42:3, 42:8, 42:17, 42:22, 43:4, 43:12 probability 47:13, 47:14, 48:13, 48:14, 48:16, 49:8, 60:7, 98:4, 98:18, 98:19, 99:4, 99:5 probably 11:2, 13:8, 13:11, 23:1, 26:8, 28:14, 48:4, 67:4 problem 65:16, 86:6 problems 86:5 procedure 57:3 process 55:11, 55:14, 57:6, 60:21,
--	---	--	---

83:21, 88:21, 89:4, 89:5, 98:1, 101:3, 102:7, 108:19 processes 36:11, 91:11 processing 17:8, 27:4, 60:15, 120:3 professor 16:18, 18:22, 19:20 profile 134:22, 135:5, 135:6 program 28:20 progress 23:21 progressive 61:4 progressively 60:20, 61:19, 63:2, 96:11, 101:4 projects 29:6, 30:2 propensity 51:15 proper 55:12 properties 47:3, 55:9 proposal 82:5 propose 139:17 proposed 89:16 proposing 102:6, 141:14 prosecution 74:8, 74:22, 75:7, 78:1, 78:8, 78:10, 79:7, 79:8, 79:11, 79:18, 80:3, 118:9	protect 146:15, 146:21, 147:8 protecting 152:3 provide 8:8, 139:22, 146:21 provided 12:19, 14:2, 60:6 provides 143:15, 146:15 pte 1:7, 6:6 public 2:6, 155:2, 156:15 publication 22:21 publications 22:1 publishable 23:1 published 48:3, 112:2 publishing 22:4 pull 15:6, 30:7, 54:6, 92:14, 109:1, 115:13, 115:19, 134:16, 135:20, 143:7 pulled 109:3 pure 125:7, 125:15, 125:18, 126:3, 126:5, 126:8, 126:18, 127:6, 127:7, 127:8 pursuant 2:5 put 28:4, 33:21, 54:5, 107:5, 135:8, 141:15,	152:7 putting 49:18 pv 4:6, 6:5, 29:13 <hr/> Q <hr/> qualify 45:11 quality 91:10 quantum 47:1, 47:10, 47:21 question 8:11, 8:12, 8:16, 8:18, 8:21, 8:22, 9:22, 24:15, 25:1, 34:12, 35:4, 38:15, 58:2, 71:18, 79:16, 125:12, 131:15, 137:5, 142:11, 150:4, 152:20 questions 9:8, 9:11, 153:12 quickly 18:6 quite 11:16, 55:22 quote 122:8, 127:6, 149:9, 149:14, 149:17, 150:18, 151:12, 151:14 quotes 150:13 quoting 122:5, 151:17 <hr/> R <hr/> r&d 28:2 raise 17:8	random 18:11, 83:22, 84:2 range 55:1, 55:3, 55:4, 55:7, 58:6, 58:14, 58:21, 58:22, 60:17 rapidly 112:3, 128:6 rate 15:1 rather 7:22 ratio 65:20, 126:22 rca 56:19, 57:4, 57:16, 57:18, 58:4, 58:5, 59:6, 59:10 reaches 133:20 react 55:22 reactive 55:22 read 71:9, 74:3, 74:21, 79:9, 79:18, 80:2, 110:21, 140:10, 140:20, 154:3 reading 78:1, 149:8, 150:19 reads 91:1, 97:18, 138:22, 139:5, 139:21, 143:14 realignment 145:8 really 49:11, 67:4, 67:11, 78:10, 136:12, 138:15, 150:22
---	--	---	---

rear 88:3, 151:2 reask 8:12 reason 9:1, 9:6, 9:17, 9:18, 9:21, 35:21, 80:3, 104:22, 120:22 reasonable 80:6 reasonably 102:12, 118:14 reasons 35:8, 35:20 recall 10:5, 13:7, 14:14, 22:19, 24:7, 26:4, 54:3, 65:19, 78:2, 78:6, 78:7, 78:13, 79:6, 79:12, 79:19, 87:16, 106:7 receive 7:17 received 16:2, 16:7 recent 23:5 recently 20:3, 21:22, 72:5 recess 59:16, 103:18, 143:6 recipe 59:10 recipes 58:7 recite 71:5, 72:11, 72:14, 72:17, 93:1 recited 40:9, 78:15, 79:3	recites 72:3 recognize 139:1 recognizes 140:11, 145:20, 147:19, 149:20 recombination 19:18, 36:11, 91:11, 110:3, 129:4, 149:10, 149:18, 149:22, 150:11, 150:20, 151:4, 151:6 record 6:19, 8:9, 103:16, 153:14, 153:15, 155:9 recovering 9:17 rectangular 53:20 reduce 102:8, 149:21 reduced 150:1 reduces 124:22 reducing 124:21 reduction 100:17 refer 13:14, 13:17, 15:3, 90:17 reference 40:9, 80:12, 80:14, 80:15, 80:19, 92:19, 92:22, 130:7, 130:19 references 81:5 referred 125:7 referring 30:22, 32:16, 33:3, 78:3,	78:4, 104:8, 108:16 refers 30:18, 33:15, 35:14, 75:1, 100:4, 107:22, 123:7, 129:13 reflect 47:8 reflected 61:18 reflection 47:13 regard 12:8, 14:4 regarding 30:16, 31:5, 114:22, 117:16 regardless 59:6, 67:8, 75:2 regents 16:17, 17:1 regime 63:9 region 61:13, 84:3, 111:13, 117:9, 133:4, 133:5 regions 61:7, 61:8, 61:12, 69:6 regrowth 152:9 relate 31:18, 107:15 related 12:4, 13:2, 21:13, 21:18, 23:13, 23:22, 25:19, 26:4, 38:14, 58:3, 79:10, 79:17, 93:10, 106:4, 137:6, 150:5, 156:1 relates 31:3, 33:11,	79:20, 80:11, 105:19, 109:13, 116:7, 118:7, 126:20, 145:17, 147:21, 153:5 relatively 99:3, 151:3 relevant 21:5, 22:8, 29:8, 39:10, 88:20, 89:5, 99:22, 134:11, 138:16 reliability 28:5 remain 143:19 remember 13:18, 22:4, 25:19, 26:10, 26:20, 114:10 repeat 91:20 replace 137:18 replacement 145:22 replacing 138:10, 139:7, 152:1 report 37:10, 51:22, 125:5 reported 1:22, 125:6, 149:13 reporter 8:9 represented 155:13 representing 25:13 require 48:1, 71:19, 71:21 requirement 40:7 research 17:9, 17:13,
--	--	---	--

19:4, 20:20, 21:1, 29:1, 29:5, 29:6, 29:8, 30:1, 122:22 researching 41:17 resides 70:10 resistance 37:5, 37:7, 62:7, 62:12, 62:19, 91:13, 91:15, 92:8, 97:22, 98:4, 98:15 resistances 36:22 resistivity 94:19 respect 33:7, 119:7, 119:22, 130:19 respectfully 25:3 response 24:11, 31:21 responsibilities 17:5 restricted 78:18 restricting 102:9 result 130:13 results 23:1, 44:14, 93:14, 98:3, 109:11, 125:6, 128:16 retain 53:7 retained 14:7, 14:13 retaining 51:17, 53:2 reveal 24:10, 24:21	revealing 24:16 reverse 25:17, 36:4, 91:8, 91:9, 106:17, 106:19, 129:20, 129:22 review 9:20, 11:22, 12:4 reviewed 11:5, 67:22, 76:16 reviewing 11:15, 81:14 rho 90:14, 90:15, 90:16, 90:18, 91:6, 91:12, 91:16, 91:19, 91:22, 92:2, 92:7, 93:18, 94:19, 95:3, 95:12, 95:22, 96:8, 96:21, 97:10, 97:19, 99:5, 99:12, 101:6, 103:8, 103:9, 105:15 rid 126:1, 138:18 right 10:13, 25:18, 46:5, 54:21, 56:19, 58:16, 62:16, 67:17, 82:2, 88:12, 88:21, 92:19, 94:13, 96:14, 98:15, 99:13, 101:13, 103:4, 103:5, 105:20, 109:4, 114:2, 114:6, 130:21, 131:12, 137:17, 138:13, 138:21, 140:19, 144:19, 145:15, 145:16,	146:6, 151:13 right-hand 104:6 rise 77:2 road 128:7 roadblock 112:5 role 17:6, 17:14, 18:8, 18:11, 19:3, 19:19, 76:19 room 17:11 roughly 33:6, 33:7, 48:6, 55:7 row 102:11 rules 8:5 rupture 51:21 ruptured 61:8 rupturing 51:16, 51:18 <hr/> S <hr/> said 14:5, 17:17, 20:1, 20:17, 22:20, 39:6, 49:15, 50:3, 52:8, 67:18, 67:22, 72:7, 89:3, 89:5, 108:14, 119:15, 119:21, 123:22, 148:1 sake 72:22 same 14:4, 19:7, 24:13, 40:14, 44:17, 45:6,	45:9, 45:22, 58:11, 65:15, 66:14, 66:20, 86:12, 87:13, 89:10, 104:19, 105:12, 108:21, 110:15, 114:5, 114:8, 120:21, 154:4 sample 111:7 samples 91:3, 149:16 samsung 27:1 sanjay 1:12, 2:1, 5:2, 6:2, 6:20, 24:9, 30:9, 154:2, 155:5, 155:17 saturate 129:21 saturation 36:5, 91:9, 94:20, 106:18, 106:19 say 21:12, 22:5, 22:16, 33:6, 35:12, 44:6, 62:14, 67:7, 72:22, 74:2, 76:8, 78:9, 79:20, 79:21, 88:2, 91:14, 101:16, 106:16, 115:19, 122:8, 137:3, 149:1, 149:14, 149:17, 152:19 saying 52:13, 59:20, 76:14, 97:12, 103:11, 112:19, 131:16, 137:16, 140:7, 140:16, 140:20 says 16:2, 16:20,
---	---	--	--

18:7, 18:21, 41:9, 46:2, 73:5, 73:9, 84:19, 90:11, 90:18, 91:1, 93:12, 94:13, 94:18, 95:9, 95:19, 101:20, 102:16, 106:15, 110:1, 116:17, 118:1, 121:21, 129:2, 134:13, 145:16, 146:14, 147:20, 148:8, 153:5 schottky 77:3 science 41:15 scope 38:21, 39:2, 39:10, 43:6 screen 8:2, 56:14, 136:15 scroll 23:15, 29:10, 56:17, 56:21, 70:7, 93:4, 94:4, 97:15, 101:10, 101:19, 102:17, 103:21, 106:12, 109:7, 125:1, 127:12, 146:12 scrolling 15:18 se 19:14 second 25:15, 25:18, 39:11, 56:18, 56:22, 65:6, 99:15, 99:18, 100:2, 100:19, 100:20, 101:2, 101:16, 102:9, 104:15, 105:2,	105:9, 109:8, 116:17, 126:10, 136:22, 142:19 second-to-last 143:10 seconds 9:19 sections 44:9 see 23:16, 34:13, 37:11, 38:3, 52:5, 52:19, 53:3, 54:16, 54:22, 56:22, 65:4, 66:1, 66:16, 70:4, 72:10, 73:3, 81:17, 85:5, 90:8, 94:5, 96:10, 97:18, 98:5, 99:9, 99:20, 100:3, 101:1, 101:9, 101:12, 102:4, 103:21, 104:3, 104:5, 109:8, 109:10, 109:18, 109:21, 110:6, 121:15, 125:2, 125:9, 125:13, 125:14, 127:12, 129:5, 134:9, 142:10, 143:12, 143:21, 148:6, 148:14, 151:19 seen 30:12, 82:21, 92:18, 94:18, 115:21, 125:18, 136:2 selected 23:5 semiconductor 17:7, 17:8, 19:8, 20:6, 20:7, 20:13, 27:2, 77:2,	91:14 semiconductors 76:22 semitransparent 47:12 sense 45:6, 114:20, 130:11, 130:14 sent 7:18, 54:15, 136:13 sentence 90:8, 106:15, 116:17, 122:5, 138:21, 139:5, 139:21, 140:6, 143:10, 143:12, 146:14, 147:20, 148:6, 148:8 separate 75:13, 75:22, 118:16 separated 119:7 series 18:1, 92:8 serve 76:19, 90:5, 124:18 session 5:5 sessions 5:8 set 155:6, 156:8 severe 110:16, 112:16, 113:6, 113:8, 113:10 shallow 86:15 shankin 4:14, 15:17, 65:12 shape 134:21, 135:10 sheet 154:7	short 50:1, 143:4 short-circuit 107:9, 107:11 shortcut 13:13 shorter 13:16, 86:14 should 66:8, 79:11, 137:17, 140:7 shoulder 9:16 show 34:13, 35:4, 37:3, 40:20, 63:20, 66:14, 66:20 showing 61:20, 104:18 shown 8:2, 53:19, 66:18, 67:19, 100:3, 102:7, 130:20 shows 61:2, 65:18, 108:6, 108:9, 127:14 side 50:2, 53:17, 73:17, 77:12, 77:14, 77:18, 77:21, 88:3, 88:9, 101:13, 109:9, 131:20, 131:21 sidley 3:4, 6:12, 14:8, 14:9 signature 154:10 signature-k9lvk 156:13 signed 154:7 significant 48:18, 60:18,
---	--	---	---

66:5, 101:21, 102:13, 103:5, 103:7, 110:10 significantly 63:15 sih4 65:21 silane 65:21, 127:1 silicon-containi- ng 127:2 similar 32:5, 76:19, 139:6 similarly 148:10 simplistically 61:11 simply 32:6 since 20:16, 22:12, 22:22, 23:8, 46:13, 79:3, 152:1 single 40:8, 40:17 single-crystal 84:13, 90:2, 111:5, 119:6, 119:21, 127:22, 128:15 sio2 53:11 siodop 84:20 sipos 65:19, 125:5, 125:10, 125:11, 126:20 sir 43:9 sitting 11:21, 41:3, 43:21, 77:5, 77:6, 78:13 six 29:2	size 120:5 sizes 120:1, 120:3 skill 37:20, 41:7, 42:16, 56:2 skilled 67:1, 88:5, 148:11, 148:19 skip 109:17 sky 32:18 slightly 105:11, 117:17 small 33:22, 61:12, 62:14, 62:16, 141:21 smaller 48:10 snodgrass 4:4, 6:7 so-called 36:3, 53:18, 55:17, 57:4, 85:11, 91:8, 107:2, 107:10, 107:14 solaria 26:7 some 8:4, 9:20, 18:15, 23:20, 28:3, 29:6, 30:3, 50:14, 53:5, 62:1, 62:20, 67:9, 68:13, 74:1, 75:21, 76:5, 80:17, 81:1, 89:3, 100:14, 107:4, 109:16, 112:9, 113:21, 122:17, 128:13, 134:5 somebody 9:22	someone 41:13 something 10:10, 14:15, 36:8, 115:10 sometimes 32:3 somewhere 75:12, 80:7 sorry 11:18, 38:15, 39:22, 52:2, 54:13, 65:14, 78:19, 80:10, 81:22, 82:17, 91:21, 101:11, 101:20, 108:14, 109:7, 119:14, 125:11, 125:12, 126:13, 131:15, 138:4, 138:5 sort 30:2, 55:7, 58:21, 61:1, 128:7, 141:18, 145:1 source 70:14, 70:15, 73:5, 73:10, 84:10, 84:16, 134:5, 134:6 sources 84:13 south 3:5 space 32:19 speak 51:11 speaking 126:14 species 127:1, 127:2 specific 34:13, 35:4, 37:3, 91:12, 94:19, 123:22, 142:11	specifically 22:10, 24:6, 31:13, 32:15, 35:5, 48:9, 68:13, 71:8, 78:6, 79:19, 123:17, 134:8, 148:20, 150:5 specifications 71:10, 71:11 specs 74:4, 120:13, 120:21 spoken 14:10 squared 95:13, 95:14, 110:3 stable 94:11 standard 57:3 stands 100:5, 126:11, 126:16 stanford 28:20 start 20:9, 20:22, 22:3, 22:4, 28:11, 51:4, 51:7, 64:21, 73:1, 74:4 started 20:13, 21:3, 21:5, 21:20, 22:5, 22:19, 74:14 starting 53:9, 73:22, 83:6, 98:7, 132:3, 132:5, 132:9, 132:19, 133:1 starts 66:3, 66:5, 67:2, 90:9, 101:12, 109:10,
--	--	--	--

109:19, 143:11 startup 27:20, 27:21 state 6:18, 102:8, 121:11, 123:6, 124:22, 125:4 stated 93:13, 106:8 statement 42:9 statements 78:2 states 1:1, 93:16, 100:16 statistical 83:21 stay 111:16 step 58:4, 99:15, 99:17, 99:18, 99:19, 100:2, 100:4, 100:6, 100:8, 100:9, 100:19, 100:20, 101:2, 101:7, 101:16, 101:17, 104:10, 104:15, 105:2, 105:5, 105:9, 108:15, 108:19 stepped 16:21 steps 58:11, 88:6, 88:14, 88:16, 88:20, 89:4, 89:5, 89:8, 99:13 stick 98:21 still 8:17, 9:2, 36:12, 53:5, 60:9, 61:4, 62:1, 62:21,	63:13, 63:14, 64:7, 67:9, 114:13, 145:5, 146:14 stipulated 24:19 story 105:12 straight 131:14 strike 37:14, 46:17, 58:2, 64:19, 91:21, 123:21, 132:13 string 18:1 structure 32:5, 107:6, 114:10, 115:1, 117:5, 136:16, 139:6, 139:17, 143:20, 144:19, 146:11, 151:2 structures 53:16, 108:1 stuck 146:2 students 17:9, 58:8, 86:5 study 101:5, 126:20 sub 90:13, 90:14, 90:16, 90:18, 91:6, 91:12, 91:16, 91:19, 92:1, 92:2, 92:7, 93:18, 94:20, 95:3, 95:12, 95:22, 96:8, 96:21, 97:10, 97:19, 99:5, 99:12, 101:6, 103:8, 106:21, 107:2, 107:17, 107:20,	110:2, 110:13, 110:14, 110:17, 112:17, 129:3 subject 22:3, 114:20 subscript 107:21 substitute 144:6 substitution 140:8, 144:1, 146:4, 146:21, 147:7 substrate 34:19, 35:9, 70:13, 70:17, 70:19, 70:20, 70:22, 71:2, 72:1, 72:21, 73:1, 73:12, 73:16, 73:22, 74:5, 75:4, 78:18, 78:19, 84:14, 84:18, 88:4, 88:11, 90:2, 94:8, 111:6, 111:14, 116:19, 117:10, 118:3, 121:12, 122:2, 123:8, 123:16, 124:13, 127:20, 128:13, 128:15, 131:11, 132:4, 132:10, 132:19, 133:1, 133:7, 133:10, 134:18, 135:17, 137:10, 139:3 substrate's 121:14 success 44:13 sudden 60:21, 60:22, 63:3 suggested 43:18 suggests 96:22	suitable 84:20 suite 4:8 summaries 39:8 sun 32:18, 32:21, 32:22, 33:1, 33:4, 33:7, 34:2, 70:20 sun-1 93:15 sunlight 32:7, 32:20, 33:1, 33:21, 34:5, 34:18, 35:15, 36:14 supervise 17:9 supply 135:3 support 44:6, 151:16, 152:20, 152:21, 153:1 suppose 59:8 supposed 71:10 sure 6:11, 7:11, 8:7, 13:15, 15:5, 24:18, 54:3, 59:18, 65:16, 89:2, 99:19, 121:2, 121:7, 130:10, 134:7, 142:18 surface 31:7, 33:8, 57:8, 70:12, 70:18, 70:19, 70:22, 81:17, 86:14, 118:2, 121:14, 122:2, 132:5, 134:2, 134:3, 134:14,
---	---	---	---

135:2, 135:13, 146:16, 146:22, 147:8, 149:10, 149:21, 150:10, 150:19, 150:20, 151:2, 151:3, 151:6, 151:7, 151:9 surfaces 31:8, 46:4 surgery 9:16 surmount 47:9 surprising 125:6 switch 113:15 sworn 6:2, 155:7 synonymous 119:1	19:16, 117:16, 133:3, 136:21, 148:21 talked 23:11, 55:2, 105:2, 114:11, 153:4 talking 10:11, 29:12, 50:19, 50:20, 64:17, 65:3, 68:3, 79:13, 79:14, 81:18, 87:18, 105:10, 111:2, 112:14, 112:16, 114:2, 115:20, 117:6, 120:19, 124:12 talks 56:19, 81:16, 84:12, 120:16, 122:18, 134:13, 144:19, 150:7 taught 19:15, 19:21 tcl 137:19, 138:11 tco 137:13, 138:15, 139:7, 144:7 teach 17:7, 19:6, 19:10, 40:17, 58:8, 68:7, 68:9, 140:9 teaches 83:6, 137:9, 137:18 teaching 19:4, 19:7, 20:1, 20:4, 20:9, 20:13, 20:16, 152:6 teachings 106:10, 108:2, 147:13, 148:9, 148:18, 151:18, 152:18	team 18:9 tech 16:3 technical 12:20, 14:3 technician 4:14, 23:17 technicians 17:12 technique 57:13, 59:1 techniques 120:9, 120:14 technologies 21:5, 22:8 technology 16:4, 25:19, 25:21, 26:4, 26:21, 28:3, 33:10 tell 9:7, 9:10, 31:2, 37:4, 46:14, 46:18, 54:5, 63:22, 64:4, 68:13, 118:4, 130:4, 131:1, 143:3, 145:13, 148:17, 149:1 telling 127:7, 144:21 tells 94:6, 94:10 temperature 51:14, 52:18, 53:4, 58:13, 60:17, 60:18, 63:3, 63:6, 63:9, 63:10, 63:11, 63:21, 64:3, 64:17, 64:20, 84:1, 84:22, 85:10, 85:17, 85:18, 86:10, 86:11, 86:14, 86:15,	95:12, 99:12, 100:21, 101:22, 102:10, 102:11, 102:15, 104:10, 104:13, 104:14, 104:20, 105:13, 108:16, 110:15, 111:18, 112:8, 120:2, 120:3, 128:11, 129:18, 133:13 temperatures 34:16, 36:8, 51:10, 51:13, 52:22, 58:7, 58:14, 58:17, 60:16, 67:12, 94:12, 96:11, 100:12, 103:1, 105:7, 105:8, 110:11, 133:6 tempted 21:12, 22:5, 78:9, 79:20, 79:21 tend 120:4 tends 55:7, 106:20 tenure 19:5 term 31:9, 31:15, 32:13, 32:14, 37:15, 37:19, 39:18, 40:1, 42:3, 45:1, 45:4, 45:14, 74:7, 117:2, 117:17, 118:18, 123:12, 123:18, 124:5, 125:15, 129:21, 130:18 terminals 107:10 terminology 117:11, 119:2 terms 13:17, 35:5,
T			
table 99:7, 99:9, 102:18, 102:20, 104:19 take 9:2, 9:19, 15:16, 15:17, 17:22, 30:21, 33:6, 43:14, 59:14, 62:11, 87:10, 99:20, 103:14, 142:21, 143:2, 143:4 taken 59:16, 103:18, 143:6, 155:8 takes 22:2, 22:22 taking 6:6, 47:2, 114:6, 151:18, 151:22 talk 19:9, 19:11,			

64:11, 97:8, 124:20 terrible 131:15 test 28:4 testified 6:3, 10:14, 25:8, 29:20 testify 12:1, 12:8 testifying 9:15, 23:6 testimony 59:19, 154:4, 154:6, 155:9 texas 7:1, 16:19, 17:3, 17:4, 18:7, 18:21, 19:22, 27:19 textured 31:7 texturizing 81:16 th 155:18, 156:9 thank 15:22, 25:14, 27:14, 108:4, 135:18 themselves 34:7, 34:9 theory 19:11, 20:8, 48:3 therefore 75:2, 106:21 thermal 88:6, 91:2, 108:19, 149:15 thermally 46:3, 94:11, 121:14, 121:22, 122:9 thick 48:17, 59:8, 60:9, 69:9,	90:4, 99:4, 111:19, 128:8 thicker 48:10, 141:20 thickness 48:2, 48:6, 48:16, 50:7, 54:1, 54:18, 54:22, 56:4, 57:20, 60:8, 64:16, 66:10, 98:20, 99:2, 111:18, 120:6, 122:1, 124:18 thicknesses 54:16, 58:11, 58:18, 58:20 thin 21:11, 49:4, 49:9, 49:10, 49:21, 60:6, 69:7, 69:21, 88:6, 99:2, 123:2, 128:7, 141:22, 143:16 thin-film 18:16, 26:5 thing 87:13, 104:19 things 13:16, 19:18, 34:9, 36:9, 66:11, 74:8, 124:17 think 9:6, 10:5, 10:12, 13:1, 15:19, 21:3, 22:20, 24:4, 25:3, 27:10, 28:15, 33:2, 33:10, 37:3, 42:19, 44:19, 47:10, 61:10, 65:21, 67:8, 68:12, 68:14, 72:6, 77:7, 92:5, 102:6,	105:7, 106:6, 107:18, 136:9, 140:10, 142:8, 147:19, 152:6 thinner 48:12, 49:7, 69:20 third 26:3, 41:6, 42:15, 138:21 thought 89:3, 108:14, 131:12, 138:4, 142:17 thousand 21:3, 67:14, 67:18 thousand-angstrom 59:1 thread 96:13, 97:13, 103:11 three 13:18, 13:19, 20:2, 22:22, 41:20 three-quarters 109:18 through 7:22, 8:1, 8:4, 18:5, 32:22, 38:13, 47:18, 47:21, 49:10, 55:19, 62:6, 62:16, 62:20, 62:21, 98:2, 98:12, 109:17, 109:19, 111:14, 112:5, 112:6, 112:10, 115:4, 135:16, 143:16, 148:9, 148:16, 148:17 throughout 33:5 thrust 29:4, 29:9, 30:2	thrusts 29:2 thursday 1:14, 155:18 tied 90:19 ties 100:15 time 10:8, 11:9, 21:4, 23:1, 28:15, 44:20, 44:22, 51:15, 58:14, 60:19, 64:16, 64:18, 66:10, 85:20, 86:10, 86:11, 86:15, 99:13, 104:11, 104:12, 104:15, 105:13, 108:22, 111:18, 112:8, 128:11, 133:13, 133:17, 153:12 times 10:4, 10:6, 10:16, 10:17, 11:2, 11:12, 51:13, 58:7, 58:15, 58:17, 85:14, 93:17, 93:18, 95:13, 95:16, 103:1, 105:8, 110:2, 129:3, 129:15, 134:15, 134:17 title 93:6 toc 152:1 today 7:19, 9:8, 9:11, 9:15, 11:4, 77:6 today's 5:5 together 18:1, 107:12
--	---	---	---

told 22:7, 30:1, 33:13, 38:10, 56:6, 58:19, 60:7, 66:8, 72:19, 80:5, 92:5, 113:1, 127:18, 147:11	translucent 47:12 transmission 47:14 transparent 137:13 transport 19:17, 49:19, 97:21 traverse 62:18 traversing 32:18 treated 84:21 treatment 50:13, 128:10 treatments 51:9, 52:17 trial 1:2, 10:14 tribromide 134:7 tried 39:9 true 27:11, 42:14, 42:19, 56:6, 77:17, 148:1, 154:4, 155:9 truth 9:7, 9:10 try 8:12, 70:8 trying 22:13, 24:12, 38:13, 49:14, 81:17, 86:1, 86:7, 92:1, 96:10, 96:13, 96:18, 97:13, 101:4, 115:3, 131:14, 140:9, 142:20 tunnel 46:2, 46:5, 46:7, 46:18, 47:5, 47:11,	48:1, 48:16, 49:18, 49:20, 50:2, 50:6, 50:10, 50:20, 51:4, 51:8, 52:16, 53:10, 53:22, 59:21, 60:3, 60:6, 60:13, 60:16, 61:4, 61:5, 61:7, 61:12, 61:22, 62:2, 62:3, 62:22, 63:7, 63:16, 68:11, 68:18, 69:20, 69:22, 98:7, 99:1, 99:2, 101:5, 111:11, 111:14, 111:19, 112:11, 121:12, 121:21, 122:12, 122:14, 122:15, 122:20, 122:22, 123:2, 137:10, 139:1, 141:22, 143:17, 144:3, 144:10, 144:13, 146:4, 146:9, 146:20 tunneling 19:17, 21:10, 21:17, 46:11, 46:12, 46:14, 47:1, 47:17, 47:22, 48:4, 48:8, 48:13, 48:14, 48:15, 48:17, 48:18, 48:22, 49:4, 49:8, 53:7, 55:8, 55:13, 59:3, 59:5, 59:9, 60:7, 60:10, 62:17, 67:2, 68:4, 68:7, 69:8, 69:10, 90:3, 90:5, 97:21,	98:1, 98:4, 98:12, 98:17, 98:19, 98:20, 98:22, 99:3, 99:4, 124:19, 139:15 tunnelling 48:2 turn 16:1, 37:9, 45:16, 52:4, 52:6, 56:13, 65:7, 65:12, 66:12, 67:20, 70:2, 80:9, 82:16, 83:4, 87:2, 87:4, 89:13, 90:6, 92:9, 93:3, 97:14, 99:7, 105:16, 105:17, 108:5, 109:6, 116:13, 116:15, 123:4, 127:10, 135:19, 136:6, 137:15, 141:4, 148:5, 149:7 two 7:14, 7:16, 11:14, 19:7, 20:4, 21:2, 41:16, 44:5, 44:9, 45:7, 50:1, 61:11, 76:21, 76:22, 86:9, 96:12, 96:20, 104:13, 105:7, 107:11, 114:19, 124:11, 128:16, 131:22, 137:18, 138:2 two-step 102:2 type 26:10, 45:7, 45:10, 48:8, 49:19, 71:20, 71:22, 72:1,
--	--	--	---

72:21, 75:2, 75:3, 75:4, 75:6, 78:22, 86:6, 117:5, 117:8, 117:9, 117:14, 117:19, 118:5, 122:14, 145:17, 147:22 types 71:6, 72:4, 72:11, 72:18, 75:6, 76:18, 76:21, 78:15, 81:12, 84:12, 117:20, 118:11, 119:18 typically 34:1, 100:10, 100:12, 111:19, 132:22 typo 122:10	64:10, 104:8, 114:12, 122:12, 133:16 understanding 32:12, 37:18, 45:14, 133:17 understands 74:15 understood 8:16, 24:14 unexpected 44:14 uniformly 49:9, 49:21 united 1:1 universe 124:10 universities 29:3 university 16:8, 16:13, 16:19, 17:2, 17:3, 17:4, 18:21, 19:21, 27:18 unless 8:18 unmarked 7:14, 7:15 unquote 127:6, 149:13 until 88:15, 120:4 use 7:21, 33:14, 34:5, 35:6, 57:13, 58:10, 58:16, 59:7, 60:11, 76:6, 80:18, 82:12, 85:7, 86:17, 91:2, 102:2, 107:21, 108:19, 111:21, 117:17, 122:18, 144:22, 145:3, 145:6, 145:11, 149:15,	152:7, 153:2, 153:6, 153:9 useful 49:1, 49:11, 49:12, 49:16 uses 32:6, 55:16, 56:7, 82:1, 140:12 using 34:6, 55:12, 55:14, 55:17, 57:5, 57:8, 76:3, 76:7, 76:12, 83:13, 83:17, 84:4, 102:6, 105:10, 106:1, 107:18, 126:15, 130:18, 140:11, 140:14, 150:8, 151:1 usually 98:3, 108:1, 132:7 uv 55:19, 56:7, 57:13	26:17, 27:1, 27:6, 34:21, 66:18, 103:2 vertical 25:21 view 47:20 virginia 2:7, 155:3, 156:16 virtually 1:13, 2:2, 155:9, 155:17 vis-à-vis 35:8, 91:11 voc 97:9, 107:6, 113:12, 150:2, 150:11, 151:4 voltage 36:6, 92:7, 96:10, 97:9, 107:3, 107:7, 129:17, 140:2, 140:18, 150:21 voltmeter 107:5 volts 53:13, 53:15, 85:16
U		V	W
uh-huh 101:15, 132:20 ultimately 92:6 ultraviolet 55:19 unambiguous 109:11 under 28:22, 32:2, 32:10, 33:16, 35:6, 36:16, 36:19, 36:20, 91:9, 99:12 undergrad 58:8, 86:5 underlined 25:12 underlying 32:4, 128:13 understand 8:11, 8:13, 9:4, 12:7, 39:18, 57:20,		value 63:13, 64:14, 91:17, 92:2, 92:10, 113:9, 130:21 values 57:18, 63:4, 63:15, 92:1, 94:2, 97:10 vapor 120:16, 126:12, 126:16 variable 99:1 variation 58:20 verbal 8:8, 8:10 versus 25:5, 26:7,	wafer 84:21, 88:9 wafers 57:4 wait 98:11 walk 38:13 wall 126:11, 126:15 want 6:9, 15:16, 15:17, 23:17, 24:9, 24:21, 37:5, 54:10, 59:2, 59:5,

59:14, 59:18, 74:15, 86:21, 99:20, 103:14, 112:19, 113:11, 134:16, 137:2, 142:21, 148:6, 151:6 wanted 59:6, 59:9, 65:15, 74:13, 121:2, 142:17 washington 3:13, 4:9 water 55:18 wave 47:3, 47:11 way 21:6, 55:18, 57:5, 101:11, 109:19, 112:3, 156:5 ways 121:8, 135:4 we'll 54:20, 73:1, 117:16, 136:20, 136:21 we're 7:22, 8:1, 113:15, 115:17, 136:10, 136:19, 150:13, 151:17, 151:18 we've 59:13, 64:17, 103:13, 109:3, 109:16, 113:17, 114:17 week 11:16 went 12:22, 13:11, 64:7, 64:12 whatever 7:22, 8:1, 43:22, 134:7 wherein 70:22	whereof 156:8 wherever 133:9 whether 32:2, 32:10, 33:14, 36:16, 38:1, 38:7, 38:17, 64:13, 71:5, 71:12, 72:3, 72:4, 74:16, 78:4, 79:17, 108:21, 115:3, 115:6, 131:1, 144:22 whistle 146:2 whistles 141:19, 145:2 whitehead 1:22, 2:5, 155:2 whole 56:22 william 3:9, 11:21 window 69:6 windows 69:4, 141:21, 141:22 wisconsin 4:7 within 117:9 without 24:16, 33:15, 53:6, 76:9, 76:10, 76:12, 125:19, 125:21, 130:8, 134:2, 135:12 withstand 18:3 witness 59:15, 103:15, 155:5, 155:10, 156:8	won 27:12 wondering 49:16 word 143:11 work 14:20, 21:15, 21:17, 24:6, 27:18, 28:17, 29:19, 29:22, 30:4, 34:15, 36:19, 36:20, 125:5 worked 13:2, 14:8, 18:7, 18:9, 18:12, 18:17, 21:7, 21:10, 22:11, 22:14, 27:7, 112:2, 122:20 working 21:3, 21:6, 21:20, 22:3, 22:20, 23:20, 28:11, 46:12 world's 18:10 worst 97:1 wouldn't 49:12, 49:16, 62:6, 75:16, 144:18, 148:2 write 12:15, 12:18 writing 13:4, 13:9 wrote 12:9 <hr/> Y <hr/> yeah 10:12, 10:13, 12:14, 13:17, 13:19, 14:17, 14:19, 15:13,	22:13, 27:10, 27:11, 31:12, 35:11, 39:7, 43:14, 52:12, 52:15, 54:22, 55:11, 56:11, 56:16, 58:1, 64:2, 66:19, 68:20, 69:18, 70:8, 73:18, 74:20, 81:9, 81:20, 87:17, 95:7, 96:6, 96:7, 96:18, 100:7, 101:19, 102:16, 102:22, 103:7, 103:15, 104:17, 106:3, 106:13, 107:21, 109:12, 113:21, 114:12, 115:8, 116:15, 120:21, 122:11, 122:16, 123:21, 126:7, 129:9, 131:9, 137:3, 137:8, 138:6, 138:14, 140:16, 145:16, 146:8, 150:17 year 10:9, 14:15 years 18:20, 22:2, 22:6, 22:22, 41:16, 41:20, 48:4, 57:6 yesterday 11:8, 11:10, 11:14 york 3:12 yourself 6:10, 12:15 <hr/> Z <hr/> zenith 32:22, 33:4 zero 50:8, 65:21,
---	---	--	--

126:4, 127:3, 129:21, 132:2, 132:12 zhao 4:5, 6:8 zirconium 122:21 zoom 15:21, 23:18, 56:15, 103:22 zro2 122:21	70:10, 80:15, 80:18, 81:10, 114:5, 114:11, 115:1, 120:11, 124:3 08 147:20	67:21, 87:3, 87:5, 105:17, 115:14, 115:15, 115:19, 148:4 1004 5:12, 15:8, 15:9 1006 5:13, 82:18, 82:19 1007 5:14, 92:15, 92:16, 103:20 1008 5:15, 54:7, 54:8, 109:2, 109:4, 128:20 1009 5:16, 135:21, 135:22, 143:8 101 116:19, 121:12, 122:2 1039 13:14, 14:5 1040 13:20, 82:18, 82:19, 92:16 106 87:4, 87:5 107 46:3, 87:20, 121:13, 121:22 108 46:4, 116:20, 121:12 11 29:11 1100 63:17, 64:1, 64:10, 64:12, 85:2, 85:7 115 5:19 12 95:16 1200 64:4, 64:5,	85:1 135 5:16 14 93:17, 110:2, 129:4 144 148:9, 148:17, 149:5, 152:17 147 150:13, 150:15 15 5:12, 95:21, 122:1, 136:14 151 148:9, 148:17, 152:17 156 1:21 16 121:11, 134:15, 134:17, 137:15, 138:22, 139:21 18 136:10, 136:12, 136:16, 137:5 185 127:11 19 123:6 198 148:5 1981 16:9 1983 16:13, 18:8 1987 18:8, 18:22, 20:13 1990 18:22, 21:9, 21:12, 22:12, 46:13
0	1		2
0008 141:5, 143:11 0018 136:7 008 145:16 01039 1:5, 5:18, 12:9, 12:13, 13:3, 13:14, 115:14, 115:15 0104 5:10, 30:10, 135:22 01040 1:6, 12:10, 15:7, 15:9, 30:8, 54:7, 54:8, 92:15, 109:2, 135:21 0139 116:4 053 7:15, 30:16, 30:18, 30:22, 31:3, 31:5, 31:18, 32:9, 33:10, 36:15, 40:12, 41:2, 42:21, 43:3, 43:11, 44:13, 45:19, 45:22, 51:22, 52:3, 67:22, 68:6,	1,000 102:1, 102:15, 102:21 1-sun 31:9, 31:11, 32:3, 32:10, 32:13, 32:14, 33:3, 33:14, 33:17, 34:4, 34:10, 34:21, 35:1, 35:6, 35:18, 36:12, 36:16, 36:20, 36:22, 106:11 1.1 53:14 1.5 32:3, 33:9, 33:15 10 48:20, 50:7, 55:2, 58:21, 93:17, 93:18, 95:13, 95:16, 110:2, 122:1, 129:3, 134:15, 134:17 100 126:5, 127:8 1000 53:4, 63:10, 64:6, 85:2, 85:7, 110:15, 112:15, 112:20, 112:22, 113:1, 113:3 1003 5:11, 5:19, 30:8, 30:10,		
			20 1:14, 54:18,

55:2, 58:22, 125:2, 155:18 2000 21:4, 21:20 20001 3:13 20015 4:9 2008 22:16, 23:2, 28:15, 41:19 2009 22:17, 28:15 2010 21:4 2011 22:2, 22:21 2015 29:16 2017 29:16 2019 27:9 202 3:14, 4:10 2022 25:9 2024 1:5, 1:6, 5:10, 5:18, 10:10, 10:12, 12:9, 12:10, 12:13, 13:3, 13:14, 15:7, 15:9, 23:12, 30:8, 30:10, 54:7, 54:8, 82:19, 92:15, 92:16, 109:2, 115:14, 115:15, 116:4, 135:21, 135:22 2025 1:14, 16:22, 155:18, 156:9 2027 156:12 2052 4:9	206 137:10, 137:20, 138:3, 138:7 21 125:3 213 3:7 22 40:4 222 137:13, 138:11 224 137:12, 138:3, 138:11 226 137:11, 138:3, 138:10 228 137:10, 137:21, 138:9 24 153:15, 155:18 245 93:4 249 97:14 25 1:14, 155:18 263 121:20 2a 136:11, 138:2 <hr/> 3 30 5:11, 48:4, 57:5, 156:9 31 156:12 315 117:16 32 37:10, 37:11, 37:21 350 3:5 371 4:10	38 90:9 39 82:17, 83:5 <hr/> 4 4-megabit 18:10 40 13:11, 48:4, 48:21, 57:5, 83:13, 88:5 401 46:4 402 46:3 4054 3:14 408 3:14 41 88:5 410 4:8 42 83:13, 84:19 4413 3:13 45 33:7, 41:12 450 100:12, 100:13 49 116:15, 116:17, 121:10, 122:6 4b 45:18, 45:21 <hr/> 5 149:11 50 13:11 51 116:14 516 7:15, 40:14, 41:4, 42:21,	43:3, 43:11, 44:17, 45:19, 45:22, 68:1, 68:6, 80:22, 81:4, 81:10, 113:15, 113:19, 114:5, 114:10, 114:18, 114:22, 115:6, 115:11, 115:18, 116:11, 116:18, 120:11, 120:19, 121:17, 121:21, 124:1 52 45:16 5335 4:7 54 5:15 575266 1:20 58 123:5 59 1:15, 70:3, 120:15, 155:18 <hr/> 6 6 26:20 61 149:6 65 150:17 650 15:2 6633 3:7 67 121:20 6861 4:10 <hr/> 7 743 56:12, 56:14, 109:7, 128:21 745 109:6
---	--	--	--

<div>8</div> <div>8,222,516</div> <div>1:8, 116:8</div> <div>8,878,053</div> <div>1:9, 30:19</div> <div>800</div> <div>108:12</div> <div>82</div> <div>5:13</div> <div>84</div> <div>127:11</div> <div>850</div> <div>65:2, 66:1, 66:15, 66:20, 67:3, 108:10, 108:13, 108:14, 130:12, 130:22</div> <div>86</div> <div>80:9, 80:10</div> <div>896</div> <div>3:7</div>	
<div>9</div> <div>9</div> <div>1:15, 155:18</div> <div>900</div> <div>66:1, 66:3, 66:5, 66:15, 66:20, 85:1, 102:1, 102:10, 102:15, 102:21, 110:11</div> <div>90071</div> <div>3:6</div> <div>901</div> <div>3:12</div> <div>91</div> <div>89:13</div> <div>92</div> <div>5:14, 90:7</div> <div>95</div> <div>51:22, 52:3, 52:8, 52:9, 62:14, 105:17</div>	