Exhibit 2029



Transcript of Zachary Holman, Ph.D.

Date: May 8, 2025
Case: Hanwha Solutions Corp. -v- Maxeon Solar Pte. Ltd. (PTAB)

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WORLDWIDE COURT REPORTING & LITIGATION TECHNOLOGY

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

- - - - - - - - - - - - x

HANWHA SOLUTIONS CORPORATION, : Case Nos. IPR 2024-01199, IPR2024-01203

Petitioner, :

v. :

MAXEON SOLAR PTE, LTD., : U.S. Patent Nos. 8,878,053, 8,222,516

Patent Owner. :

- - - - - - - - - - - - X

Deposition of ZACHARY C. HOLMAN, Ph.D.

Conducted Virtually

Thursday, May 8, 2025

11:57 a.m. EDT

Job No.: 580887

Pages 1 - 267

Reported by: Debra A. Whitehead

Deposition of ZACHARY C. HOLMAN, Ph.D., conducted virtually.

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

IPR2024-01199
Maxeon Exhibit 2029

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C O N T E N T S

EXAMINATION OF ZACHARY C. HOLMAN, Ph.D. PAGE

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By Mr. Selwyn 253

EXHIBITS MARKED IN TODAY'S SESSION

(None Marked)

EXHIBITS MARKED IN PRIOR SESSIONS

(Not Attached)

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P R O C E E D I N G S

ZACHARY C. HOLMAN, Ph.D.,

having been duly sworn, testified as follows: 11:57:05

EXAMINATION BY COUNSEL FOR PATENT OWNER 11:57:05

BY MS. ZHAO: 11:57:05

Q Dr. Holman, good morning. I'm Jing Zhao. 11:57:18

I'm counsel for Patent Owner Maxeon. 11:57:22

Can you please state your full name, for 11:57:25

the record. 11:57:26

A Yes. My name is Zachary Charles Holman. 11:57:27

Q Where are you joining this call from? 11:57:31

A From Phoenix, Arizona. 11:57:34

Q Is Mr. Selwyn in the room with you? 11:57:35

A Yes, he's seated next to me. 11:57:43

Q Is anyone else in the room with you? 11:57:44

A Yes, another attorney for WilmerHale is 11:57:46

seated in the room, Bobby Hampton. 11:57:51

Q Do you have any documents in front of 11:57:54

you? 11:57:57

A I do not presently. 11:57:57

MS. ZHAO: Mr. Selwyn, I believe we 11:58:02

shipped some binders to Mr. Holman. Are those 11:58:04

available to him? 11:58:08

MR. SELWYN: They are. I have them right here, I will hand them to Dr. Holman. 11:58:09 11:58:10

MS. ZHAO: Thank you. 11:58:12

Q Dr. Holman, do you have any medical conditions that would affect your answers today? 11:58:23 11:58:25

A No, I do not. 11:58:31

Q Before I begin I would like to go over some ground rules. Please let me know if you don't understand any of my questions. If you answer my question, I will assume that you understood the question. 11:58:31 11:58:33 11:58:35 11:58:37 11:58:39

Is that fair? 11:58:41

A Yes. 11:58:42

Q If your attorney objects, you will still need to answer the question. The only exception is when your attorney instructs you not to answer. 11:58:42 11:58:45 11:58:48

Is that fair? 11:58:51

A Yes. 11:58:52

Q Let me know if you need breaks. But before you go on break, you will need to answer any pending questions I just asked. 11:58:52 11:58:56 11:58:58

Do you understand? 11:59:00
A I understand. 11:59:01
Q How did you prepare for your deposition today? 11:59:02 11:59:06
A I have met with counsel and I have reviewed my declaration and the supporting materials in it. 11:59:09 11:59:12 11:59:16
Q Which counsel did you meet with? 11:59:18
A Counsel members of WilmerHale, including Mark Selwyn and Bobby Hampton. 11:59:22 11:59:26
Q Approximately how long was the meeting with counsel? 11:59:29 11:59:31
A I met with counsel for on the order of 20 hours in preparation for this deposition. 11:59:34 11:59:40
Q Did you speak with anyone else in preparation for this deposition? 11:59:45 11:59:48
A No, I have not. 11:59:50
Q You are here to testify on two IPR cases. Correct? 11:59:51 11:59:56
A That's correct. 11:59:58
Q One of them is numbered IPR2024-01199. Correct? 11:59:58 12:00:06

A I believe so. That's what the binder in front of me says. I don't have other access to numbers, but yes. 12:00:13 12:00:16 12:00:18

Q You submitted a declaration for this IPR. Correct? 12:00:19 12:00:22

A Yes, I did. 12:00:24

Q And that declaration is in the binder. Right? Can you check? 12:00:24 12:00:28

A Yes, I find it in the binder. 12:00:34

Q Thank you. 12:00:35

MS. ZHAO: And for the record, I am referring to Exhibit 1003 of IPR2024-01199. 12:00:37 12:00:38

(IPR2024-01199 Exhibit 1003, previously marked, not attached.) 12:00:45 12:00:45

Q This declaration relates to U.S. Patent Number 8,878,053. 12:00:45 12:00:48

Is that right, Dr. Holman? 12:00:52

A Yes. 12:00:57

Q I'm sorry, your audio cut off a little bit. Was that a yes? 12:00:58 12:01:01

A That was a yes. 12:01:02

Q Thank you. 12:01:03

You call this patent the '053 patent in your declaration. Right? 12:01:05 12:01:09

A Yes. 12:01:10

Q I will call this declaration the '053 declaration, then. 12:01:10 12:01:14

Is that okay? 12:01:15

A That is good. Thank you. 12:01:16

Q Did you prepare the '053 declaration all by yourself? 12:01:18 12:01:22

A The '053 declaration is my words, my opinions, and my words and my opinions only. I did not type all of the words of the '053 declaration into the word-processing software; others from counsel have also contributed to the typing process. 12:01:26 12:01:28 12:01:32 12:01:37 12:01:42 12:01:45

Q Did you type any of the words in the '053 -- 12:01:45 12:01:49

A Yes, I did. 12:01:49

Q How many hours have you spent drafting the '053 declaration? 12:01:50 12:01:55

A I believe I spent approximately 120 hours on the '053, '516, and '315 declarations together. 12:02:01 12:02:09

And approximately half of that was dedicated to the '053 declaration, and approximately half of that was dedicated to the '053 and '516 declarations together. 12:02:19 12:02:22 12:02:26 12:02:31

I did not account or have not accounted specifically how much was spent on the '053 versus '516, as they refer to the same specification and often my work on the two of them were combined. 12:02:34 12:02:37 12:02:41 12:02:48

Q Is it possible that you spent more time on one than the other between the '053 and the '516? 12:02:51 12:02:56 12:02:59

MR. SELWYN: Objection. Form. 12:03:01

A Certainly it's possible. It's even likely. If I were to guess, I believe I spent more time on the '516 declaration than the '053. But certainly I spent at least more than 25 hours on each. 12:03:03 12:03:06 12:03:11 12:03:17 12:03:23

Q Sitting here today, do you still agree with all the statements in the '053 declaration? 12:03:26 12:03:28

A I agree with all of the statements. In my review I did find one typo. It appears on Page 60 of the '053 declaration, Paragraph 97. 12:03:33 12:03:36 12:03:40

Q Okay. 12:03:50

A Second sentence that presently says, "In response to this rejection, the applicant did not amendment the claims." That should say, "The applicant did not amend the claims." 12:03:51 12:03:54 12:03:58 12:04:01

I did not find any other typos or errors in my review. 12:04:03 12:04:06

Q Other than that typo, is there anything you wish to alter in the '053 declaration? 12:04:08 12:04:13

A No. 12:04:16

Q Is there anything you wish to add to the '053 declaration? 12:04:17 12:04:20

A No. 12:04:22

Q Let's go to Paragraph 8 of the '053 declaration. 12:04:22 12:04:28

This paragraph opens with, "While a postdoctoral researcher." 12:04:30 12:04:34

Do you see that? 12:04:35

A Yes, I do. 12:04:36

Q What time frame are we talking about here? 12:04:37 12:04:42

A I became a postdoctoral researcher in 12:04:43

2010, in September. And I continued in that role until 2013 in March. And the years are given in the preceding paragraph, although the months that I've just provided are not. 12:04:46 12:04:51 12:04:58 12:05:06

Q The first sentence mentions silicon solar cells. 12:05:06 12:05:11

Do you see that? 12:05:11

A Yes. 12:05:12

Q Can you elaborate on what silicon solar cells are? 12:05:12 12:05:15

A Yes. What I'm referring to in this section, and what I elaborate on in the background section of my declaration, is solar cells based on a silicon wafer, which is a slab of silicon to which subsequent process steps are performed, including diffusions, additions of layers such as passivation layers or deposited emitters, addition of metal contacts and so forth to turn that silicon wafer into a functioning solar cell. That's what I'm talking about when I say silicon solar cells. 12:05:16 12:05:18 12:05:22 12:05:26 12:05:33 12:05:38 12:05:42 12:05:48 12:05:52 12:05:56 12:05:58

Q Other than silicon solar cells, are there 12:05:59

any other types of solar cells? 12:06:05

A Yes. 12:06:08

Q Can you tell me what they are? 12:06:08

A Sure. Solar cells have historically been made with other what we call absorber materials, that is the primary layer responsible for absorbing light. 12:06:10 12:06:14 12:06:17 12:06:20

Q Would that be the wafer -- I'm sorry. 12:06:22

A That is the wafer for a silicon solar cell, that's correct. 12:06:24 12:06:27

Q Thank you. Please continue. 12:06:27

A For -- for other types of solar cells, cadmium telluride has been used as an absorber layer, so has gallium arsenide, so has a mixture of copper, indium, gallium, and selenium, which is commonly referred to as CIGS, C-I-G-S, for short. 12:06:30 12:06:33 12:06:40 12:06:45 12:06:52

Amorphous silicon, which is not a wafer but is a deposited thin film of silicon in an amorphous state, has also been used as an absorber. These are amongst the most common types of solar cells, and solar cells are commonly referred to by their absorber. 12:07:00 12:07:02 12:07:08 12:07:13 12:07:14 12:07:18

So a cadmium telluride solar cell is how a POSITA, for instance, would refer to a solar cell at a cadmium telluride absorber layer. Silicon solar cell is how a POSITA would refer to a solar cell that has crystalline silicon wafer-based absorber. 12:07:22 12:07:28 12:07:31 12:07:37 12:07:41 12:07:43

Q So a solar cell using amorphous silicon as the wafer would be called amorphous silicon solar cell? 12:07:44 12:07:49 12:07:53

Is that right? 12:07:53

A That's correct. 12:07:55

Q And a POSITA would understand that that means something different than a silicon solar cell. Right? 12:07:55 12:07:57 12:08:01

A That's correct. The language that you've used was the common language and has been the common language for referring to those two types of solar cells. 12:08:02 12:08:04 12:08:07 12:08:11

Q Were silicon solar cells the most common type of solar cell in the market at the time of your postdoctoral research? 12:08:12 12:08:16 12:08:19

A Yes. 12:08:22

Q What about in 2008? 12:08:22

A Yes. 12:08:26

Q At the bottom of Page 4, last line, you mention an article titled "Current losses at the front of silicon heterojunction solar cells." 12:08:26 12:08:34 12:08:38

Do you see that? 12:08:41

A Yes, I do. 12:08:41

Q What is a heterojunction solar cell? 12:08:43

A A heterojunction solar cell, and more specifically a silicon heterojunction solar cell, is a particular flavor of silicon solar cell. So like all silicon solar cells, it's based on a silicon wafer, and the layers added to the front and rear surface place it in this subset that we call silicon heterojunction solar cells. 12:08:47 12:08:50 12:08:54 12:08:59 12:09:03 12:09:11 12:09:14

In particular the heterojunction refers to the deposition of amorphous silicon thin-film layers, including an emitter and back-surface field onto the wafer to form the silicon heterojunction. 12:09:18 12:09:20 12:09:25 12:09:29 12:09:33

In fact, silicon heterojunction is shorthand for amorphous silicon crystalline 12:09:35 12:09:37

silicon heterojunction solar cell. 12:09:42

And in these solar cells it is important 12:09:47

to note that the amorphous silicon is not the 12:09:50

absorber layer, it is the crystalline silicon. 12:09:53

That is to say, these are a class of silicon cell, 12:09:56

not amorphous silicon cells. 12:10:00

Q Does the heterojunction solar cell 12:10:05

include more than one emitter? 12:10:09

A No. Solar cells commonly include one 12:10:10

emitter. An emitter is a layer that is oppositely 12:10:14

doped from the absorber or, in a silicon solar 12:10:17

cell, a wafer. I elaborate this on the background 12:10:21

section of my declaration. 12:10:24

And a silicon heterojunction includes one 12:10:27

emitter, one layer that is oppositely doped the 12:10:30

wafer. 12:10:34

Q You said earlier silicon heterojunction 12:10:37

is shorthand for amorphous silicon crystalline 12:10:44

silicon heterojunction solar cell. 12:10:47

Where does the crystalline silicon come 12:10:51

into play? 12:10:54

A That refers to the wafer. 12:10:56

Q You also said heterojunction solar cell is a particular flavor of silicon solar cells. Are there other flavors of silicon solar cells? 12:11:04 12:11:07 12:11:10

A Yes. 12:11:14

Q Can you tell me -- 12:11:17

A If you refer to -- one moment, please. Beginning on Page 70 -- excuse me, Paragraph 74 of my declaration, I describe some of the evolution of silicon solar cell technology. And as additional features were added to silicon solar cells, they were commonly grouped or referred to by shorthand names for a particular flavor of silicon solar cell, like the silicon heterojunction. 12:11:18 12:12:04 12:12:07 12:12:12 12:12:21 12:12:24 12:12:29 12:12:33 12:12:36

Other common versions would include an aluminum BSF solar cell -- 12:12:37 12:12:39

Q I'm sorry, where are you reading from? 12:12:42

A Oh, I'm elaborating on the information rooted in Section B of my background, Overview of Solar Cell Efficiency. And I'm answering your question about other types or flavors of silicon solar cell. 12:12:44 12:12:50 12:12:56 12:12:59 12:13:03

Q Where are you -- can you direct me to where it says aluminum BSF solar cell? 12:13:08 12:13:11

A I wasn't referring to a particular paragraph when I mentioned aluminum BSF. I was answering your question about types or flavors of silicon solar cell. And the underlying physical principles of an aluminum BSF solar cell and the other types of solar cells that I was going to describe in answering your question are rooted in this Section B of the background of my declaration, which describes improvements to solar cells over time. 12:13:17 12:13:19 12:13:22 12:13:27 12:13:34 12:13:40 12:13:42 12:13:45 12:13:50 12:13:54

For example, to reduce recombination, which is described in detail in this section. 12:13:56 12:14:00

Q Okay. So we talked about heterojunction solar cells, aluminum BSF solar cells. What other flavors are there? 12:14:08 12:14:14 12:14:18

A Another flavor of solar cell was referred to as a PERC solar cell, P-E-R-C, passivated emitter and rear. Passivation referring to the process of reducing surface recombination, and you find that in this section of my declaration. 12:14:22 12:14:24 12:14:32 12:14:35 12:14:39

Q Do heterojunction solar cells always include an amorphous silicon thin film layer? 12:14:46 12:14:50

A They traditionally do. As I mentioned, heterojunction silicon solar cell has been adopted by the community as shorthand for amorphous silicon crystalline silicon heterojunction solar cell. 12:14:57 12:15:01 12:15:03 12:15:07 12:15:11

Q Is there a homojunction silicon solar cell as well? 12:15:11 12:15:14

A Yes. There are multiple flavors of silicon homojunction solar cell. We recently discussed aluminum, BSF, and PERC solar cells. These would be types of homojunction solar cell. 12:15:19 12:15:24 12:15:28 12:15:32

Q When you say "silicon solar cell," would a person of ordinary skill in the art typically understand that to be a homojunction solar cell? 12:15:36 12:15:43 12:15:46

MR. SELWYN: Objection. Form. 12:15:50

A No, not necessarily. A silicon solar cell, as I described previously, is one in which the absorber is a silicon wafer. 12:15:56 12:16:00 12:16:01

Q In 2008 would you say there were more homojunction solar cells in the market than 12:16:04 12:16:14

heterojunction solar cells? 12:16:18

A Yes. 12:16:20

MR. SELWYN: Objection. Form. 12:16:21

A Yes. 12:16:22

Q Are there different types of heterojunction solar cells, different flavors, so to speak? 12:16:22 12:16:34 12:16:38

MR. SELWYN: Objection. Form. 12:16:38

A Can you elaborate on perhaps what aspects might be different or what you're interested in? 12:16:45 12:16:48

Q For example, heterojunction with intrinsic thin layer, or HIT cells, are one type of heterojunction cells. Right? 12:16:50 12:16:55 12:17:00

A In fact, most heterojunctions included an intrinsic thin layer, also of amorphous silicon. 12:17:04 12:17:09

So a heterojunction solar cell again includes a junction between two dissimilar materials; that is to say amorphous silicon on one side and crystalline silicon on the other. 12:17:14 12:17:17 12:17:21 12:17:24

The amorphous silicon was commonly added as multiple layers, at least one of which was intrinsic. 12:17:27 12:17:32 12:17:37

So when a POSITA referenced a heterojunction solar cell, the -- they commonly understood that to include or likely include an intrinsic layer. The HIT, heterojunction with intrinsic thin layer, is a trade name introduced by Sanyo in particular. 12:17:38 12:17:42 12:17:48 12:17:52 12:17:56 12:18:00

Q Would it be accurate to say then that HIT cells and heterojunction cells can be used interchangeably? 12:18:08 12:18:15 12:18:17

MR. SELWYN: Objection. Form. 12:18:19

A HIT cells, HIT, that wording, refers to a specific Sanyo, later acquired by Panasonic, trademark and trade name for a product, and it is an instance of a silicon heterojunction solar cell. 12:18:24 12:18:28 12:18:33 12:18:36 12:18:40

So if you were to look, for example, at the academic literature or what other companies may have been doing, they didn't call it a HIT solar cell generally unless they were talking about Sanyo, later Panasonic's, product. 12:18:41 12:18:42 12:18:46 12:18:49 12:18:51

Q Let's go to Paragraph 10 of the '053 declaration. 12:18:58 12:19:02

A Okay.
Q In this paragraph you talk about your research interests as a professor. Correct?
A Yes.
Q Is this referring to research you are currently conducting?
A I do have an active research group at the moment, but this paragraph describes my research interests in the past 12 years as while I've been a professor. And so my research interests and focus areas have evolved over that time, and this paragraph is describing the breadth of those research interests.
Q Does the paragraph include your current research interests?
A Yes, it does.
Q Let's cover these research interests, starting with "Contacts to solar cells."
Can you elaborate on what that means?
A Yes. What I'm referring to there is the physics and material science of layers that are added to the surface of silicon solar cells or

other types of solar cells or materials that are diffused into the surface, the wafer surface of silicon solar cells or other types of solar cells, in order to extract electrons at one location and holes at another location as is necessary for a solar cell to function. 12:20:16 12:20:21 12:20:25 12:20:29 12:20:32 12:20:36

Q What types of solar cells do you typically use in this research? 12:20:39 12:20:45

A If you look at my publications in I believe it's Appendix A, you will find that we have done -- my research group has done research on contacts to silicon solar cells, also to cadmium telluride solar cells, and also to Perovskite solar cells. 12:20:54 12:20:56 12:21:00 12:21:04 12:21:09 12:21:16

Q Can you tell me what Perovskite solar cells are? 12:21:17 12:21:27

A Yes. I previously mentioned absorber materials, including silicon, cadmium telluride, CIGS, and gallium arsenide. 12:21:27 12:21:31 12:21:36

In the last decade additional -- an additional absorber material has attracted the interest of the academic first and subsequently 12:21:40 12:21:43 12:21:48

industry of solar cells. And it's called Perovskite, which is named after a Polish researcher. It refers to a particular crystal structure. And that material is used as an absorber layer. 12:21:54 12:21:58 12:22:00 12:22:05 12:22:12

And a common -- commonly researched Perovskite material is methyl ammonium lead iodide. That is one example, but the word "Perovskite" refers to a family of materials that have the same crystal structure as, for example, that material. 12:22:15 12:22:19 12:22:23 12:22:27 12:22:29 12:22:32

Q Next is "interconnection of solar cells." 12:22:38

Can you tell me what that means? 12:22:47

A Yes. As I describe, I believe, at the very beginning of the Technology Background section of my declaration, in the Overview of Solar Cells section, solar cells are commonly wired together. This process is called interconnection. So that multiple solar cells are connected in series, which increases the voltage, or in parallel, which increases the current. And that these are commonly then packaged, for 12:22:52 12:23:01 12:23:04 12:23:09 12:23:14 12:23:19 12:23:21 12:23:26 12:23:29

example, with a piece of glass on the front and what we call a back sheet, a polymeric layer on the back, to form a module or panel. 12:23:35 12:23:38 12:23:41

And so interconnection refers to the process by which one solar cell is electrically connected or wired to another solar cell. 12:23:46 12:23:47 12:23:53

Q Is it accurate to say that a module of solar cells is I guess a group of solar cells? 12:23:59 12:24:05

MR. SELWYN: Objection. Form. 12:24:09

A A module comprises more than just a group of solar cells, but a module contains a group of solar cells. 12:24:13 12:24:17 12:24:23

And I suppose I should clarify I'm using "comprise" in the nonlegal sense as -- in that sentence. I can clarify, perhaps. 12:24:26 12:24:29 12:24:33

A module has solar cells, but more than just a group of solar cells. 12:24:36 12:24:39

Q Have you heard of the term "array of solar cells" before? 12:24:41 12:24:46

A Yes. 12:24:49

Q Does it mean the same thing as a module? 12:24:51

A No. Actually, the word "array" is more 12:24:55

commonly used for modules or panels than for cells. 12:24:59 12:25:06

So if a POSITA refers to a solar array, they are then typically referring to a collection of solar panels, each of which contains a collection, or grouping, to use your word, of solar cells. 12:25:07 12:25:10 12:25:12 12:25:16 12:25:19

Q A collection of solar cells would be more accurate than grouping of solar cells. Right? 12:25:20 12:25:23

MR. SELWYN: Objection. Form. 12:25:26

A Either one is acceptable. 12:25:30

Q Next on the list is "light management in silicon solar cells." 12:25:35 12:25:40

Can you tell me a bit more about that? 12:25:41

A Yes. Optimally all of the light incident upon, let's say, a silicon solar cell that is above -- excuse me, that has photon energies exceeding the band gap energy of silicon -- and I can come back in a moment to explain that if you would like -- should be absorbed in the silicon wafer and not in surrounding layers such as an emitter. 12:25:46 12:25:51 12:25:57 12:26:02 12:26:07 12:26:08 12:26:10 12:26:17

And when that is done, then the solar cell generates its maximum current. And if its current is maximized, its efficiency will increase. 12:26:18 12:26:21 12:26:24 12:26:27

So light management in silicon solar cells is about maximizing the amount of useful light that can be absorbed in the wafer, showing that it's not, we use the word "parasitically" absorbed elsewhere in the solar cell. 12:26:28 12:26:31 12:26:33 12:26:38 12:26:42

Q Next is "silicon-based tandem solar cells." 12:26:45 12:26:58

Can you tell me more about that? 12:26:58

A Yes. Silicon solar cells alone, if they're operating under typical conditions on earth, have a maximum theoretical efficiency of just under 30 percent. That means they can convert 30 percent of the power in incoming light to electrical power. Only 30 percent. 12:27:00 12:27:05 12:27:11 12:27:18 12:27:21 12:27:26

One way to increase the efficiency further in the history of solar is one of increasing efficiency, is to put a solar cell having a different material and different band 12:27:30 12:27:33 12:27:38 12:27:44

gap -- I brought that word up before -- on top of silicon, where that second material, second solar cell, beneficially absorbs and converts into electricity the visible light, passes through it the infrared light, which is then absorbed and beneficially converted into electricity by silicon solar cell. 12:27:47 12:27:51 12:27:58 12:28:01 12:28:05 12:28:09 12:28:12

So these two, and it could be more than two, but two solar cells working together are called a tandem. And one example would be a Perovskite silicon tandem, where the top cell, we call it, the one closer to the sun, is Perovskite, and the bottom cell, we call it, is silicon. 12:28:14 12:28:16 12:28:19 12:28:24 12:28:28 12:28:32

Q You said if silicon solar cells are operating under typical conditions on earth they have an efficiency of just under 30 percent. 12:28:39 12:28:51 12:28:53

What are typical conditions on earth? 12:28:56

A Yes, so what I meant by that is that, in order to define an efficiency and be able to compare the efficiency of my solar cell in my laboratory with your solar cell in your laboratory, we have to agree upon similar 12:29:01 12:29:04 12:29:08 12:29:11 12:29:14

measurement conditions. 12:29:17

And so since I believe about the 1990s -- 12:29:20

it may have been earlier I'm not exactly sure -- 12:29:27

the standard conditions for measurement have been 12:29:30

what we call AM 1.5G. AM stands for air mass. G 12:29:32

stands for global. So air mass 1.5 global. 12:29:41

This is a set of illumination conditions. 12:29:46

It specifies a spectrum and an intensity of that 12:29:48

spectrum under which measurements are done in 12:29:52

laboratory environments. Because in the real 12:29:55

world outside it could be dusk, it could be noon 12:29:58

in Arizona, a person could -- a solar cell could 12:30:04

be in space on its way to Venus. The illumination 12:30:08

conditions could vary, and the functional 12:30:11

efficiency of the solar cell vary. 12:30:14

So what I was referring to when I said 12:30:15

silicon has a efficiency, theoretical efficiency 12:30:18

limit just under 30 percent, is under the 12:30:23

standardized measurement conditions that the field 12:30:29

has adopted. 12:30:32

Q Did silicon-based tandem cells exist in 12:30:32

2008? 12:30:45

A I'm not sure. Perovskite silicon tandem solar cells did not exist, but Perovskites are not the only type of material that you can use in conjunction with silicon in a tandem. 12:31:00 12:31:07 12:31:10 12:31:12

I can't offhand think of a report of a different silicon-based tandem. But the literature is vast, and it may be that there were demonstrations prior to 2008. 12:31:18 12:31:25 12:31:28 12:31:32

Q Would it be accurate to say that tandem cells are heterojunction cells? 12:31:41 12:31:43

A No. Heterojunction, and in particular silicon heterojunction, refers to the flavor of the -- of a silicon cell. A tandem cell is a silicon cell plus another type of solar cell. 12:31:49 12:31:56 12:32:00 12:32:04

Q Let's go to Paragraph 16 of the '053 declaration. 12:32:16 12:32:18

A Okay, I am there. 12:32:19

Q Here you talk about founding three companies. Correct? 12:32:20 12:32:23

A Yes. 12:32:27

Q You first talk about the company Beyond Silicon. You state that this company is 12:32:27 12:32:30

developing Perovskite/silicon tandem solar cells. 12:32:32

Do you see that? 12:32:36

A Yes. 12:32:37

Q Is there something novel about this Perovskite/silicon tandem solar cell that you were developing? 12:32:37 12:32:48 12:32:55

MR. SELWYN: Objection. Form. 12:32:55

A The company is developing novel structures, materials and processes for the fabrication and manufacture of Perovskite silicon tandem solar cells, yes. 12:32:56 12:33:00 12:33:04 12:33:08

Q Is it accurate to say that the Perovskite/silicon tandem solar cell you're talking about in this paragraph is the same as a silicon-based tandem cell? 12:33:10 12:33:25 12:33:28 12:33:31

MR. SELWYN: Objection. Form. 12:33:36

A The Perovskite/silicon tandem solar cell I am referring to in this paragraph is an instance of a silicon-based tandem solar cell. 12:33:38 12:33:44 12:33:45

Q Has Beyond Silicon developed any products that went into manufacturing? 12:33:48 12:33:53

A Not yet. 12:33:56

Q Does Beyond Silicon have any patents? 12:33:58

A Beyond Silicon is the exclusive -- has an exclusive license to a granted patent from Arizona State University, where the co-founders of Beyond Silicon were inventors on that patent while at the university. 12:34:06 12:34:10 12:34:17 12:34:22 12:34:25

Q The cofounders would include you. Right? 12:34:30

A That is correct. 12:34:32

Q So you are an inventor on the patent we just talked about. Right? 12:34:33 12:34:37

A That is correct. 12:34:39

Q As a founder, what was your role in Beyond Silicon? 12:34:39 12:34:44

A What is my role now or what has it been since 2021? 12:34:46 12:34:49

Q Can you tell me about both? 12:34:50

A Sure. Since the beginning of the company I have primarily contributed to its technology strategy and its business-development efforts. So that means understanding potential customers, understanding market dynamics, understanding potential entry points for the product that it's 12:34:54 12:35:00 12:35:04 12:35:08 12:35:13 12:35:15

developing, and shaping the development pathway of its products accordingly. 12:35:20 12:35:25

However, being a founder means also sometimes being the janitor at the company and doing all sorts of other odds and ends as well. 12:35:28 12:35:32 12:35:35

Q Were you just talking about your role as a founder in the initial stages of the company? 12:35:44 12:35:45

A I was describing the scope of my contributions since 2021, including at present. 12:35:51 12:35:56

Q So you still have an active role in Beyond Silicon today. Right? 12:36:04 12:36:06

A I do, primarily in business development and technology strategy. 12:36:09 12:36:11

Q Next is the company SunFlex Solar. You state that this company develops interconnected back-contact solar cells. 12:36:12 12:36:22 12:36:26

Do you see that? 12:36:28

A Yes. 12:36:30

Q Can you tell me about interconnected back-contact solar cells? 12:36:34 12:36:38

A Yes. The company doesn't make back-contact solar cells, it makes the 12:36:41 12:36:44

interconnection method and the associated materials. 12:36:46 12:36:49

So it purchases back-contact solar cells, which are a particular flavor of silicon solar cells. And it has developed materials and methods for wiring them together, as we discussed previously, interconnecting them. 12:36:50 12:36:55 12:37:00 12:37:07 12:37:09

In this case rather than wires as you might traditionally think of them, the metal used to connect one solar cell to adjacent solar cells is aluminum foil. And the method by which the aluminum foil is attached to the solar cell is not, for example, with a soldering iron, but using a laser welding process. 12:37:12 12:37:15 12:37:20 12:37:24 12:37:29 12:37:33 12:37:36

Q Can you tell me a bit more about what back-contact solar cells are? 12:37:40 12:37:44

A Yes. A back-contact solar cell is one in which the metal electrodes or metal contacts that collect electrons and collect holes are both on the back or rear or nonsunward side of the solar cell. 12:37:50 12:38:07 12:38:12 12:38:17 12:38:27

Q Are back-contact solar cells typically 12:38:27

heterojunction cells? 12:38:31

A Not necessarily. Back-contact refers to the arrangement of the metal contacts, as just described. And heterojunction refers to layers that are in contact with the wafer, namely amorphous silicon layers. 12:38:33 12:38:39 12:38:42 12:38:47 12:38:52

So there are heterojunction back-contact solar cells, there are also homojunction back-contact solar cells. There are heterojunction solar cells that are not back-contact but have metal contacts on both sides, and there are homojunction solar cells that are not back-contact. 12:38:53 12:38:56 12:38:59 12:39:02 12:39:04 12:39:08 12:39:12

Q Were back-contact solar cells common in 2008? 12:39:15 12:39:18

A Can you elaborate by what you mean by "common"? 12:39:23 12:39:25

Q Common in the market in 2008? 12:39:26

MR. SELWYN: Objection. Form. 12:39:34

A Back-contact solar cells were commercially available in the market in 2008, and they were a known technology at least in the 12:39:38 12:39:41 12:39:44

1980s, if not earlier. They were not the most common solar cell available in the market in 2008. 12:39:49 12:39:56

Q What was the most common solar cell available in the market in 2008? 12:40:03 12:40:08

A It would -- 12:40:10

MR. SELWYN: Objection. Form. 12:40:11

A The most prevalent solar cell in 2008 that you could commercially buy would be a silicon solar cell that had contacts on its front and rear side. And it would be a silicon homojunction solar cell. 12:40:15 12:40:19 12:40:21 12:40:25 12:40:30

Many others were available, but that was most found. 12:40:31 12:40:32

Q Is there a name for a solar cell with contacts on front and rear side? 12:40:35 12:40:39

A In my declaration I believe I call them both side contacted solar cells. That's an accurate naming, but not one that would commonly be used, say, in 2008. 12:40:45 12:40:50 12:40:56 12:40:59

Typically they would just be called silicon solar cells, and one would refer to a back-contact solar cell by adding words like 12:41:02 12:41:05 12:41:07

back-contact if one were specifying that the contacts were on the back side. 12:41:12 12:41:15

Q Has SunFlex Solar developed any products that went into manufacturing? 12:41:18 12:41:28

A SunFlex Solar has developed -- 12:41:30

MR. SELWYN: Let me just, we don't have a Protective Order or confidentiality or, so what you say will be in a potentially public transcript. 12:41:32 12:41:33 12:41:37 12:41:42

Jing, I don't know if you are searching for anything more than just general public information, but I just caution the witness. 12:41:45 12:41:46 12:41:48

MS. ZHAO: I'm not searching for anything more than public information. 12:41:51 12:41:52

Q So feel free to answer to the extent that you can. 12:41:55 12:41:57

A Okay. Thank you for that clarification. 12:41:58

SunFlex Solar has developed products that have been in pilot production but not yet for commercial sale. 12:42:04 12:42:07 12:42:10

Q And can you tell me about your role in SunFlex Solar? 12:42:10 12:42:15

A Yes. Quite similar to my role in Beyond Silicon, I primarily focus on business development and technology strategy. That means I'm often the person interacting with prospective customers and understanding what their needs are and whether or not SunFlex Solar has either the technology already developed or the potential to develop the technology and have a competitive advantage in meeting their needs. 12:42:16 12:42:21 12:42:24 12:42:27 12:42:32 12:42:35 12:42:38 12:42:44 12:42:45

Q I have the same questions for the third company, Swift Coat. Can you tell me what Swift Coat does? 12:42:46 12:42:53 12:43:01

A Yes. Swift Coat is a coatings technology company. A coating is a thin layer that gets added to a substrate. 12:43:02 12:43:07 12:43:11

Most of the coatings that Swift Coat has developed are deposited on glass, and they are used in the solar module market on the front glass or in architectural glass or other applications of glass. 12:43:16 12:43:18 12:43:23 12:43:29 12:43:35

The product that Swift Coat has focused on most has been antireflection coatings on glass. 12:43:36 12:43:38

And when I said it's a coatings technology company, I mean that it develops equipment and processes on -- with that equipment to provide its customers with full coating solutions. 12:43:44 12:43:47 12:43:50 12:43:54

Q You said a coating is a thin layer that gets added to a substrate, but in your company the coating is used on glass that is not directly on the substrate. Right? 12:43:57 12:44:06 12:44:12 12:44:15

A We use the word "substrate" in our field to refer generally to something to which layers may be added. 12:44:18 12:44:20 12:44:24

So a substrate need not exclusively refer to a silicon wafer. When we're talking about silicon solar cells, it would be common for a POSITA to use substrate, wafer, interchangeably. But in other fields, including solar modules, a substrate could refer to a piece of glass, it could refer to a piece of paper, a piece of aluminum foil. It is any literally substrate to which things may be added. 12:44:26 12:44:30 12:44:33 12:44:35 12:44:41 12:44:44 12:44:47 12:44:51 12:44:55

Q And has Swift Coat developed any products that went into manufacturing? 12:44:57 12:45:02

A Swift Coat is at the moment right now transitioning its equipment and process into manufacturing with a customer. It is on the cusp or transition of manufacturing. 12:45:06 12:45:11 12:45:15 12:45:19

Q And can you tell me about your role in Swift Coat? 12:45:22 12:45:25

A Yes. Similar to the other two companies, I have focused on business development and technology strategy, which means customer engagement, identifying opportunities where Swift Coat's technology may generate value, and then aligning the company's development efforts with those customer needs and other business opportunities. 12:45:27 12:45:30 12:45:33 12:45:36 12:45:42 12:45:44 12:45:47 12:45:50

MS. ZHAO: I am about to dive into another section. Are you doing okay, do you want a five-minute break? 12:45:56 12:45:58 12:46:02

THE WITNESS: I'm fine to proceed. Thanks for asking. 12:46:05 12:46:06

Q Okay. Let's go to Paragraph 43 of the '053 declaration. 12:46:09 12:46:12

A Okay. 12:46:22

Q Second sentence of this paragraph states, "A solar cell is typically made of a slab of silicon, called a wafer, and thin layers added to each side of the wafer." 12:46:23 12:46:25 12:46:28 12:46:33

Do you see that? 12:46:34

A Yes, I do. 12:46:35

Q Then you talk about three forms of silicon in this paragraph. Correct? 12:46:35 12:46:39

A Yes. I say that silicon can come in different forms, and I elaborate on three examples starting with, "For example, silicon can be monocrystalline." I also talk about polycrystalline as another example and amorphous silicon as a third example of the forms of silicon. 12:46:53 12:46:55 12:47:00 12:47:04 12:47:06 12:47:10 12:47:12

Q And at the end of this paragraph on the next page you state, "These three types of silicon have long been used in solar cells." 12:47:14 12:47:16 12:47:19

Do you see that? 12:47:22

A Yes, I do. 12:47:25

Q When you say "used in solar cells" here, do you mean used as wafers? 12:47:26 12:47:28

A Not necessarily. The words are carefully chosen to be accurate. Monocrystalline silicon has been used as a wafer. Polycrystalline silicon, also called multicrystalline silicon, has been used as a wafer; but it's also been used as added or deposited layers. 12:47:32 12:47:35 12:47:40 12:47:45 12:47:49 12:47:52

Amorphous silicon has not been used as a wafer. Wafers are free-standing things that you can hold in your hand. That's not the case for amorphous silicon. Amorphous silicon has been deposited as a layer. That could be on a wafer, could also be on a piece of glass. This is what I mean when I say all three types have been used in solar cells. 12:47:56 12:47:57 12:48:00 12:48:03 12:48:06 12:48:10 12:48:13 12:48:16

Q Earlier we talked about amorphous silicon solar cells as sort of a flavor of solar cell. 12:48:17 12:48:28

Do you remember? 12:48:31

A Yes. 12:48:32

Q So just to clarify, when you say "amorphous silicon solar cells," you are referring to the use of amorphous silicon not as a wafer. 12:48:32 12:48:39 12:48:40

Right? 12:48:45

A Correct. I'm referring it -- I'm referring to amorphous silicon as the absorber. 12:48:46 12:48:48

So again, to clarify, and repeating what I said previously, solar cells were commonly named after their absorber. The function of the absorber is to absorb the light and generate electron-hole pairs that will then be collected at the metal contacts to generate electricity. So an amorphous silicon solar cell is one that has an amorphous silicon absorber. 12:48:54 12:48:58 12:49:01 12:49:05 12:49:10 12:49:13 12:49:16 12:49:19

However, we don't call that absorber a wafer in the case of amorphous silicon, because a wafer is something that you can hold in your hands, that is free-standing; and amorphous silicon doesn't come in that -- that form. 12:49:21 12:49:24 12:49:27 12:49:31 12:49:35

Q Let's go to Paragraph 53. 12:49:40

A Okay. 12:49:58

Q Starting on Line 2 you state that "Diffusion involved driving dopant atoms from a dopant source into a silicon wafer or a polysilicon wafer at high temperatures in a furnace." 12:49:58 12:50:01 12:50:05 12:50:10 12:50:13

Do you see that?
A Yes. One correction. You said "into a silicon wafer or polysilicon wafer," but I said "into a silicon wafer or polysilicon layer." 12:50:13 12:50:14 12:50:18 12:50:23
Q You're right. I'm sorry. 12:50:27
What does driving dopant into something mean? 12:50:29 12:50:31
A That refers to a process called diffusion, in which in this case atoms move from regions of relatively higher concentration to regions of relatively lower concentration governed by a process called Fick's law, F-I-C-K, Fick's law. 12:50:33 12:50:36 12:50:42 12:50:45 12:50:49 12:50:55
And here this is the driving dopant atoms into a silicon wafer or polysilicon layer, is a process of purposefully diffusing impurity atoms, dopant atoms, into the wafer or layer. 12:50:56 12:51:01 12:51:05 12:51:11
Q And what temperature are you referring to when you say "high temperatures in a furnace"? 12:51:17 12:51:20
A That depends. It depends on the material through which the dopant atoms are moving, or materials. And it depends on the type of dopant 12:51:25 12:51:31 12:51:36

atom as well. 12:51:41

So one can't say specifically without 12:51:43

additional information. 12:51:46

Q Would it be accurate to say that the 12:51:50

temperatures could be quite different depending on 12:52:00

which dopant atoms and materials are used? 12:52:04

MR. SELWYN: Objection. Form. 12:52:09

A Without knowing what "quite different" 12:52:12

means, I couldn't answer. 12:52:15

I can say that there are instances 12:52:18

throughout my declaration and throughout the art 12:52:23

that I refer to that provide some diffusion 12:52:26

temperatures for particular instances. 12:52:30

For example, there are references 12:52:34

included, like Froitzheim, that refer to diffusion 12:52:36

temperature ranges of 900 to 1200 degrees Celsius, 12:52:41

or Gan, which refers to temperature ranges of 900 12:52:47

to 1000 degrees Celsius. 12:52:53

And regarding your most recent question, 12:52:56

in my background section I talk about a process 12:52:59

called co-diffusion, which was a process by which 12:53:02

multiple types of dopants were driven in in the 12:53:08

same process. 12:53:14

So while it may be the case that 12:53:16

different dopant atoms diffusing perhaps into the 12:53:19

same or different layers or wafers could be done 12:53:22

so at different temperatures, there are also 12:53:29

instances, including in my declaration, of them 12:53:32

being diffused or driven in at the same time. 12:53:35

Q So what do you mean here when you say 12:53:39

"high temperatures," though? 12:53:46

A I mean an elevated temperature. I've 12:53:52

just given examples from the references that 12:53:54

include, for example, 900 to 1200 degrees C as a 12:54:00

range. That would be an example of a high 12:54:04

temperature. But I mean an elevated temperature. 12:54:07

Q What is the lowest number for a 12:54:12

temperature that you would consider to be 12:54:19

elevated? 12:54:22

MR. SELWYN: Objection. 12:54:24

Q I'm just trying to understand at what 12:54:27

point, at what temperature, would you consider 12:54:28

temperature to be elevated? 12:54:30

MR. SELWYN: Objection. Form. 12:54:32

A In this instance here I'm talking about doping, and doping was a technique that came from the semiconductor industry from nearly 100 years ago and was adopted by the solar industry. And so I believe a POSITA would be very familiar with doping. It was used and is used in every solar cell. 12:54:34 12:54:37 12:54:41 12:54:44 12:54:49 12:54:54 12:54:58

And that the way to get to accelerate the movement of dopant atoms into a wafer or layer is to increase the temperature. 12:55:01 12:55:04 12:55:08

And so what I'm talking about here when I say "high temperatures in a furnace" is decreasing the amount of time for this diffusion process to happen by increasing -- increasing the temperature. And I have provided some example ranges which appear in the references that I've included. 12:55:12 12:55:15 12:55:19 12:55:21 12:55:27 12:55:30 12:55:34

But the temperature that I'm referring to isn't meant to be limited to that. So there may be diffusion processes that happen below Froitzheim's 900 degrees C. But at 55 degrees Celsius one would be waiting a very, very long 12:55:38 12:55:39 12:55:43 12:55:47 12:55:53

time indeed. 12:55:56

Q But you would not consider 55 degrees Celsius to be a high temperature for doping or driving dopants? 12:56:00 12:56:02 12:56:08

A Within the -- within the context of this paragraph and my reference to high temperatures for diffusion, I am not imagining 55 degrees C. I am imagining what a POSITA would understand about doping silicon, which is at higher temperatures than that, yes. 12:56:09 12:56:11 12:56:14 12:56:21 12:56:23 12:56:27

Q Within the context of this paragraph, would you consider 200 degrees C to be a high temperature? 12:56:28 12:56:32 12:56:35

MR. SELWYN: Objection. Form. 12:56:39

A A POSITA would understand that for many doping processes conducted in the fabrication of silicon solar cells, 200 degrees C is not commonly used for diffusion. 12:56:41 12:56:44 12:56:48 12:56:54

There are other ways to dope other than diffusion. And I talk about ways, for example, of forming an emitter without diffusion, for example by deposited layers, that may occur, and they 12:56:57 12:57:00 12:57:06 12:57:12

commonly do occur at temperatures as low at 200 degrees C. 12:57:15 12:57:18

But this paragraph is about diffusion and using elevated temperatures to do so. And a POSITA would appreciate that common practice was not to diffuse at 200 degrees C but at higher temperatures. 12:57:19 12:57:23 12:57:26 12:57:28 12:57:33

Q What about 400 degrees C? 12:57:33

MR. SELWYN: Objection to form. 12:57:39

A I will stick to my answers that I've provided, that I have given examples, for example, from Froitzheim, that include a range of temperatures, for example 900 to 1200 degrees C, that lower temperatures may -- may be used. 12:57:46 12:57:47 12:57:51 12:57:56 12:58:01

For your specific case of 400 degrees C, which dopant atom are you envisioning and into which layer, and how deep would you like the dopant to go? 12:58:05 12:58:11 12:58:15 12:58:17

Q Is there any possible combination of dopant atom and layer and depth that would warrant a 400 degree C diffusion? 12:58:21 12:58:24 12:58:30

MR. SELWYN: Objection. Form. 12:58:34

A For silicon solar cells in particular? 12:58:36

Q In the context of your Paragraph 53, are you referring to silicon solar cells in particular? 12:58:38 12:58:49 12:58:55

A The first sentence of my Paragraph 53 says that a common doping technique was diffusion into a silicon wafer or polysilicon layer. 12:58:55 12:58:59 12:59:03

Yes, I'm speaking of materials found in silicon solar cells. 12:59:07 12:59:10

Q Okay. So my question then is, is there any possible combination of dopant atom and layer and depth in a silicon solar cell that would warrant a 400 degree C diffusion? 12:59:13 12:59:16 12:59:20 12:59:23

MR. SELWYN: Objection. Form. 12:59:28

A I would say that 400 degrees Celsius was not a common temperature to diffuse, for example, boron or phosphorus from a dopant source into a polysilicon layer or silicon wafer; and that the references that I've provided have given suitable temperature ranges for doing so. 12:59:40 12:59:49 12:59:54 12:59:58 13:00:02 13:00:07

But there may be other instances -- I don't have the full references -- excuse me, the 13:00:09 13:00:13

full literature at my fingertips -- for which doping or diffusion was done at temperatures as low as 400 degrees C. 13:00:15 13:00:21 13:00:25

Q I don't mean to annoy you with this, but I am really trying to understand what "high temperatures" means in this sentence. So I'll ask the same question again with respect to 600 degrees C. 13:00:38 13:00:40 13:00:42 13:00:45 13:00:48

MR. SELWYN: Objection. Form. 13:00:50

A Okay. I think my answer will be the same. I have provided suitable temperature ranges for instances that are relevant to, for example, the '053 patent, for example boron doping and phosphorus doping. And a POSITA would understand what was common processes in 2008 for doping. And 600 degrees C is similar to my answer to 400 degrees C. May have been used for select doping or a diffusion processes, but the references that I have provided have explained or teach a range, for example 900 to 1200 degrees C, that in this case is hotter than your 600 degrees C hypothetical. 13:00:52 13:00:54 13:00:59 13:01:10 13:01:15 13:01:23 13:01:33 13:01:38 13:01:43 13:01:48 13:01:56 13:02:01 13:02:05

Q So in the context of Paragraph 53, you would not consider 600 degrees C a high temperature. 13:02:07 13:02:09 13:02:12

Is that right? 13:02:13

MR. SELWYN: Objection. Form. 13:02:15

A That isn't what I said. I elaborated that in this I'm introducing a concept of doping and what a POSITA would have known. And that a POSITA would have known how to drive dopant atoms from a dopant source into a silicon wafer or a polysilicon layer. 13:02:17 13:02:21 13:02:26 13:02:30 13:02:36 13:02:40

And I described Fick's law, which has the underlying physics of diffusion. And I described that lower temperatures require longer times for atoms to diffuse. Or I believe I said it in the form of elevated or higher temperatures cause diffusion to occur more quickly. 13:02:42 13:02:46 13:02:48 13:02:57 13:03:00 13:03:03

And so at 600 degrees C, diffusion would be slower than, for example, at 800 degrees C. But there may be instances in which a POSITA wanted slower diffusion. So I would just again ask for additional context for your hypothetical 13:03:07 13:03:10 13:03:15 13:03:18 13:03:23

in order to provide an answer that I'm -- I'm more comfortable with. 13:03:27 13:03:32

Q What instance would a POSITA want slower diffusion? 13:03:33 13:03:37

A Well, for example, if a POSITA wanted to diffuse dopants just into the very surface of a region, and not very deep, then slowed, controlled diffusion would help that. 13:03:49 13:04:02 13:04:06 13:04:11

Or if a structure contained hydrogen, and hydrogenation was known to reduce defects at grain boundaries, hydrogen is very mobile in silicon. And if a POSITA did not want the hydrogen to diffuse out while dopants diffused in, then a POSITA might choose lower temperatures and slower diffusions. 13:04:14 13:04:23 13:04:28 13:04:31 13:04:35 13:04:38 13:04:43

So that would need to be understood within the context of the solar cell structure and aims of the fabricator. 13:04:44 13:04:46 13:04:52

Q Typically with silicon solar cells, would a POSITA want to diffuse dopants just into the very surface of a region and not very deep? 13:04:57 13:05:02 13:05:05

MR. SELWYN: Objection. Form. 13:05:09

A That depends on the particular structure that the POSITA is making. 13:05:14 13:05:17

I describe one instance of doping in the background section when I describe formation of emitters. And you would find, for example, in the literature and common knowledge to a POSITA, shallow emitters and also selective emitters that are only formed over part of the wafer surface. 13:05:21 13:05:30 13:05:35 13:05:37 13:05:39 13:05:45

So even within this one instance of emitter formation, those making solar cells sometimes wished for deeper diffusions and sometimes wished for more shallow diffusions. 13:05:50 13:05:53 13:06:00 13:06:02

MR. SELWYN: Jing, when you get to a good breaking point. 13:06:11 13:06:13

MS. ZHAO: Yeah, I was just thinking that. Should we take a break now? 13:06:14 13:06:15

MR. SELWYN: Sure. Five minutes or so. 13:06:18

MS. ZHAO: Sounds good. 13:06:20

MR. SELWYN: Thank you. 13:06:22

THE WITNESS: Thank you. 13:06:23

(A recess was taken.) 13:06:24

BY MS. ZHAO: 13:13:33

Q Let's go to Paragraph 54 of the '053 declaration. 13:13:34 13:13:37

A Okay, I'm there. 13:13:44

Q In this paragraph you talk about phosphorus diffusion. Right? 13:13:46 13:13:47

A Correct. 13:13:50

Q And you mention on Page 29, fifth line, applying heat to drive the phosphorus into the silicon. 13:13:50 13:13:56 13:13:59

Do you see that? 13:13:59

A Yes. 13:14:03

Q Typically what is the temperature of the heat being applied here? 13:14:03 13:14:05

MR. SELWYN: Objection. Form. 13:14:09

A So in this particular instance I'm talking about, again, diffusing into a silicon wafer or a polysilicon layer. And I cite many references at the end of this paragraph that show this. So we can look to those references. 13:14:12 13:14:14 13:14:28 13:14:35 13:14:39

So, for example, Smith I believe teaches a temperature of around 1000 degrees Celsius. Froitzheim teaches a temperature range, as I 13:14:43 13:14:47 13:14:52

described previously, of 900 to 1200 degrees Celsius. 13:14:56 13:15:01

So these are examples provided in the references of commonly used temperatures for performing this step. 13:15:02 13:15:06 13:15:12

Q Using Froitzheim as an example, what happens if you apply heat under 900 degrees Celsius? 13:15:13 13:15:24 13:15:27

A Per my previous answer, the laws of diffusion tell us that the movement from the dopants into the polysilicon layer or silicon wafer will occur more slowly. 13:15:33 13:15:38 13:15:41 13:15:48

Q Would it be accurate to say, then, if you go above 1200 degrees for Froitzheim, then the dopant would diffuse more quickly? 13:15:55 13:16:00 13:16:09

MR. SELWYN: Objection. Form. 13:16:14

A Yes. And in general, increasing the diffusion temperature will cause atoms to diffuse more quickly, or equivalently deeper, for the same amount of time. And conversely, decreasing the temperature will cause them to diffuse more slowly, or equivalently shallower, for the same 13:16:17 13:16:20 13:16:25 13:16:30 13:16:33 13:16:38

amount of time. 13:16:41

Q Could there be a situation where the diffusion would be too shallow for a structure? 13:16:45 13:16:48

MR. SELWYN: Objection. Form. 13:16:53

A I'm not sure what you mean, what "too shallow" means or what the structure is that you have in mind. 13:16:56 13:16:59 13:17:01

Q For example, for Froitzheim, if I applied heat under 900 degrees Celsius -- 13:17:01 13:17:05

MR. SELWYN: Objection. Form. 13:17:12

Q -- would that result in a diffusion that would be too shallow for Froitzheim? 13:17:13 13:17:17

MR. SELWYN: Objection. Form. 13:17:21

A Froitzheim teaches that 900 to 1200 degrees Celsius is a suitable range for the process and structure that he has in mind. 13:17:22 13:17:25 13:17:27

Froitzheim doesn't tell us what happens if you go below 900 degrees Celsius. One would expect, a POSITA would expect, per my previous answer, that the diffusion would be slower. And a POSITA would expect that if the temperature was low enough that there would be very little 13:17:31 13:17:33 13:17:39 13:17:42 13:17:47 13:17:50

diffusion. However, what is low enough is not specified by Froitzheim. 13:17:56 13:18:01

Q What would happen to Froitzheim's structure if there was very little diffusion? 13:18:06 13:18:08

MR. SELWYN: Objection. Form. 13:18:13

A I'm turning to Froitzheim's structure. 13:18:26

Q And for the record, you're looking at Exhibit 1004. Correct? 13:18:44 13:18:46

(Exhibit 1004, previously marked, not attached.) 13:18:46 13:18:46

A I was referring to Paragraph 107 in my declaration, which is in the overview of the prior art section in Froitzheim, but it shows the same structure as Exhibit 1004, yes. 13:18:51 13:18:56 13:19:00 13:19:02

Figure 3 of Exhibit 1004 particularly. 13:19:07

So Froitzheim teaches diffusion of N-type dopants into the front of the wafer and P-type dopants into the rear of the wafer. And it's helpful to look at the purpose of those two layers, and therefore the purpose of the two -- of the diffusions. 13:19:12 13:19:21 13:19:27 13:19:34 13:19:37 13:19:40

And Froitzheim teaches that the N-type 13:19:43

diffusion at the front reduces surface recombination and can help the formation of low-resistance contact to the front metal contacts. And the P-type layer at the rear is -- forms the emitter, and an emitter is necessary for a solar cell to function, as it must collect electrons in one location and holes at the other. 13:19:52 13:19:59 13:20:03 13:20:08 13:20:13 13:20:17 13:20:21

So if -- if the P-type layer, for example, were not diffused successfully, and so emitter was not formed, then a solar cell, Froitzheim solar cell, would not work. One needs to form an emitter, for example. 13:20:24 13:20:31 13:20:39 13:20:43 13:20:46

Or if the N-type layer was not diffused into the front surface of the wafer, then some of the features of Froitzheim's solar cell, like reduced surface recombination, would not be realized. 13:20:49 13:20:51 13:20:54 13:21:01 13:21:04

Q When you say if the P-type layer were not diffused successfully, what do you mean by that? 13:21:08 13:21:10

A I was referring to what you suggested before, where perhaps too low a temperature or too low -- too short a time was used to move dopants 13:21:15 13:21:17 13:21:21

into the wafer, or in the case of the combination with Gan, Gan's polysilicon layer in order to form an emitter. 13:21:30 13:21:33 13:21:39

Q And when you say, "If the N-type layer was not diffused into the front surface of the wafer," do you also mean too low of a temperature or too short of a time might cause that? 13:21:40 13:21:43 13:21:47 13:21:51

A For example, yes. 13:21:56

Q The N-type layer would be from phosphorus diffusion. Right? 13:21:57 13:22:07

A Phosphorus is one impurity atom that results in N-type doping in silicon, and it is an impurity atom that is taught by Froitzheim. 13:22:13 13:22:16 13:22:20

Q Earlier you talked about Froitzheim's temperature range of 900 to 1200 degrees Celsius. Correct? 13:22:28 13:22:31 13:22:37

A Correct. 13:22:42

Q Is that specifically for diffusion of the N-type dopant? 13:22:42 13:22:45

A No. Froitzheim discusses these diffusion temperatures, and in Paragraph 42 of Froitzheim. And this is following Froitzheim's discussion of 13:23:15 13:23:22 13:23:30

the formation of a boron dopant source layer. So Froitzheim is speaking here about the P-type emitter in Froitzheim's cell. 13:23:33 13:23:42 13:23:47

And then Paragraph 43 of Froitzheim says that the further steps for providing the front side N plus layer, in addition to the formation of the front and rear side contacts, can also be conducted according to steps described in two other patents or patent applications which Froitzheim incorporates by reference. 13:23:50 13:23:55 13:24:01 13:24:03 13:24:06 13:24:11 13:24:14

Q Have you reviewed those two patents? 13:24:18

A I don't recognize them from their numbers alone. I may have done. 13:24:23 13:24:26

Q Let's go to Paragraph 58 of your declaration. 13:24:31 13:24:41

Here at the end of the paragraph you state that, "In the field of solar cell technology, emitter usually refers to the region or layer that is oppositely doped from the substrate." 13:24:50 13:24:52 13:24:56 13:24:59 13:25:01

Do you see that? 13:25:02

A Yes. 13:25:03

Q What is your basis for saying that? 13:25:03

A This is common knowledge that a POSITA would have. It's been true for decades and comes to solar cells from transistors, where the word "emitter" first got its name. So this is common knowledge that a POSITA has. 13:25:11 13:25:14 13:25:17 13:25:24 13:25:26

In addition, you'll find that the '053 and '516 patents also use emitter in this way, and that in the prosecution history of the '053 and -- patent and another patent, the '771 patent in the same family, that Maxeon has confirmed this meaning for the word "emitter." 13:25:28 13:25:34 13:25:40 13:25:46 13:25:51 13:25:57

Q And on the next page, Page 33, you show a figure of Froitzheim's cell. 13:25:59 13:26:02

Do you see? 13:26:05

A Yes, I do. 13:26:07

Q According to your definition of emitter, the dark blue layer labeled P-type layer would be the emitter in Froitzheim. Right? 13:26:08 13:26:11 13:26:15

A That is correct. 13:26:20

Q And this emitter would have gone through the dopant diffusion process. Right? 13:26:20 13:26:25

A Yes. Paragraphs 40 through 42 of Froitzheim describe the formation of this emitter, including the diffusion of dopants into it. 13:26:32 13:26:41 13:26:45

(Clarification by the court reporter.) 13:27:01

A Into it. Into the wafer, is fine. 13:27:05

Q So would it be accurate to call this dark blue layer the doped silicon emitter layer? 13:27:05 13:27:09

MR. SELWYN: Objection. Form. 13:27:17

A I don't think those were the use -- the words that Froitzheim uses, and those aren't the words that a POSITA would normally use. A POSITA would call it an emitter or a diffused emitter. But I didn't hear anything technically inaccurate about your statement. 13:27:21 13:27:24 13:27:27 13:27:33 13:27:36 13:27:39

Q And the light green N plus region would not be called an emitter. Right? 13:27:41 13:27:45

A That is correct. 13:27:49

Q Is there a name for this N plus region? 13:27:50

A Yes. It's commonly called a front surface field, if it's at the front of a solar cell and it has the same polarity as the wafer. 13:27:58 13:28:02 13:28:07

And perhaps you can give me one moment as 13:28:15

well. So Froitzheim uses these words in Paragraph 18 of Froitzheim. When talking about the N plus layer he identifies it as a front surface field, which is the language that a POSITA would use as well. 13:28:17 13:28:37 13:28:42 13:28:45 13:28:49

Q Is it accurate to call the structure of Froitzheim a silicon solar cell? 13:28:52 13:28:54

A Yes. Per our earlier discussion, the absorber is a silicon wafer, and this would be described as a silicon solar cell. 13:28:59 13:29:02 13:29:05

Q Could I also describe this as a homojunction solar cell? 13:29:07 13:29:13

A That is correct. Because the emitter is diffused into the wafer in Froitzheim, this would be described as a homojunction solar cell. 13:29:15 13:29:18 13:29:25

Q Let's go to Paragraph 61. 13:29:28

A Okay. 13:29:41

Q In this paragraph you talk about depositing the emitter. Right? 13:29:41 13:29:43

A That's correct. 13:29:46

Q Does depositing an emitter turn the solar cell into a heterojunction solar cell? 13:29:48 13:29:52

A Not necessarily. I can elaborate, if you would like. 13:29:56 13:30:04

Q Please do. 13:30:04

A In particular, hetero comes from the Greek for different. And so in a heterojunction, the host materials on either side of the junction are different. So amorphous silicon is different from crystalline silicon, that is referred to as a heterojunction. 13:30:07 13:30:10 13:30:13 13:30:16 13:30:20 13:30:24

If crystalline silicon is deposited on crystalline silicon, then one normally does not call that a heterojunction. 13:30:24 13:30:27 13:30:30

Q With a deposited emitter, would you still need to go through dopant diffusion? 13:30:36 13:30:38

MR. SELWYN: Objection. Form. 13:30:42

A You may. For example, Gan and Borden both teach deposited emitters. And I have included those as references in my ground. And both of them teach diffusion. 13:30:45 13:30:51 13:30:54 13:30:59

However, it may also be possible to deposit a layer that has dopants already in the layer as part of the deposition process. And in 13:31:04 13:31:08 13:31:11

that case an additional diffusion step may not be necessary. 13:31:17 13:31:19

That, for example, is commonly done with the deposition of amorphous silicon in silicon heterojunction solar cells. 13:31:22 13:31:24 13:31:27

Q In Paragraph 61 you mention amorphous silicon and polycrystalline silicon emitter layers. Correct? 13:31:29 13:31:43 13:31:46

A Yes. I say they were well known by 2008, and I give reference to Li, for example, and Okayasu. 13:31:48 13:31:52 13:31:59

Q Are these materials typically used for deposed emitters? 13:32:06 13:32:11

MR. SELWYN: Objection. Form. 13:32:13

A Deposed emitters? Did you mean deposited emitters? 13:32:14 13:32:17

Q Deposited -- I'm sorry, deposited emitters. 13:32:17 13:32:21

MR. SELWYN: Objection. Form. 13:32:21

A Can you ask that question one more time for me, please. 13:32:24 13:32:27

Q Let me ask one by one. Is amorphous 13:32:27

silicon a material that is typically used for deposited emitters? 13:32:30 13:32:34

MR. SELWYN: Objection. Form. 13:32:38

A Yes, amorphous silicon can be and commonly was used in silicon solar cells as a deposited emitter. Li, for example, teaches this. 13:32:39 13:32:42 13:32:46

Q If you deposit an amorphous silicon emitter onto a silicon substrate, would you then have a heterojunction solar cell? 13:32:52 13:32:58 13:33:05

MR. SELWYN: Objection. Form. 13:33:11

A Yes, an amorphous silicon emitter deposited onto a crystalline silicon wafer would be called a heterojunction solar cell. 13:33:13 13:33:16 13:33:19

Q What if you use a polycrystalline silicon emitter and you deposit that onto a crystalline silicon wafer; would you then also have a heterojunction solar cell? 13:33:23 13:33:32 13:33:36 13:33:40

A That particular structure of a multicrystalline -- or polycrystalline I believe you said -- emitter deposited onto a crystalline silicon wafer, as for example shown in Okayasu in Paragraph 60 of my declaration, was not commonly 13:33:46 13:33:48 13:33:51 13:33:54 13:34:01

referred to as a heterojunction solar cell, in particular because there's crystalline silicon on both sides of the junction. 13:34:04 13:34:10 13:34:14

Although this structure of the crystalline silicon is different in that one of them -- or could be different in that the wafer could be monocrystalline or polycrystalline, and then the emitter as specified here is polycrystalline. 13:34:15 13:34:20 13:34:22 13:34:25 13:34:28 13:34:31

Q Now we talked about diffuse emitters, amorphous silicon emitters, and polycrystalline silicon emitters. Right? 13:34:31 13:34:43 13:34:46

A That's correct. 13:34:51

Q At a high level, can you tell me what the difference is between these three emitters? 13:34:51 13:34:55

A Can you elaborate on what sort of differences you're interested in? Differences in the performance? Difference in the fabrication of them? Difference in the cost to make them? 13:35:04 13:35:05 13:35:08 13:35:09

Difference in what? 13:35:12

Q All of the above would be great. Let's start with differences in performance. Are there 13:35:17 13:35:19

any differences in performance between the three? 13:35:25

MR. SELWYN: Objection. Form. 13:35:27

A There could be. It depends on the 13:35:28

specific instance. 13:35:30

I don't believe I have enough information 13:35:34

to make any definitive statements, but there are 13:35:37

some trends. And you can find these in the 13:35:43

references of my declaration. 13:35:46

For example, diffused emitters could 13:35:51

suffer from high surface recombination in a solar 13:36:01

cell. Deposited emitters such as amorphous 13:36:06

silicon or polycrystalline silicon could provide 13:36:09

very good surface recombination. Recognized, for 13:36:15

example, by low J naught values, J sub zero 13:36:20

values, as for example taught by Gan. 13:36:25

Particularly if they included an 13:36:28

intrinsic amorphous silicon layer in the case of a 13:36:30

deposited amorphous silicon emitter, as taught by 13:36:34

Li and as used in heterojunctions. Or an oxide 13:36:39

layer, as taught by Gan or Borden, for example. 13:36:44

However, an amorphous silicon emitter 13:36:55

could have other drawbacks. And these are taught, 13:36:58

for example, by Li, who talks about parasitic absorption in amorphous silicon emitters. 13:37:05 13:37:11

So there can be differences in performance. But any particular instance of one of these emitters may have these -- its performance may vary from the implementations of the emitter by others. 13:37:14 13:37:16 13:37:20 13:37:29 13:37:32

One moment to pause here. I just want to let you know that our speaker just said battery low. It's also our microphone. I have it plugged in, so I'm not sure why it's saying that. 13:37:36 13:37:38 13:37:41 13:37:45

(Discussion off the record; technical difficulty.) 13:37:49 13:37:49

A So perhaps you can just shout at us or raise your hand if I go silent, and we'll find a different setup. 13:37:53 13:37:55 13:38:00

Q Okay. 13:38:01

A I'm not sure I fully answered your question. So if perhaps you would like more of an answer to it, you could ask again. 13:38:05 13:38:07 13:38:09

Q No. That was very helpful. 13:38:11

Can you also talk about the difference in 13:38:15

fabrication between these three types of emitters? 13:38:16

MR. SELWYN: Objection. Form. 13:38:21

A Again, I can give you general guidelines without referring to any specific instance. And these follow what you'll find in my declaration, which is that a diffused emitter is typically made in a process in a furnace at high temperature -- we've had an extended discussion about high temperature -- in which a dopant source added onto one or the other surface of the wafer provides dopant atoms that diffuse into the wafer surface and form the emitter. That's how a diffused emitter as described here is typically made. 13:38:24 13:38:27 13:38:31 13:38:36 13:38:44 13:38:48 13:38:51 13:38:58 13:39:03 13:39:07 13:39:11

And a deposited emitter is commonly but not always made in a vacuum chamber. Wafer is loaded into a vacuum chamber. Gases are introduced into the vacuum chamber that those gases include silicon atoms. And the silicon atoms rain down upon the wafer -- I'm oversimplifying -- and a layer is grown. 13:39:13 13:39:18 13:39:22 13:39:25 13:39:30 13:39:33 13:39:38

And depending on the specific conditions, that layer could be an amorphous arrangement of 13:39:41 13:39:43

silicon atoms or a crystalline, polycrystalline arrangement of silicon atoms. 13:39:46 13:39:51

And included in that deposition process there may also be dopant atoms that are incorporated as the silicon emitter is deposited. Li teaches that, for example. 13:39:54 13:39:57 13:40:00 13:40:06

Alternatively, there may be no dopant atoms that are included in the deposition process, and a dopant source may be added to the -- or over the polysilicon layer, or amorphous silicon layer. And those dopants may be diffused in per, once again, my discussion of the diffused emitter. 13:40:08 13:40:11 13:40:18 13:40:25 13:40:30 13:40:35

So there are combinations that are possible here, but that gives you a broad overview of how these may be fabricated. 13:40:39 13:40:41 13:40:45

Q Earlier you also mentioned a difference in cost. 13:40:46 13:40:51

Can you tell me more about that? 13:40:51

A Once again, without -- without detailed scenarios, it's hard to do so. 13:41:00 13:41:02

But as described in references that I've included, for example Smith or, for example, Li, 13:41:06 13:41:10

in general more processing steps tends to increase costs. Higher temperature steps can also increase costs. And these are taught in the references that I have included. 13:41:15 13:41:20 13:41:25 13:41:28

So take that, please, in the context of what I described previously of common processing, common fabrication methods, for each of these. 13:41:28 13:41:31 13:41:34

Q So typically would diffuse emitters involve more processing steps? 13:41:39 13:41:45

MR. SELWYN: Objection. Form. 13:41:49

A More processing steps than what? 13:41:51

Q Than deposited emitters. 13:41:54

MR. SELWYN: Objection. Form. 13:41:58

A I couldn't answer that without additional detail. 13:42:00 13:42:05

In any given fabrication sequence, perhaps done at a particular company, there may be more or fewer steps. A POSITA understood from -- from the literature how to make diffused emitters and how to make deposited emitters, and understood things like I've described of diffused emitter being made commonly in a furnace process, and a 13:42:09 13:42:15 13:42:20 13:42:27 13:42:30 13:42:33 13:42:38

deposited emitter commonly made in a vacuum process, vacuum deposition process. 13:42:42 13:42:46

But whether or not one required more steps than the other could depend, for example, on whether or not one has implemented Smith's teachings, which I include for in situ doping, in which multiple diffusion steps are performed in one loading of the wafer into the tool. 13:42:50 13:42:52 13:42:58 13:43:01 13:43:06 13:43:11

(Clarification by the court reporter.) 13:43:19

Q If in situ doping is not used, would it be accurate to say that diffused emitters require more processing steps than deposited emitters? 13:43:22 13:43:27 13:43:31

MR. SELWYN: Objection. Form. 13:43:35

A No, not necessarily. Once again, more details are needed. 13:43:36 13:43:40

I can envision scenarios in which that is true and also in which the opposite is true. I need more details about, for example, two process sequences to make a comparison. 13:43:42 13:43:44 13:43:47 13:43:51

Q In 2008 which type of emitter was most commonly used in the market? 13:43:54 13:44:01

A "In the market," you mean in commercially 13:44:05

available products? 13:44:08

Q Yep. 13:44:09

A Diffused emitters were more commonly used in the market at that time. 13:44:10 13:44:13

Q Let's go to Paragraph 68. 13:44:19

A Okay. 13:44:33

Q On Page 40, starting on the second line, you talk about "solidifying paste into the final contacts and makes electrical contact between the paste and an N-type or a P-type region or layer." 13:44:33 13:44:36 13:44:36 13:44:47

Do you see that? 13:44:49

A Yes, I do. 13:44:50

Q To be clear, in a particular solar cell you would want at least one metal contact to make electrical contact with an N-type region. Right? 13:44:50 13:44:54 13:44:58

A That is correct. And this is described in many places, including, if I remember correctly, the beginning of the '053 patent itself, that a metal contact should make electrical contact to an N-type region and another metal contact should make electrical contact to a P-type region. 13:45:03 13:45:07 13:45:11 13:45:15 13:45:20 13:45:24 13:45:27

Q And by N-type region you mean N-type doped region. Right? 13:45:30 13:45:33

A That's what N-type means, yes. 13:45:35

Q And P-type region would be P-type doped region. Right? 13:45:37 13:45:44

A That's correct. 13:45:45

Q Typically in solar cells are there more than one N-type doped regions? 13:45:45 13:45:52

MR. SELWYN: Objection. Form. 13:45:55

A There can be. For example, we were looking moments ago at Froitzheim's Figure 3, for example, on end of page -- Paragraph 58 of my declaration. 13:45:59 13:46:08 13:46:13 13:46:17

And in this instance you can identify three different regions with N-type doping. The wafer itself has an N-type background doping level. There is a light green region that extends across much of the front surface that has heavier N-type doping identified as an N plus region. And then 38 in this image has a slightly different color green, and it has heavier doping still. It is under the metal contacts. And Froitzheim 13:46:19 13:46:24 13:46:29 13:46:33 13:46:36 13:46:41 13:46:47 13:46:55 13:47:01

describes this as an optional selectively doped region for making low-resistance contact to the metal contacts. 13:47:03 13:47:08 13:47:13

We talked previously about surface recombination as quantified by J naught, and that is one important parameter in selecting or designing an emitter. 13:47:14 13:47:19 13:47:24 13:47:28

The other one is its contact resistance, and commonly parameterized by a parameter called rho C. Rho as in the Greek letter. And that's true for an emitter. 13:47:30 13:47:40 13:47:45 13:47:47

But those same two parameters are also what a POSITA would look to in designing a good front surface field, as shown here by Froitzheim. 13:47:48 13:47:53 13:47:56

So what Froitzheim is teaching in this instance is a way to make lower low C, lower contact resistance. So here's an instance of a solar cell that has three in this case N-type regions. 13:47:59 13:48:01 13:48:07 13:48:09 13:48:12

Q Is this also true for P-type doped regions in a solar cell, can there be more than one P-type doped region? 13:48:13 13:48:17 13:48:21

A There can be. In the Froitzheim solar cell shown on Paragraph 58 of my declaration, there is only one. 13:48:26 13:48:28 13:48:31

But several of the references that I have included are motivated to switch from P-type wafers, which were more prevalent in the industry in 2008 than N-type wafers, to N-type wafers. We find this in Froitzheim as part of the motivation. We find this in Li as part of the motivation as well. 13:48:34 13:48:37 13:48:45 13:48:47 13:48:54 13:48:56 13:48:59

So for a solar cell that had a P-type wafer, there could likely be two or more P-type regions, one of which has heavier doping and is near a front or rear surface and to which metal makes contact. 13:48:59 13:49:02 13:49:07 13:49:13 13:49:17

Q Can you give me a example of a solar cell that has more than two P-type regions? 13:49:18 13:49:23

A Yes. In fact, the solar cell structure of Froitzheim, once again in Paragraph 58 of my declaration, could be made -- although this isn't taught by Froitzheim -- with everything labeled P-type reversed to N-type and everything labeled 13:49:27 13:49:31 13:49:36 13:49:41 13:49:44

N-type reversed to P-type. And in that instance there would be three P-type regions of the solar cell. 13:49:48 13:49:50 13:49:57

Q Are there any solar cells that have more than one P-type doped region and more than one N-typed regions -- I'm sorry, more than two? More than two P-type doped regions and more than two N-type doped regions? 13:49:57 13:50:00 13:50:05 13:50:09 13:50:13

MR. SELWYN: Objection. Form. 13:50:14

A So two of each is not sufficient to answer yes to your question. You want three or more of each. 13:50:16 13:50:19 13:50:22

Is that correct? 13:50:23

Q Let me ask this question again just for clarity. 13:50:24 13:50:26

Are there any solar cells that have more than two P-type doped regions and more than two N-type doped regions? 13:50:27 13:50:29 13:50:36

MR. SELWYN: Objection. Form. 13:50:38

A I just want to clarify one more time. That means that two of each does not meet the criteria of your question. You want three or more 13:50:40 13:50:42 13:50:45

of each, because you said more than two and more than two. So that's three or greater, or three or greater. 13:50:47 13:50:50 13:50:54

Is that correct? 13:50:54

Q Yes. 13:50:56

A Such a solar cell is certainly possible. Figure 5 of Froitzheim, which is Exhibit 1004, shows doping 55 and 38 specifically under the contact regions. A structure similar to this, but incorporating some other things taught by Froitzheim, could have what you're describing, but I don't have a particular instance that I could point to in mind. 13:51:08 13:51:12 13:51:19 13:51:37 13:51:45 13:51:47 13:51:50 13:51:53

So I will say a solar cell could have that. There very well may have been one made. I don't have an instance to point to you -- point you to, excuse me. 13:51:54 13:51:57 13:52:00 13:52:03

Q Are you aware of any solar cells that have a passivation layer between the metal contact and a doped region? 13:52:04 13:52:11 13:52:15

A Between the metal contact and any doped region or ... 13:52:20 13:52:25

Q The doped region where typically the metal contact would make electrical contact with a doped region. 13:52:28 13:52:34 13:52:39

A And again, there are a minimum of two of those in each solar cell, a metal contact making electrical contact to an N-type region and one making contact to a P-type region. So you -- either of those? 13:52:40 13:52:43 13:52:47 13:52:50 13:52:53

Q Yes. 13:52:54

A Okay. Yes, I am aware of such instances. In my '053 declaration, for example, I refer to Borden. Give me just one moment, please. 13:52:55 13:53:01 13:53:05

Actually, I want to clarify and make sure I understood your question. Can you repeat again? A passivation layer between which layer and which? 13:54:08 13:54:10 13:54:14

Q Metal contact and -- 13:54:16

A Metal contact. 13:54:19

Q -- a doped region specifically where the metal contact would make electrical contact with a doped region. 13:54:20 13:54:23 13:54:27

A Okay. Thank you. 13:54:29

So back to my '053 declaration. I 13:54:36

apologize. I hadn't understood your question correctly the first time. 13:54:40 13:54:42

You can -- you can read, for example, in Paragraph -- it's a long paragraph, 67. No. Excuse me, 68. Page 40. "In many case the paste," here I'm referring to paste of metallic particles that the end of solar cell fabrication becomes the metal contact, "was designed to fire through an antireflection coating located between the wafer and the paste." 13:54:47 13:54:52 13:54:59 13:55:08 13:55:11 13:55:14 13:55:17 13:55:20

So in many instances the wafer, for example, if it had a diffused emitter, its surface layer would be the doped layer that you're referring to, and the antireflection coating was frequently an electrically insulating layer used for passivation of the wafer surface in addition to providing antireflection. 13:55:23 13:55:25 13:55:31 13:55:32 13:55:36 13:55:41 13:55:46

So this is an instance of paste over an antireflection layer that's also a passivation layer, below which is a doped silicon region to which the paste will make electrical contact in particular during the firing through process. 13:55:50 13:55:53 13:55:57 13:56:03 13:56:07

Q When you fire the paste through -- I'm sorry. You would be firing the paste through the antireflection coating. Right? 13:56:11 13:56:17 13:56:19

A Correct. And again, the antireflection coating is in many cases also a passivation layer, as described in many pieces of art that I have included. 13:56:24 13:56:27 13:56:30 13:56:33

Q And so when the paste is fired through the antireflection coating, to then make electrical contact with the doped silicon region, would there still be antireflection coating between the paste and the doped silicon region? 13:56:34 13:56:37 13:56:42 13:56:47 13:56:50

A Yes. If you -- if you were to take a cross-sectional view of the solar cell after this firing-through process, you would find that the antireflection coating is intact in most places, and the paste remains on top of or over the antireflection coating in most places; but there are some instances where metal paste particles have made their way through the antireflection coating, filaments of the paste, and that those filaments touch the surface of the wafer making 13:56:56 13:57:03 13:57:08 13:57:11 13:57:15 13:57:19 13:57:22 13:57:26 13:57:31 13:57:35

electrical contact. 13:57:40

Q There's only electrical contact between 13:57:45

the paste that makes it -- makes itself through 13:57:47

the antireflective coating. 13:57:49

Is that right? 13:57:52

MR. SELWYN: Objection. Form. 13:57:53

A Yes. Let me try to explain again. 13:57:55

Most of the paste resides on top of or 13:57:57

over the antireflection coating. But in the 13:58:02

fire-through process some of -- some of it will 13:58:05

reach through the antireflection coating and touch 13:58:07

the wafer surface, thereby electrically connecting 13:58:11

the wafer to the paste through the antireflection 13:58:15

coating. But the majority of the antireflection 13:58:19

coating between the paste or metal contact and the 13:58:21

wafer will be intact. 13:58:28

Q Is it accurate to say that there would 13:58:31

not be current flowing through the portions where 13:58:36

the antireflection coating is intact? 13:58:40

A That is correct. The antireflection 13:58:44

coating, being an insulator, does not pass 13:58:46

current. So the current passes through the 13:58:50

localized regions where the paste has reached from the metal contact down through the antireflection coating to touch the wafer. 13:58:54 13:58:57 13:59:00

MS. ZHAO: We've been going for about an hour again. Do you want to take a break? 13:59:05 13:59:06

MR. SELWYN: We're happy to take five minutes. 13:59:10 13:59:11

MS. ZHAO: Okay. Let's do that. 13:59:11

(A recess was taken.) 13:59:13

BY MS. ZHAO: 14:06:02

Q Let's go to Paragraph 55 of the '053 declaration. 14:06:03 14:06:05

I'm so sorry, I meant Page 55. 14:06:18

A Okay, I'm there. 14:06:36

Q On this page you show Figure 1 of the '053 patent. Right? 14:06:36 14:06:40

A Correct. 14:06:41

Q Is this a silicon solar cell? 14:06:41

A Yes, it is. 14:06:52

Q And is this a homojunction solar cell? 14:06:52

A The solar cell has a polycrystalline emitter and I believe a monocrystalline silicon 14:07:01 14:07:05

wafer. It is not -- a POSITA would not have referred to it as a heterojunction solar cell. 14:07:13 14:07:19

It may or may not have been referred to as a homojunction solar cell at the time. And I say that because if I am remembering correctly, that the N-type wafer is monocrystalline and the P-type emitter I know is polycrystalline. Then a POSITA may or may not have used the word "homojunction" to refer to it. A POSITA would certainly call it a silicon solar cell. 14:07:28 14:07:29 14:07:37 14:07:43 14:07:47 14:07:53 14:07:57 14:07:59

Q Would there be a third category if a POSITA would not have called it a heterojunction solar cell, may not have called it a homojunction solar cell, then is there a third name? 14:08:09 14:08:11 14:08:14 14:08:19

MR. SELWYN: Objection to form. 14:08:21

A No, there's not. Homojunction and heterojunction are exclusive categories. I just meant to say that heterojunction was used as of the priority date in 2008 to refer to specifically most commonly amorphous silicon crystalline silicon heterojunctions. Other types of solar cells that didn't have such a thing were commonly 14:08:22 14:08:25 14:08:29 14:08:33 14:08:38 14:08:41 14:08:44

homojunctions, but they were typically referred to as silicon solar cells, as opposed to specifically calling them homojunctions. 14:08:46 14:08:48 14:08:54

Q Let's go to Paragraph 112. 14:08:55

A Okay. 14:09:15

Q In Footnote 5 you talk about concentrator solar cells being a category of solar cells, and you talk about nonconcentrator solar cells in the next sentence. 14:09:15 14:09:21 14:09:22 14:09:25

Do you see that? 14:09:26

A Yes, I do. 14:09:28

Q Besides the use of lenses, mirrors, et cetera, are there any other differences between concentrator solar cells and nonconcentrator solar cells? 14:09:28 14:09:34 14:09:38 14:09:38

A There can -- 14:09:46

MR. SELWYN: Objection. Form. 14:09:46

A There can be. 14:09:49

So a concentrator solar cell is one that -- or is a term that we use to describe solar cells that are used under light concentration. And as I mention in this footnote, one way of 14:09:50 14:09:54 14:10:01 14:10:05

achieving such concentration is by adding a system or apparatus that uses lens or mirrors to provide that concentration. 14:10:08 14:10:10 14:10:15

And nonconcentrator solar cells, also called one-sun solar cells, are those that are operating without such concentration. 14:10:16 14:10:20 14:10:24

So to come to your question, under concentration the short-circuit current density of a solar cell increases. It typically increases linearly with the concentration. And one loss in -- power loss in solar cells is due to resistance. And in fact, one category of that resistance is contact resistance, which I describe in detail in the background section. 14:10:26 14:10:31 14:10:36 14:10:40 14:10:47 14:10:50 14:10:52 14:10:55

As the current goes up, the loss, power loss due to resistance, increases. And so it's important to decrease the resistance of the solar cell. And the more concentration the solar cell is going to be under, the more you want to decrease the resistance by, for example, using more metal, enlarging the volume of the metal contacts. 14:10:59 14:11:02 14:11:06 14:11:11 14:11:13 14:11:17 14:11:20 14:11:26

So this is an instance of how a solar cell is to be used for concentration may differ in its design from one that isn't. 14:11:27 14:11:31 14:11:36

However, many things about solar cells that are to be used under concentration or not are the same. They both use absorbers. For example silicon wafers they use diffused regions, they have to have emitters, they have to have passivation layers, they have to have contacts. And so many elements are -- are the same, and there was learning constantly between communities that were focused on concentrator solar cells and those focused on nonconcentrator solar cells because so much of the underlying physics and materials and device structures. 14:11:38 14:11:40 14:11:44 14:11:50 14:11:54 14:11:55 14:11:58 14:12:06 14:12:09 14:12:12 14:12:14 14:12:17

Q You mentioned enlarging the volume of metal contacts. Any other differences in designs between concentrator solar cells and nonconcentrator solar cells? 14:12:21 14:12:25 14:12:28 14:12:31

MR. SELWYN: Objection. Form. 14:12:32

A There could be. It depends on, for example, how much concentration the solar cell 14:12:33 14:12:37

would be used under. 14:12:42

You know, we don't distinguish, when we 14:12:44

use the word "concentrator solar cell," whether 14:12:46

it's going to operate under two-suns equivalent or 14:12:49

2,000-suns equivalent, although those are 14:12:54

different conditions. 14:12:58

So one thing that becomes more prevalent 14:13:00

under higher concentration is Auger recombination. 14:13:05

That's A-U-G-E-R, after the French man. And I 14:13:10

believe I talked about Auger recombination in my 14:13:16

background section. 14:13:19

And it is a recombination mechanism that 14:13:21

increases with higher carrier density. And 14:13:24

carrier density increases with concentration. 14:13:31

So, for example, having the emitter at 14:13:35

the front side or the back side of the solar cell 14:13:39

might be a design choice that a person would make 14:13:42

depending on the concentration that the solar cell 14:13:46

would operate under. 14:13:52

Q Besides the location of the emitter and 14:13:53

the size of the metal contact, what other design 14:14:00

differences could there be between concentrator 14:14:05

solar cells and nonconcentrator solar cells? 14:14:09

MR. SELWYN: Objection. Form. 14:14:12

A So far I have limited my response to thinking about silicon solar cells. Commonly a lot of the development work for concentrator solar cells was directed to nonsilicon solar cells, like gallium-arsenide-based multijunction solar cells. 14:14:18 14:14:21 14:14:25 14:14:28 14:14:33

So you might change the type of solar cell altogether. And we can talk about why, if you would like. 14:14:39 14:14:44 14:14:48

Also, under concentration the solar cells will generate more heat. And solar cells like to operate under light, but they don't like to operate hot. So adding an apparatus around the solar cell to remove heat is important, particularly as the concentration goes up. For example, a heat sink or even active cooling with water. So these would be some other choices that a person may consider if he or she wanted to make a concentrator -- concentrator solar cell. 14:14:49 14:14:53 14:14:57 14:15:01 14:15:10 14:15:13 14:15:17 14:15:22 14:15:27 14:15:33

Q You mentioned multijunction solar cells. 14:15:37

Can you tell me what that is? 14:15:42

A Yes. We previously talked about tandem solar cells, in particular in the context of Perovskite/silicon tandem solar cells. And I told you it was two solar cells in a tandem, one designed to optimally to use the visible spectrum, and one designed to use the infrared spectrum. 14:15:44 14:15:48 14:15:52 14:15:56 14:15:58 14:16:02

A multijunction solar cell is a generic term for two or more junctions. So tandems would fall under multijunctions, but so would stacking three solar cells together or four. 14:16:04 14:16:06 14:16:09 14:16:12

And the idea is to better use the solar spectrum than a single material, like silicon alone could. 14:16:15 14:16:20 14:16:23

Q So if you stack two solar cells together, you would have two junctions. Right? 14:16:26 14:16:32

A That's correct. 14:16:36

Q Which means each solar cell only has one junction. 14:16:36 14:16:41

Is that always true? 14:16:41

MR. SELWYN: Objection. Form. 14:16:44

A We talk about solar cells as having one PN junction. And we use the word "junction" to 14:16:47 14:16:55

refer to PN junction in shorthand, yes. So each solar cell, or we would commonly call them subcell in a multijunction solar cell, would have one junction, one PN junction. 14:16:58 14:17:06 14:17:09 14:17:12

Q In 2008 were concentrator solar cells common in the commercial solar cell market? 14:17:14 14:17:20

A There were multiple companies offering concentrator solar cells, solar panels, or solar systems. Around 2008 was a time of lots of different offerings in the solar industry. The industry hadn't yet seen the consolidation that came -- the consolidation and -- yeah, that came over the next decade. 14:17:28 14:17:32 14:17:39 14:17:44 14:17:48 14:17:51 14:17:58

So there were -- there were several companies offering concentrator solutions. It was not as common as nonconcentrator solar cells or modules. 14:18:00 14:18:03 14:18:08 14:18:16

Q In Paragraph 112 you also mention a backside contact solar cell. 14:18:17 14:18:23

Do you see that? 14:18:24

A I do. 14:18:25

Q And then you cite Exhibit 1015, Swanson. 14:18:26

Right? 14:18:31

(Exhibit 1015, previously marked, not attached.) 14:18:31

A Yes, I also cite 1005, Gan, in the same paragraph. 14:18:37

Q Do you know if Swanson discloses a concentrator solar cell? 14:18:41

A I have read Swanson, but I don't have it in front of me. If you'd like to pull it up, we can look together. But I don't remember offhand. 14:18:54

MS. ZHAO: I will upload it real quick for you. 14:19:00

MR. SELWYN: Is it in his binder? 14:19:04

MS. ZHAO: I don't think so. 14:19:06

MR. SELWYN: Okay. 14:19:09

THE WITNESS: Yeah, I don't see it. 14:19:11

MR. SELWYN: Okay. Go ahead, then. 14:19:12

MS. ZHAO: I am going to upload it to the chat. It should be available now. Can you just open it up for me real quick and let me know if Swanson discloses a concentrator solar cell? 14:19:13

A One moment, please. Try that again. My 14:19:14 14:19:15 14:19:18 14:19:28 14:19:33 14:19:56

PDF -- there we go. Second time was a charm. 14:20:24

Okay, I have briefly reviewed Swanson. I haven't reread every word. I can if you want, but it will take a few moments. But from what I see and what I remember of my previous reading, Swanson describes a solar cell without any particular description of its intended use, and talks about the disclosure as not being limiting. 14:22:47 14:22:50 14:22:53 14:23:00 14:23:04 14:23:09 14:23:17

Swanson doesn't talk about use in a concentrator. Swanson doesn't talk about use at one sun in a flat-plate module. But that is to say, as I mentioned before, Swanson doesn't talk about the use for his invention being limited to any use cases. But Swanson does include other publications on the first and second page of the patent that refer to concentrator solar cells. And I believe from the titles also nonconcentrator solar cells, both of them, including a paper from Swanson, for example, titled The Promise of Concentrators. 14:23:23 14:23:28 14:23:33 14:23:37 14:23:40 14:23:47 14:23:51 14:23:55 14:24:03 14:24:07 14:24:11 14:24:15

So to answer your question, I don't see that the invention is limited to any use case; but 14:24:16 14:24:18

the other publications suggest that Swanson was aware of both concentrator and nonconcentrator use cases. 14:24:23 14:24:26 14:24:29

Q Could the structure of Swanson's solar cell be used in a concentrator solar cell? 14:24:31 14:24:36

A Yes, it could be. It would -- the solar cell would produce power under -- under concentration. 14:24:44 14:24:48 14:24:50

Q The solar cell in the '053 patent is not a concentrator solar cell. Right? 14:24:55 14:24:58

A The '053 patent is silent, similar to Swanson, on the use of the solar cell. It's not limited to a concentration or nonconcentration scenario. 14:25:10 14:25:15 14:25:21 14:25:29

Q Could the structure of the '053 patent be used in a concentrator solar cell? 14:25:29 14:25:33

MR. SELWYN: Objection. Form. 14:25:38

A Yes, the solar cell in the '053 patent would similarly produce power under concentration. 14:25:50 14:25:55

Q Let's go to Paragraph 115 of the '053 declaration. 14:26:01 14:26:05

A Okay. 14:26:18

Q First I would like you to look at the figure on the next page. Would you say the structure is a silicon solar cell? 14:26:18 14:26:20 14:26:22

A Yes, Smith teaches a silicon solar cell. 14:26:27

Q Is it a homojunction solar cell? 14:26:30

A Yes, it is a homojunction solar cell. The emitter and the wafer are made out of the same material, they are one in the same wafer. 14:26:45 14:26:48 14:26:54

Q Does Smith teach a concentrator solar cell? 14:26:57 14:27:03

A Smith, similar to Swanson, does not describe any limitations of his invention to particular use cases, and in particular to concentrator or nonconcentrator applications. But similar to Swanson, in the Other Publications section on the first page, there is reference to concentrator and what appears to be nonconcentrator solar cells in -- in those other publication titles, suggesting that Smith was at least aware that solar cells can be used in multiple use cases, including concentration and nonconcentration. 14:27:15 14:27:23 14:27:28 14:27:32 14:27:35 14:27:39 14:27:43 14:27:47 14:27:51 14:27:56 14:28:00 14:28:04

Q In Paragraph 115 you say that "Smith talks about a first in situ step where the wafer is heated to 1000 degrees C to diffuse two types of dopants." 14:28:05 14:28:13 14:28:17 14:28:21

Do you see that? 14:28:22

A Yes, I do. 14:28:28

Q And in the next paragraph you say that Smith talks about a second in situ step where the furnace conditions are changed to about 750 degrees C, then to 975 degrees C. 14:28:28 14:28:32 14:28:35 14:28:38

Do you see that? 14:28:42

A Yes, I do. 14:28:44

Q Can you help me understand what the 750 degrees C is for? 14:28:44 14:28:49

A Yes. Give me just one moment. 14:28:57

So it was common and well known at the time that in the phosphorus diffusion could be done, and with two steps. And I describe this in Paragraph 54 of my background section of my declaration. 14:29:26 14:29:31 14:29:38 14:29:42 14:29:46

And in particular I talk about vaporizing what we call POCl, P-O-C-L, 3, phosphorus 14:29:48 14:29:50

oxychloride, in a furnace. And that a vaporized liquid reacts with a surface of the wafer to form a glass that has phosphorus atoms in it. And then those phosphorus atoms are commonly diffused into the wafer. 14:29:56 14:30:02 14:30:06 14:30:14 14:30:18

And those two steps, forming the glass and diffusing or driving in the dopants, were commonly separated. And that is I believe what Smith is describing in this two-step process. 14:30:18 14:30:21 14:30:24 14:30:28

So I believe the 750-degree step is directed at forming the phosphorus-containing glass. And then the second step in this case at 975 degrees is directed at driving phosphorus dopants -- dopant atoms into the front side of the silicon wafer. 14:30:32 14:30:35 14:30:40 14:30:44 14:30:49 14:30:52

Q And the 1000 degrees would be to vaporize the liquid? 14:30:53 14:30:59

A No. The 1000-degree step, which is the first step in Smith's two-step in situ process, is for driving dopants in glass regions on the back side of the solar cell into the solar cell. And subsequently Smith treats the front side of the 14:31:02 14:31:05 14:31:13 14:31:19 14:31:38

solar cell with this two-step process. 14:31:41

Maybe if I can summarize again. Smith's 14:31:44

wafer goes into the furnace already having 14:31:46

patterned boron-containing and 14:31:50

phosphorus-containing glass layers on its back 14:31:53

side. The first step diffuses those dopants into 14:31:56

the back side. Then while the wafer is in the 14:31:58

same piece of equipment, Smith teaches that's what 14:32:05

he means by in situ. A glass layer is formed on 14:32:08

the front side containing phosphorus, and the 14:32:13

phosphorus is diffused. And those two things are 14:32:18

Smith's disclosed second step. 14:32:23

Q Does the second in situ step affect the 14:32:27

dopants in the back surface in any way? 14:32:31

A Smith does not teach that there is or is 14:33:24

not any affect of the second step on the results 14:33:26

of the first step. This is in the bottom of 14:33:35

Column 3 and the top of Column 4, that Smith 14:33:40

describes the second step. 14:33:44

Smith describes that this in situ process 14:33:49

of using two steps in the same wafer loading 14:33:54

simplifies the fabrication process, and that that 14:33:58

would be appreciated by a POSITA. 14:34:01

Smith doesn't say whether there is either 14:34:06
beneficial or -- or negative consequences on the 14:34:07
second step to the -- to the first step. But 14:34:13
given that Smith is directed at simplifying 14:34:17
fabrication sequences, my reading is that Smith 14:34:21
didn't find, for example, that the second step was 14:34:30
destructive. 14:34:35

Q But would a POSITA understand the second 14:34:42
in situ step to affect the dopants in the back 14:34:46
surface in any way? 14:34:50

A I believe a POSITA would understand what 14:34:53
Smith teaches, which is that one wafer loading is 14:34:55
a simplified process sequence and provides 14:35:07
advantages in the manufacturing of solar cells. 14:35:09
And Smith doesn't disclose that there are adverse 14:35:12
consequences or, in fact, even beneficial 14:35:17
consequences, which there could be, with the 14:35:20
second step interacting with the results of the 14:35:24
first step. 14:35:26

So I don't believe that a POSITA would 14:35:28
expect from Smith that there were such effects. 14:35:32

Smith doesn't teach it. 14:35:37

Q Could 700 degrees -- would heating to 700 degrees C affect dopant in the back surface in any way, in general? 14:35:41 14:35:46 14:35:53

MR. SELWYN: Objection. Form. 14:35:56

A This relates to our conversation earlier about temperatures. And you'll recall that the other things that I brought up at the time that determined diffusion are time. It's very important. And also what the dopant atoms are and what the host material is. 14:35:58 14:36:02 14:36:05 14:36:09 14:36:11 14:36:16

So Smith doesn't teach a time that I see. I believe because Smith says in the beginning that persons of ordinary skill in the art would recognize, however, that the invention can be practiced without one or more of the specific details in other instances, while no details are not shown or described to avoid obscuring aspects of the invention. 14:36:19 14:36:23 14:36:31 14:36:34 14:36:36 14:36:39 14:36:43 14:36:46

So I believe Smith appreciated that a POSITA would be able to make design choices, such that the second steps that he -- the second step 14:36:47 14:36:49 14:36:56

that he described wouldn't, for example, have negative consequences on the results of the first step. 14:36:59 14:37:02 14:37:04

Q How long would a POSITA apply heating of 750 degrees for in this situation? 14:37:06 14:37:16

A It doesn't teach that. A POSITA would look to the other art if the POSITA had not himself or herself performed similar diffusions, and would learn from that art what an appropriate time might be. 14:37:22 14:37:28 14:37:33 14:37:37 14:37:40

Q Have you performed similar diffusions before? 14:37:44 14:37:47

A I, personally, have not performed such diffusions. My students, however, have. 14:37:48 14:37:51

Q But do you have an idea of how much time you would be applying this heat of 700 degrees -- 750 degrees C for? 14:37:56 14:37:58 14:38:03

A Yes, I do. It would depend on the details that I described previously. But I could disclose, for example, that when my students have done diffusions of phosphorus into the surface of silicon wafers, such as silicon wafers, a first 14:38:09 14:38:15 14:38:17 14:38:20 14:38:25

step may be on the order of minutes. It's not as short as seconds, and it's not as long as hours. 14:38:30 14:38:34

Q Apply heat of 750 degrees C for minutes, would that have any effect on a dopant on the back surface? 14:38:36 14:38:46 14:38:52

A I believe I've already answered this question. That -- that Smith doesn't describe -- doesn't disclose any consequences positive or negative. And that Smith doesn't describe details of the time, for example, used for this, this stuff. 14:38:52 14:38:54 14:39:04 14:39:08 14:39:16 14:39:26

And Smith describes that this multistep process is -- provides a method for the simplification of the manufacturing of solar cells. 14:39:27 14:39:29 14:39:34 14:39:41

Smith also talks -- forgive me, I'm looking for a particular place within Smith. Yes. To come back to your question, Smith doesn't teach that there are -- there are consequences of the 750 degree C step on the dopants on the rear side of the solar cell. 14:39:42 14:40:58 14:41:14 14:41:18 14:41:23 14:41:29

Q Even though Smith doesn't teach the 14:41:32

consequences, would a POSITA know what the consequences might be? 14:41:35 14:41:39

A A POSITA -- a POSITA would know. A POSITA would -- would expect that 750 degrees C, being lower than the 1000 degrees C used in the previous step, provided that the time was not very long, provided that the dopants being diffused in the previous step, yes, they are phosphorus and boron, that the diffusion at 750 degrees C of dopants at the rear side of the solar cell would be substantially slower than they were at 1000 degrees C when they were moved in. And so the POSITA would not expect that they would -- that they would move appreciably. 14:41:45 14:41:48 14:41:57 14:42:03 14:42:12 14:42:17 14:42:23 14:42:29 14:42:32 14:42:37 14:42:40 14:42:45

Q They being the dopants, right? When you say -- 14:42:49 14:42:53

A That's correct. 14:42:54

Q -- they would not move, you meant the dopants would not move. Right? 14:42:54 14:42:57

A Yes. Once again, subject to information about how long the diffusion occurs. 14:43:01 14:43:08

Q I'd like to ask you the same questions 14:43:18

with respect to the 975 degrees C. 14:43:20

So first of all, would a POSITA know how 14:43:24

long to apply heat of 975 degrees for? 14:43:27

A Smith believes so. And Smith leaves out 14:43:35

details and includes a sentence indicating that 14:43:38

details are left out in cases in which -- in which 14:43:43

case -- in cases in which the step or process is 14:44:00

likely well known. 14:44:17

(Clarification by the court reporter.) 14:44:17

Q So in your opinion, how long would the 14:44:21

POSITA apply heat of 975 degrees C for? 14:44:22

A As I describe in my background section, 14:44:44

diffusion of phosphorus dopants into a wafer 14:44:49

surface to form an emitter is a common process 14:44:54

that used two steps -- commonly used two steps. 14:44:57

And that there was considerable literature and 14:45:05

teaching in the literature dating back decades on 14:45:08

how to do such diffusions. 14:45:12

And as I described previously, that the 14:45:16

length of time for a diffusion needs to be 14:45:19

considered also with temperature. Here Smith is 14:45:25

teaching the temperature of 975 degrees C for this 14:45:33

diffusion on the front side of -- of the wafer. 14:45:39
And literature for diffusions at the time again 14:45:46
were on the order of they could be as short as 14:45:50
minutes, they could be as long as hours. And what 14:45:55
a person doing the diffusion would choose depends 14:46:02
on the particular goals, as we described 14:46:08
previously, of whether they wanted a shallow 14:46:11
diffusion or a deep diffusion, for instance. 14:46:14
Q To achieve the structure disclosed in 14:46:17
Smith, would the heating be more on the minutes 14:46:27
side or the hour side? 14:46:29
A We can't know that, as Smith does not 14:46:33
disclose, to my recollection, a target depth of 14:46:40
the -- of Smith's front surface diffusion. And 14:46:52
Smith likely doesn't disclose such a depth 14:47:00
because, as I mentioned previously, diffusions 14:47:04
into the surface of wafers were very common as of 14:47:08
the time of Smith's writing. 14:47:14
Q I just want to make sure I understood 14:47:27
what you just said. 14:47:29
So would a POSITA have an idea of how 14:47:31
deep he would want the dopant of Smith to go in a 14:47:35

diffusion process? 14:47:41

A Yes. A POSITA would know how to do 14:47:44

diffusions. A POSITA would understand that Smith 14:47:48

is describing a diffusion to dope the front 14:47:52

surface of the wafer. A POSITA would have access 14:47:56

to many, many -- yeah, a POSITA would understand 14:48:00

also the design choices associated with the 14:48:12

diffusion. Because as I described previously, a 14:48:15

POSITA would understand time and temperature 14:48:18

matter, and also the dopant atoms that are 14:48:22

diffusing, and also what they're diffusing through 14:48:26

and/or into. 14:48:29

So a POSITA would have an understanding 14:48:31

of these things because they have been common in 14:48:35

the field for decades, and in the semiconductor 14:48:37

field for decades still before that. 14:48:43

Q But based on all that knowledge, do you 14:48:45

have an educated guess on how long the POSITA 14:48:52

would apply heating of 975 degrees C? 14:48:55

MR. SELWYN: Objection. Form. 14:48:59

A A POSITA would apply heating for an 14:49:02

appropriate time given the conditions that I just 14:49:08

described, depending on the particular values for each of those things. 14:49:12 14:49:18

Q So you don't have an opinion of how long a POSITA would apply heating for in this situation. Right? 14:49:24 14:49:27 14:49:30

MR. SELWYN: Objection. Form. 14:49:31

A I think a POSITA would know how to apply heating to a time that was appropriate to the POSITA's structure, piece of equipment, dopant atoms, material into which they're doping, introducing the dopant atoms, et cetera. 14:49:33 14:49:38 14:49:41 14:49:48 14:49:52

Q But sitting here today, you could not tell me what that time would be. Right? The time for how long a POSITA would apply heating of 975 degrees C. Right? 14:49:56 14:49:58 14:50:02 14:50:06

MR. SELWYN: Objection. Form. 14:50:07

A No, I can't tell you that you should use 14-and-a-half minutes or 80 minutes without having the information that a POSITA would have with making ordinary design choices. 14:50:10 14:50:14 14:50:18 14:50:22

Q Would a POSITA know the consequences of applying heating of 975 degrees C for minutes, 14:50:30 14:50:32

what the consequences of that would be on the dopants on the back surface? 14:50:40 14:50:42

MR. SELWYN: Objection. Form. 14:50:45

A I think that maybe you'd like to ask the question another way. What the consequences are, that could be quite open ended. And you mentioned minutes. And 1 minute and 800 minutes are both minutes. So perhaps you could provide me a little more guidance. 14:51:04 14:51:08 14:51:11 14:51:15 14:51:19 14:51:21

Q Let's say under ten minutes would be the time a POSITA applied heating of 975 degrees C to the structure of Smith. 14:51:22 14:51:25 14:51:32

Would a POSITA know what the consequences would be of that heating to the dopants on the back surface? 14:51:34 14:51:38 14:51:42

A What a POSITA would know is -- first of all, a POSITA has access to Smith's teachings, which are silent upon any beneficial or -- or drawbacks associated with it. But are silent likely because Smith describes at the first paragraph of -- first in the detailed description that a POSITA would know. 14:51:48 14:51:51 14:51:55 14:52:01 14:52:05 14:52:08 14:52:11

A POSITA would understand Fick's law, which I've described previously, which says that dopants would -- dopants move from places of high concentration to low concentration, and that their movement is determined by the time and temperature. 14:52:14 14:52:17 14:52:20 14:52:24 14:52:31 14:52:32

And so if a POSITA had particular concerns about dopants that were already in the structure moving, then a POSITA would know to modulate, for example, the time or the temperature in order to achieve the desired result as taught by Smith. 14:52:34 14:52:39 14:52:45 14:52:47 14:52:51 14:52:55

Q Earlier we talked about heating of 750 degrees for minutes. And you opined that a POSITA would know that in that situation the dopants would not move. 14:52:58 14:53:02 14:53:10 14:53:12

Do you remember that? 14:53:14

A Yes. I don't think those were my exact words. But I conveyed that a POSITA would understand Fick's law that time and temperature determine diffusion of dopants; and that if dopants were diffused into the substrate at 1000 14:53:17 14:53:19 14:53:22 14:53:27 14:53:31

degrees C, their movement would be much slower at 750 degrees C. 14:53:34 14:53:37

Q Would that answer change if we changed 700 degrees -- 750 degrees to 975 degrees C? 14:53:39 14:53:44

A It would change just as Fick's law teaches. So at 975 degrees C the dopants will move faster than at 750 degrees C, and they will move slower than at 1000 degrees C. 14:53:49 14:53:52 14:53:56 14:54:01

Q So in a situation of 750 degrees C, where you testified that the dopants -- a POSITA would not expect that the dopants would move, in the situation of 975 degrees C would a POSITA expect the dopants to move? 14:54:06 14:54:12 14:54:15 14:54:20 14:54:24

MR. SELWYN: Objection. Form. 14:54:26

A A POSITA would understand Fick's law, which says that if you wait long enough the dopants would move. "Wait long enough" being -- you know, could be -- if you wait days to lifetimes, everything diffuses. That's what Fick's law says. 14:54:30 14:54:33 14:54:37 14:54:42 14:54:45 14:54:48

But a POSITA would understand that Fick's law says that less movement will happen in less 14:54:50 14:54:52

time. And so therefore, a POSITA can take Smith's teachings and apply their existing knowledge and their ordinary ingenuity in order to achieve an outcome where, for example, Smith's structure is fabricated in the way that Smith envisions. 14:54:58 14:55:03 14:55:12 14:55:17 14:55:29

Q Well, at 975 degrees C, how long would you need to apply the heating for in order for the dopants to start moving? 14:55:31 14:55:40 14:55:46

A Maybe you can be more specific about "start moving." 14:55:54 14:55:57

Fick's law says that movement can occur at any temperature, but the amount of movement will depend on the temperature and the time. 14:55:58 14:56:06 14:56:09

And so when I say it can occur at any movement, I mean that in minutes at lower temperatures there might be 0.001, that is to say, an immeasurable amount of movement. And at higher temperatures for the same amount of time they could move nanometers. And at higher temperatures still in the same amount of time they could move microns. 14:56:12 14:56:14 14:56:22 14:56:26 14:56:29 14:56:31 14:56:34 14:56:37

So a POSITA would understand Fick's law, 14:56:38

the physics that, for example, I teach my students in class, that says that time, temperature, and concentration gradients determine diffusion, and that the diffusion coefficient, how fast things move, depends on what those dopant atoms are and what they're moving in. 14:56:43 14:56:47 14:56:54 14:56:57 14:57:01 14:57:06

So when you say "starts to move," this isn't -- I'm unable to provide a clear answer without talking -- without more specifics. 14:57:09 14:57:12 14:57:19

Q Let's say in this exact situation we have in Smith, where we have a first step in situ heating to 1000 degrees C, and then a second step in situ where the furnace conditions are changed to 750 degrees C, and then to 975 degrees C, how long would you need to apply the heating of 750 degrees C in order for the dopants on the back surface to become more diffused? 14:57:24 14:57:27 14:57:32 14:57:39 14:57:42 14:57:52 14:57:58 14:58:05

MR. SELWYN: Objection to form. 14:58:10

A Can you please define "more diffused" for me. 14:58:12 14:58:15

Q For the dopants to go deeper into the substrate. 14:58:17 14:58:27

A Can you please define "deeper" for me. 14:58:29

Q Do you -- what is your understanding of the word "deeper"? 14:58:31 14:58:36

MR. SELWYN: Objection. Form. 14:58:39

A Deeper in the context of a diffusion means further into, for example, the wafer or layer. 14:58:43 14:58:47 14:58:50

Q Okay. So based on that understanding, how long would you need to apply heating for of 750 degrees for the dopant to be diffused deeper? 14:58:52 14:58:56 14:58:59

MR. SELWYN: Objection. Form. 14:59:07

A I'm still unable to answer the question because you asked for a number, a time, but without specifying what "deeper" or what "further" means. 14:59:08 14:59:10 14:59:14 14:59:18

I understand what the word "deeper" means, but I can't understand -- I can't answer a quantitative question with qualitative boundary conditions. 14:59:18 14:59:20 14:59:22 14:59:25

Q Is there an amount of time where I can apply heating of 750 degrees but the dopants do not become -- but the dopant particles do not move 14:59:26 14:59:39 14:59:48

in the substrate at all? 14:59:54

MR. SELWYN: Objection. 14:59:56

Q Is that possible? 14:59:56

MR. SELWYN: Objection. Form. 14:59:57

A At room temperature atoms vibrate even -- 15:00:04

and certainly at higher temperatures. And we 15:00:11

would say that they move. They go like this, for 15:00:13

instance. 15:00:16

So I don't think that's what you mean 15:00:17

with your question, though. 15:00:21

Q What do we -- what do we mean when we 15:00:33

talk about diffusion of dopants? Can you remind 15:00:36

me? 15:00:40

MR. SELWYN: Objection. Form. 15:00:40

A Yes. We mean the movement of dopants 15:00:41

from a source of high concentration, for example a 15:00:45

dopant source as taught by Smith or Gan or others, 15:00:49

to a location of lower concentration, for example 15:00:55

a wafer surface or a layer such as polysilicon 15:01:01

deposited on the wafer. 15:01:07

Q When I apply heating of 750 degrees for 15:01:08

any amount of time, would that cause movement of 15:01:15

dopants from a source of high concentration to a location of lower concentration? 15:01:19 15:01:22

A So when you say "movement of dopants," do you have a distance in mind? 15:01:34 15:01:39

Q Did you have a distance in mind when you earlier said movement of dopants from a source of high concentration to a location of lower concentration? 15:01:45 15:01:47 15:01:49 15:01:52

A Yes. I teach in my background section that for emitters, for example, the -- one -- there is a depth of an emitter. It's a characteristic depth that describes how deep dopant atoms might go. If you give me one moment. 15:01:56 15:02:00 15:02:07 15:02:11 15:02:17

For example, in Paragraph 58 when I'm talking about PN junctions, I say, "Diffused regions are thin relative to the wafer's thickness, commonly extending 0.3 to 3 microns into the wafer's surface." 15:02:35 15:02:37 15:02:43 15:02:44 15:02:48

Q So if I were to apply heating of 750 degrees C in order for the dopant to travel 0.3 microns into the wafer, how long would I need to apply that heating for? 15:03:00 15:03:03 15:03:10 15:03:14

MR. SELWYN: Objection. Form. 15:03:17

Q In a situation of Smith specifically. 15:03:18

A Okay. Good. Now we have a question that is answerable, but I don't have the information in front of me to answer it. In particular, I would need the diffusion coefficients of the dopants. 15:03:22 15:03:25 15:03:28 15:03:31

But at 750 degrees C, I wouldn't expect boron or phosphorus, and a POSITA wouldn't expect boron or phosphorus, to diffuse I believe you said 0.3 microns -- 15:03:34 15:03:41 15:03:44 15:03:53

Q Yes. 15:03:54

A -- in minutes. 15:04:00

I think that that process would take hours or longer. 15:04:04 15:04:06

Q What about at 975 degrees C? 15:04:08

MR. SELWYN: Objection to form. 15:04:14

A The dopants will diffuse faster, as we discussed. And I again don't have the necessary information to calculate how long it would take them to diffuse 0.3 microns. But I would expect that it would be -- I would expect that it would be less than several hours. I don't know exactly 15:04:17 15:04:23 15:04:30 15:04:33 15:04:48 15:05:07

how quickly it will happen, but I don't think it's going to take a day, for example, for dopants to diffuse that far, for phosphorus or boron to diffuse that far at 975 degrees C in silicon. 15:05:11 15:05:16 15:05:20 15:05:24

Q Roughly speaking, we're talking about a matter of hours and not minutes. 15:05:29 15:05:33

Is that correct? 15:05:35

A I'm sorry, I meant to give an upper limit. So I mean that it would -- I would expect that it would be shorter than several hours at those -- that temperature. 15:05:37 15:05:42 15:05:44 15:05:50

Q Would it be shorter than one hour? 15:05:51

A It could be. I don't have the necessary information to perform a calculation, but it could be. 15:05:55 15:05:58 15:06:05

MR. SELWYN: Jing, when you get to a good stopping point, maybe we could -- 15:06:05 15:06:06

MS. ZHAO: I was just about to say that. 15:06:08

MR. SELWYN: Go ahead. 15:06:10

MS. ZHAO: Let's -- we can go off the record. 15:06:11 15:06:17

(A recess was taken.) 15:06:19

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Maxeon Exhibit 2029

BY MS. ZHAO: 15:35:29

Q Let's go to Paragraph 122 of the '053 declaration. 15:35:29 15:35:34

A 122, is that correct? 15:35:46

Q Yes, 122, Page 77. 15:35:47

A I'm there. 15:35:54

Q About seven lines into the paragraph you talk about "The combination of Froitzheim's back junction solar cell and Gan's polysilicon emitter" -- I'm going to skip the part in the middle here -- "would have simply involved implementing Gan's outside layer and polysilicon emitter on the back of Froitzheim's N-type silicon layer." 15:35:54 15:35:57 15:36:01 15:36:05 15:36:08 15:36:10 15:36:15 15:36:16

Do you see that? 15:36:16

A Yes. 15:36:17

Q I refer to this combination that you propose here as the Froitzheim-Gan combination. 15:36:17 15:36:22

Is that okay? 15:36:26

A Yes. 15:36:27

Q I'd like to walk through Froitzheim and Gan with you to figure out how a POSITA would 15:36:27 15:36:33

construct this Froitzheim-Gan combination. So let's first go to Exhibit 1004, Froitzheim. And if I can have you turn to Paragraph 38. 15:36:36 15:36:40 15:36:49

A Okay. 15:37:02

Q So here Froitzheim tells us that it will now discuss the method of manufacturing solar cell. 15:37:02 15:37:05 15:37:08

Do you see that? 15:37:08

A Yes. 15:37:12

Q And Paragraphs 39 to 50 discuss the manufacturing steps of Froitzheim's solar cell. 15:37:13 15:37:16

Right? 15:37:21

A Yes. 15:37:29

Q Let's walk through these steps. Starting on Paragraph 39. It talks about a silicon body layer of N-type bulk doping. Right? 15:37:29 15:37:34 15:37:38

A Right. And Froitzheim says that's typically a wafer. So it's a wafer, correct. 15:37:44 15:37:46

Q Would the Froitzheim-Gan combination use that silicon body layer or wafer? 15:37:48 15:37:53

A So in making a combination, a POSITA, as I understand it, making -- in determining whether 15:38:01 15:38:04

a combination would be obvious, a POSITA is not restricted to taking particular instances, recipes, and combining them in a wrote manner, but rather taking the teachings and applying their ordinary ingenuity. 15:38:10 15:38:15 15:38:20 15:38:23 15:38:26

So as we walk through the process that I think may be coming, I'd like to keep that in mind. 15:38:28 15:38:30 15:38:33

Froitzheim teaches a wafer. We've described that. Gan also teaches a wafer. 15:38:35 15:38:36

Q Paragraphs 40 and 41 talk about P-type doping on the rear surface of the body layer or wafer. Correct? 15:38:44 15:38:47 15:38:50

A And Paragraph 42 as well. Forty, 41, and 42. 15:39:03 15:39:06

Q Yeah. Let me ask about 40 and 41 first. 15:39:07

Would the Froitzheim-Gan combination use the processes described in Paragraphs 40 and 41? 15:39:11 15:39:14

A Paragraphs 40 through 42 describe a doping step in which a dopant source layer is added to a surface. In Froitzheim's case it's a wafer. And then that dopant source layer -- the 15:39:22 15:39:27 15:39:37 15:39:40

substrate with the dopant source layer is heated to diffuse dopants in. 15:39:45 15:39:48

And as I describe in my declaration, for example around Paragraph 135 of my declaration, Gan teaches an oxide layer and polysilicon layer. The polysilicon layer is an emitter in Gan. It can be P-type emitters are doped. They have the opposite doping polarity of the wafer. And so a POSITA could take the teachings of Gan and implement them in place of Froitzheim's diffused emitter described in Paragraphs 40 through 42 of Froitzheim. 15:39:50 15:40:24 15:40:26 15:40:33 15:40:36 15:40:41 15:40:44 15:40:49 15:40:57 15:41:01

Q Let's look at Paragraph 42 real quick anyway. 15:41:15 15:41:18

It talks about a temperature range of 900 to 1200 degree centigrade. Right? 15:41:22 15:41:24

A That is correct. 15:41:27

Q And then a preferred temperature range of 1000 to 1100 degree centigrade. Right? 15:41:28 15:41:31

A Correct. 15:41:37

Q Why does Froitzheim have a preferred temperature range that is slightly different from 15:41:38 15:41:42

the temperature range of 900 to 1200? 15:41:46

A I am not one of the inventors. I can't comment on exactly what they were thinking. But it's not uncommon, in my experience in patents, to have wider ranges, and in some cases to provide narrow ranges -- narrower ranges within those wider ranges. 15:41:52 15:41:55 15:41:58 15:42:05 15:42:08 15:42:11

Q But what is the purpose of providing a narrower range, in your experience? 15:42:12 15:42:17

A I can take Froitzheim's words here. Froitzheim says that the wafer is treated in an atmosphere that contains oxygen at a temperature of 900 to 1200 degrees centigrade, preferably between 1000 and 1100 degrees centigrade, to generate an oxide layer and to drive in the dopant. 15:42:21 15:42:29 15:42:33 15:42:35 15:42:39 15:42:43 15:42:46

So I believe in this sentence Froitzheim is providing ranges that Froitzheim believes are suitable to achieve Froitzheim's purpose of this step, which was to generate an oxide layer containing boron dopant atoms and to diffuse those atoms, in Froitzheim's case, into the wafer 15:42:47 15:42:49 15:42:52 15:42:56 15:43:01 15:43:06

surface. 15:43:09

Q Would it be -- excuse me. Would it be 15:43:10

accurate to say that the range of 1000 to 1100 15:43:16

degrees centigrade is more suitable for 15:43:23

Froitzheim's purposes than the range of 900 to 15:43:27

1200? 15:43:32

MR. SELWYN: Objection. Form. 15:43:32

A The words that Froitzheim used is -- uses 15:43:34

is preferably between 1000 and 100 -- 1100 degrees 15:43:37

centigrade, although Froitzheim before that gives 15:43:44

the range of 900 to 1200 degrees. 15:43:46

Q I'm just trying to understand what 15:43:51

"preferred temperature range" means here to a 15:43:56

POSITA. 15:43:58

A I understand "preferably" with its plain 15:44:01

and ordinary meaning. And I can't assign more 15:44:04

meaning to it than that without being one of the 15:44:07

inventors on the patent, which I'm not. 15:44:14

Q In Paragraph 42 it also talks about 15:44:17

treating the wafer in oxygen. Right? 15:44:21

A It does. That's correct. 15:44:25

Q And treating the wafer in oxygen 15:44:28

generates an oxide layer. Right? 15:44:30

A Yes, it's commonly used in the phosphorus 15:44:34

doping process that I described in my background 15:44:41

section. 15:44:52

Q Would the Froitzheim-Gan combination 15:44:52

include this oxide layer from Froitzheim? 15:44:55

A A POSITA doesn't need to take 15:45:01

Froitzheim's oxide layer. A POSITA is able to 15:45:04

take the teachings of Gan and Froitzheim 15:45:08

generally, and both of them teach a standard 15:45:11

diffusion process of phosphorus. 15:45:15

In Gan's case he teaches it, the 15:45:19

diffusion process, into -- excuse me, standard 15:45:21

diffusion process of boron. I misspoke 15:45:25

previously. 15:45:28

In Gan's case he teaches this boron 15:45:36

diffusion into a polysilicon emitter. The 15:45:39

polysilicon emitter that I have incorporated in, 15:45:42

combined with Froitzheim. And in Froitzheim's 15:45:45

case he teaches boron diffusion process into -- 15:45:48

into a wafer. 15:45:52

Gan's process provides a temperature 15:45:54

range of 900 to 1000 degrees C, which is within Froitzheim's temperature range. There's no incompatibility of those range -- ranges. Gan's process for doping the polysilicon emitter would work with Froitzheim. Froitzheim also teaches how to dope a layer. 15:45:58 15:46:02 15:46:05 15:46:11 15:46:18 15:46:21

Q Does boron diffusion always result in an oxide layer being formed? 15:46:25 15:46:40

MR. SELWYN: Can you say that again? I just couldn't hear you. 15:46:43 15:46:44

Q Sorry. Does boron diffusion always result in an oxide layer being formed? 15:46:45 15:46:48

A "Always" is a -- is a strong word. I wouldn't want to agree with that. 15:46:59 15:47:03

But as I describe in my background section, in order to diffuse boron, one requires a source of boron. And a common way to diffuse boron was from a borosilicate glass, or BSG. And that is a mixture of boron, silicon, and oxygen. The silicon and oxygen is what gives the name glass. 15:47:05 15:47:13 15:47:16 15:47:20 15:47:27 15:47:31 15:47:34

Q I'm going to Paragraph 43 of Froitzheim. 15:47:40

It talks about steps for providing the front side N plus layer. Right? 15:47:46 15:47:50

A Yes, it does. 15:47:53

Q Would the Froitzheim-Gan combination use the process described in Paragraph 43? 15:47:54 15:47:59

A Froitzheim teaches how to form the N plus layer at the -- at the front side. That's teachings that come from -- from Froitzheim, yes. 15:48:06 15:48:11 15:48:14

Q I'm sorry, I'm not sure you understood my question, so let me just make sure. 15:48:20 15:48:25

My question was, would the Froitzheim-Gan combination use the process described in Paragraph 43? 15:48:27 15:48:30 15:48:33

A Okay. And my answer is that Froitzheim teaches how to form an N plus layer, and that Froitzheim's teachings can be used in the Froitzheim-Gan combination to form that N plus layer. 15:48:40 15:48:45 15:48:54 15:48:57 15:49:01

Q This paragraph incorporates by reference two U.S. patents. 15:49:03 15:49:15

Do you see that? 15:49:16

A I do. 15:49:19

Q I believe earlier I asked you this, but let me just make sure. Have you reviewed those two patents? 15:49:19 15:49:22 15:49:24

A Yes. And my answer is the same as before, I may have, but I don't recognize them by their number alone. So I don't remember at this time. 15:49:26 15:49:29 15:49:32 15:49:35

Q Do you have a general understanding of how Froitzheim would form its front side N plus layer? 15:49:35 15:49:38 15:49:42

A I have an understanding, yes, of how Froitzheim would form an N plus layer. And I described the formation of N plus layers when I described phosphorus diffusion in my background section, in particular Paragraphs 53 and 54 of my background section. 15:49:46 15:49:48 15:49:54 15:50:01 15:50:06 15:50:10

Q Can you just generally walk me through your understanding of how Froitzheim would form its front side N plus layer? 15:50:10 15:50:19 15:50:20

A Phosphorus diffusions were well known in the art at this -- at the time. And I describe that in 54 -- Paragraph 54 of my disclosure. So I 15:50:26 15:50:29 15:50:35

can walk you through that. 15:50:39

A common method was to vaporize 15:50:43

phosphorus oxychloride in a furnace. And that 15:50:47

phosphorus oxychloride essentially with the 15:50:53

addition of -- that phosphorus oxychloride reacts 15:50:55

with the silicon wafer or polysilicon layer 15:50:59

surface, forming a glass, typically called BSG for 15:51:05

short, and then heating in a second step -- and we 15:51:14

discussed this when we were referring to Smith -- 15:51:18

can -- or will diffuse phosphorus atoms from that 15:51:23

glass into the adjacent layer or wafer surface. 15:51:27

And this was a common method for forming 15:51:33

N plus layers. 15:51:37

Q Do you have an idea of what kind of 15:51:39

heating would be applied for Froitzheim's 15:51:43

formation of the front side N plus layer? 15:51:48

A A POSITA would choose an appropriate time 15:51:55

and temperature combination per our previous 15:51:58

discussions to form that layer to the depth and 15:52:03

surface doping concentration targeted. 15:52:09

Q Do you have an idea of what that 15:52:16

appropriate time might be? 15:52:18

MR. SELWYN: Objection. Form. 15:52:20

A There are many instances in the literature, dating back decades, on how to perform phosphorus diffusions. Times commonly found would be in the tens of minutes or hours time frame. But a POSITA would not be constrained to that range per se in implementing the teachings of Froitzheim, as there is a lot known about how to make phosphorus diffusions. 15:52:26 15:52:28 15:52:33 15:52:39 15:52:42 15:52:46 15:52:52 15:52:56

Q Do you have an idea of what the appropriate temperature might be? 15:53:01 15:53:02

MR. SELWYN: Objection. Form. 15:53:04

A Similar to my answer before, it was well known how to make phosphorus diffusions, and that there were design choices, including time and temperature combinations. And a POSITA would be able to make appropriate choices to achieve the surface concentration and depth of the diffusion that he or she wanted. And one can find values in the -- in the literature for phosphorous diffusions that are I think ranging anywhere from 800 to 1200 degrees C. There's a wide range of 15:53:07 15:53:10 15:53:13 15:53:17 15:53:22 15:53:25 15:53:30 15:53:38 15:53:42 15:53:47

temperatures. And a POSITA may use temperatures even outside of those, depending on precisely the diffusion he or she was trying to achieve. 15:53:55 15:53:57 15:54:01

Q Sitting here today, you would not be able to give me a specific temperature and time combination. 15:54:03 15:54:08 15:54:13

Is that right? 15:54:13

MR. SELWYN: Objection to form. 15:54:15

A I would need more information about the rest of the solar cell in order to specify a specific time and temperature. But a large variety of times and temperatures would likely work. And a POSITA, in making the solar cell, would be able to select that time and temperature profile to achieve Froitzheim's solar cell with Gan's polysilicon oxide emitter. 15:54:16 15:54:20 15:54:25 15:54:28 15:54:31 15:54:34 15:54:38 15:54:45

What we're talking about here, things like phosphorous diffusion, date back to the 1950s. 15:54:49 15:54:52 15:54:56

Q I don't believe your declaration provides a specific time and temperature combination either. 15:54:56 15:55:04 15:55:09

Is that correct? 15:55:09

MR. SELWYN: Objection to form. 15:55:11

A Time and temperature combination for? 15:55:13

Q For how to make Froitzheim's -- I'm sorry, for how to make the front side N plus layer in the Froitzheim-Gan combination. 15:55:15 15:55:22 15:55:25

A Yes, Paragraph 165 of my declaration I talk about Froitzheim's teaching here, and that Froitzheim teaches diffusing phosphorous from the gas phase, which I described previously, to form a front side N plus layer. 15:55:29 15:55:33 15:55:36 15:55:39 15:55:43

And that there -- this was a common process known in the art. I give many references to others. I don't specify a single time and temperature profile in my declaration. 15:55:45 15:55:50 15:55:52 15:56:00

Q I just want to make sure I understand you. 15:56:02 15:56:24

Is it your position that the references you provide in Paragraph 165 of your declaration, those references provide specific time and temperature combinations for how to make front side N plus layer of the Froitzheim-Gan 15:56:25 15:56:27 15:56:34 15:56:39 15:56:43

combination? 15:56:47

A No, that's not my position. My position 15:56:51

is that the references I have -- excuse me -- 15:56:53

provided teach how to make phosphorous diffusions, 15:56:57

and that phosphorous diffusions have been known 15:57:03

for a long time. And those references, however, 15:57:05

aren't specifically aimed at Froitzheim or any 15:57:12

other reference. They teach how to make 15:57:17

phosphorous diffusions as was known for a long 15:57:20

time. 15:57:24

And a POSITA would be able to make design 15:57:25

choices in order to form the N plus layer at front 15:57:29

of Froitzheim's solar cell that achieves 15:57:36

Froitzheim's purpose with that layer. 15:57:40

Q But is it accurate to say that your 15:57:46

declaration does not provide a specific 15:57:48

temperature and time combination for how to make 15:57:56

the front side N plus layer of the Froitzheim-Gan 15:57:59

combination? 15:58:04

MR. SELWYN: Objection. Form. 15:58:07

A That is correct. My declaration does not 15:58:08

have a specific time-temperature profile, as it's 15:58:11

not necessary, when -- my understanding is it's not necessary when evaluating obviousness to assume that two steps are put together mechanistically; but, rather, that the teachings of the references and what a POSITA knew at the time inform whether or not a combination is -- is obvious. And a POSITA knew and had access to decades of information about how to make a phosphorous diffusion. 15:58:19 15:58:23 15:58:25 15:58:31 15:58:38 15:58:43 15:58:47 15:58:53 15:58:59

A POSITA doesn't require me to tell him or her, This is the specific time and temperature profile that we use. And Froitzheim understood this, I believe. Which is why the Froitzheim does not itself specify in great detail the time and temperature combination that Froitzheim had in mind. Because Froitzheim understood that the people at the time already knew how to make phosphorous diffusions. 15:59:00 15:59:03 15:59:06 15:59:10 15:59:15 15:59:22 15:59:25 15:59:28 15:59:30

Q You said earlier, "I would need more information about the rest of the solar cell in order to specify a specific time and temperature." 15:59:32 15:59:36 15:59:39

Right? 15:59:42

A What did I say that in relation to? 15:59:49

Q Let me just read this part of the 15:59:50

transcript. 15:59:52

My question was, "Sitting here today, you 15:59:53

would not be able to give me a specific 15:59:54

temperature and time combination. 15:59:57

Is that right?" 16:00:00

And your answer was, "I would need more 16:00:00

information about the rest of the solar cell in 16:00:03

order to specify a specific time and temperature." 16:00:06

You go on to elaborate on that, that you -- I just 16:00:11

want to ask, sitting here today, do you have that 16:00:17

information about the rest of the solar cell in 16:00:21

order to specify a specific time and temperature? 16:00:24

MR. SELWYN: Objection. Form. 16:00:28

A I can elaborate. 16:00:32

Froitzheim doesn't provide one specific 16:00:35

embodiment of Froitzheim's invention, but, rather, 16:00:39

Froitzheim allows for variation within his 16:00:43

invention. 16:00:48

For example, Froitzheim gives a variation 16:00:49

in the percentage coverage of the N plus doping 16:01:00

region at the front. That's in Paragraph 18. Froitzheim allows for possibilities of multiple passivation layer structures, so it can oxide silicon nitride, amorphous silicon, and doped -- N plus doped amorphous silicon. That's in Paragraph 19, et cetera. Froitzheim allows for many embodiments of Froitzheim's invention. 16:01:09 16:01:12 16:01:17 16:01:20 16:01:27 16:01:31 16:01:34

But one cannot specify the particular doping time and temperature profile, for example, without choosing a particular instance or embodiment of Froitzheim's invention. 16:01:35 16:01:40 16:01:43 16:01:47

So it's not that Froitzheim doesn't teach these things or that I don't know; it's that Froitzheim -- Froitzheim's teachings are -- allow for multiple embodiments. And one of those embodiments must be selected in order to, for example, determine, as a POSITA would know how to do based on the extensive literature, a particular doping profile. 16:01:49 16:01:51 16:01:54 16:01:58 16:02:01 16:02:05 16:02:10 16:02:16

Q Do you select a specific embodiment of Froitzheim to use in your Froitzheim-Gan combination? 16:02:17 16:02:22 16:02:25

A I do not. I do not have to, for example, choose the wafer thickness. What -- what I do is show that the teachings of Froitzheim in combination with Gan, at least for this particular grounds that we're talking about, those in combination teach all of the limitations of the claims of -- the claims that are addressed in this grounds of the '053 patent. 16:02:28 16:02:31 16:02:38 16:02:42 16:02:45 16:02:50 16:02:55 16:03:04

Q But going back to what you said earlier, the, quote, "I would need more information about the rest of the solar cell in order to specify a specific time and temperature." What information do you need in order to specify a specific time and temperature? 16:03:08 16:03:11 16:03:13 16:03:17 16:03:22 16:03:25

MR. SELWYN: Objection. Form. 16:03:29

A A POSITA would require the sorts of design choices, ordinary design choices within the allowable embodiments of Froitzheim's invention that I suggested previously and that you and I were just talking about. For example, the thickness of the wafer or the fraction of the surface area covered by the N plus layer on the 16:03:30 16:03:33 16:03:39 16:03:43 16:03:46 16:03:49 16:03:55

front. That's -- that's Paragraph 18, for instance. 16:03:58 16:04:02

So these things need to be specified in order to understand, for example, what the surface doping density should be, the surface concentration of the dopant, and the depth of the diffusion, which would then lead to a choice of a suitable diffusion profile. 16:04:03 16:04:05 16:04:09 16:04:11 16:04:14 16:04:20

Q And those information -- that information is not provided in your declaration. 16:04:29 16:04:36

Is that correct? 16:04:38

MR. SELWYN: Objection. Form. 16:04:40

A Which information? 16:04:42

Q The information you just talked about, for example, the design choices, ordinary design choices within the allowable embodiments of Froitzheim's invention, for example the thickness of the wafer or the fraction of the surface area, and so on. 16:04:43 16:04:47 16:04:51 16:04:54 16:04:58 16:05:01

MR. SELWYN: Objection. Form. 16:05:04

A I do regularly in my declaration point out that a POSITA would understand how to 16:05:07 16:05:12

implement the teachings of, for example, Froitzheim. A POSITA does have knowledge and ordinary ingenuity. And so a POSITA doesn't have to be given a recipe like a robot in order to successfully implement the teachings of the art. 16:05:21 16:05:26 16:05:32 16:05:36 16:05:40

And so I do say that regularly throughout my declaration. I was trying to read my declaration in order to answer your question and give you additional detail about how a POSITA might think about implementing the teachings. 16:05:44 16:05:49 16:05:57 16:05:59 16:06:02

Q Let me just make sure I -- you understand my question here. 16:06:06 16:06:26

A Okay. 16:06:28

Q My question was, because earlier you said -- because earlier you said, "I would need more information about the rest of the solar cell in order to specify a specific time and temperature." My question was simply the information you would need is not provided in your declaration. 16:06:28 16:06:39 16:06:41 16:06:44 16:06:47 16:06:51 16:06:54

Is that correct? 16:06:55

MR. SELWYN: Objection. Form. 16:06:57

A The information that I or a POSITA would need is provided in Froitzheim. And as I described in my previous answer, because Froitzheim teaches a range of allowable wafer thicknesses, a range of allowable N plus contact -- N plus areal coverage, et cetera, one cannot specify a particular time and temperature profile without also selecting, for example, a wafer thickness. 16:07:16 16:07:20 16:07:25 16:07:31 16:07:34 16:07:42 16:07:49 16:07:59 16:08:03

This is standard in all solar cell fabrication. One doesn't select a diffusion profile before selecting a wafer, for instance. 16:08:05 16:08:08 16:08:11

I didn't say that in my declaration because I didn't need to. I describe in the background section that solar cells date back to the 1950s, and that appreciable knowledge in the fabrication, design and fabrication of solar cells that a POSITA having regular and normal ingenuity already has access to. 16:08:15 16:08:17 16:08:20 16:08:24 16:08:29 16:08:31 16:08:37

Q When you say, "I didn't say that in my declaration because I didn't need to," what specifically are you referring to? 16:09:06 16:09:08 16:09:12

A I didn't have to state explicitly in my declaration that a POSITA makes design choices in fabricating a solar cell, design choices based on what the POSITA knows based on decades of experience and publication in the field. 16:09:15 16:09:17 16:09:24 16:09:28 16:09:35

Every POSITA understands that when they go to implement a solar cell, they will need to make design choices, that things will need to be specified, which will then influence subsequent decisions, et cetera. 16:09:42 16:09:45 16:09:48 16:09:50 16:09:55

This is routine. This is the way that solar cells or any other device is fabricated. One has to make ordinary design choices. 16:09:56 16:09:59 16:10:06

Q Let's go to Paragraph 44 of Froitzheim. 16:10:10

Is it accurate to say that according to Paragraph 44, Froitzheim first performs the P-type dopant diffusion and then the N-type dopant diffusion? 16:10:35 16:10:37 16:10:47 16:10:50

A Yes, in Paragraph 44 of Froitzheim, Froitzheim describes the N plus doping occurring after the emitter, the P-type emitter, is formed. 16:11:13 16:11:20 16:11:28

Q Is it accurate to say that those 16:11:34

diffusions are performed separately? 16:11:40

A One moment, please. 16:11:53

To answer your question, in the -- in 16:14:52

the -- in the method described in Paragraph 44 16:15:09

Froitzheim is discussing diffusion of the front 16:15:20

side N plus layer after diffusion of a P-type 16:15:23

emitter at the -- at the rear side. 16:15:31

Elsewhere in Froitzheim, Froitzheim talks 16:15:37

about the structure of the N plus layer at the 16:15:46

front and how it's -- and how it's arranged. But 16:15:51

in the fabrication sequence given that includes 16:16:04

Paragraph 44, Froitzheim is performing that 16:16:08

diffusion after the P-type diffusion into the 16:16:11

emitter. 16:16:17

Q But can I understand Paragraph 44 to mean 16:16:22

first he would apply heat to drive in the P-type 16:16:26

dopant? 16:16:29

MR. SELWYN: Objection to form. 16:16:37

A Well, that's not the first thing that's 16:16:46

done in the solar cell fabrication. 16:16:47

Q Between the diffusion of P-type dopant 16:16:52

and the diffusion of N-type dopant, can I 16:16:57

understand Paragraph 44 to mean first you apply heat to drive in the P-type dopant? 16:17:00 16:17:03

MR. SELWYN: Objection. Form. 16:17:06

A In Paragraph 40 -- 40 through 44 Froitzheim describes a process that forms a P-type diffused emitter, and then subsequently forms an N-type, N plus front surface field. 16:17:34 16:17:47 16:17:52 16:17:57

Q The process that forms a P-type diffused emitter in Froitzheim, does that involve heating? 16:18:12 16:18:15

A Yes, Froitzheim describes that in Paragraph 42 of Froitzheim. 16:18:23 16:18:28

Q And the process that forms the N-type front surface -- I'm sorry, you said N-type N plus front surface field, that process, does that involve heating? 16:18:31 16:18:38 16:18:43 16:18:45

MR. SELWYN: Objection. Form. 16:18:48

A Yes, in Paragraph 44 Froitzheim describes forming the N plus layer, the -- a diffusion. 16:18:54 16:18:56

Q So I am just trying to understand the process of forming the P-type diffused emitter and the N plus front surface field. Are we talking about two rounds of heating or just one round of 16:19:06 16:19:07 16:19:11 16:19:14

heating? 16:19:17

A I would need to have in front of me the 16:19:29

U.S. 5899704 and 6099668 patents to confirm. 16:19:32

Because Froitzheim teaches that the N plus layer 16:19:42

can be conducted according to the steps disclosed 16:19:47

therein. 16:19:52

Q Typically when you diffuse the P-type 16:19:55

dopant and then you diffuse the N-type dopant, 16:19:58

would you use two rounds of heating or one round 16:20:02

of heating? 16:20:05

MR. SELWYN: Objection. Form. 16:20:06

A I can't answer the question. That -- 16:20:08

typically I don't know what -- what process 16:20:13

sequence you're referring to or which solar cell 16:20:15

or -- it's a lack of definition that allows me to 16:20:18

answer the question. 16:20:24

Q So there is no general process of how a 16:20:24

structure like Froitzheim would be constructed? 16:20:28

MR. SELWYN: Objection. Form. 16:20:31

A There are multiple processes in how 16:20:33

diffusions occur and can be conducted. They can 16:20:39

be conducted sequentially. And one thing that 16:20:42

Froitzheim describes is that they can be conducted sequentially, as I mentioned in my previous answer, Paragraphs 40 through 44. They can also be done at the same time. That was well known and common. I describe that in my background section when I talk about co-diffusion. 16:20:47 16:20:51 16:20:56 16:21:00 16:21:06 16:21:17

"Co-diffusion" is the one word commonly used to describe diffusion of two or more types of dopants simultaneously. And I provide several pieces of -- several references where co-diffusion was used. 16:21:23 16:21:25 16:21:28 16:21:34 16:21:40

What I don't know, without looking at the patents referenced in 43 of Froitzheim, is whether Froitzheim explicitly also anticipated -- maybe that's the wrong word to use, but Froitzheim taught through those incorporated references co-diffusion. 16:21:41 16:21:45 16:21:53 16:21:56 16:21:58 16:22:05

Q When you say the process can be conducted sequentially, do you mean two rounds of heating? 16:22:05 16:22:07

A Yes, that's -- that's what I was referring to. Multiple heating steps, where discussions can be conducted through multiple 16:22:16 16:22:18 16:22:29

sequential heating steps or by diffusing multiple dopants at the same time with one heating step. Or some -- something that's somewhat in between those two options is, for example, taught by Smith, where a wafer may experience some temperature, some elevated temperature, and then change to a different elevated temperature without, for example, returning to room temperature in between. 16:22:33 16:22:36 16:22:42 16:22:44 16:22:49 16:22:56 16:22:57 16:23:00 16:23:02

Q Well, let's say I have a first heating step that diffuses a P-type dopant. 16:23:04 16:23:15

A Okay. 16:23:20

Q And I have a second heating step that diffuses an N-type dopant. 16:23:20 16:23:24

Would this second heating step affect the P-type dopant in any way? 16:23:28 16:23:31

MR. SELWYN: Objection. Form. 16:23:34

A It could. I think we had a discussion about this previously. It depends on the time and temperature of the second step and the diffusivity of I believe you said it was P-type dopants introduced in the first step, and also the 16:23:38 16:23:41 16:23:50 16:23:56 16:24:00

material in which they are -- they are located. 16:24:03

So they could diffuse further. That 16:24:08

could be a short distance or a long distance, as 16:24:14

we described. Or they could diffuse negligibly, 16:24:16

depending on the details. 16:24:22

Q So would the Froitzheim-Gan combination 16:24:24

use the process described in Paragraph 44? 16:24:31

A It could. Froitzheim teaches this N plus 16:24:46

diffusion at the front of the substrate, and that 16:24:53

could be used in the Froitzheim-Gan combination, 16:24:59

with Gan's polysilicon emitter and oxide layer at 16:25:07

the back of the solar cell. 16:25:11

So Froitzheim has all of the teachings to 16:25:12

implement an N plus layer at the front of a solar 16:25:15

cell as in the Froitzheim-Gan combination. 16:25:24

Q Paragraph 45 of Froitzheim mentions a 16:25:29

selective front surface field. 16:25:36

Do you see that? 16:25:38

A Yes, I do. 16:25:39

Q What is a selective front surface field? 16:25:45

A Froitzheim is describing a more heavily 16:25:54

doped N plus layer that is located only in certain 16:25:59

areas at the front of the solar cell. That is to say, not across the entire front of the solar cell. And in particular under the metal contacts. He describes, for example, that that can reduce the contact resistance. That is the selective front surface field that he speaks of. 16:26:04 16:26:07 16:26:11 16:26:18 16:26:20 16:26:26

Q Would the Froitzheim-Gan combination have a selective front surface field? 16:26:30 16:26:33

A It could, but it doesn't need to. That is not one of the limitations of the '053 claim. And you'll note that Froitzheim teaches the selective front surface field -- excuse me. One second. Sorry for the delay. I don't remember what the last words were that I said. Perhaps maybe, Debbie, you could remind me. 16:26:40 16:26:42 16:26:48 16:26:51 16:26:56 16:28:17 16:28:21

(The record was read.) 16:28:21

A Thank you. 16:28:42

The selective front surface field is optional, that Paragraph 45 starts with "if." And Froitzheim describes embodiments that include and that also don't include a selective front surface field. 16:28:42 16:28:47 16:28:52 16:28:55 16:29:00

Q Can we jump real quick back to your declaration, Page 78. 16:29:00 16:29:03

A Okay, I'm there. 16:29:20

Q On this page you illustrate a Froitzheim-Gan combination. Right? 16:29:20 16:29:24

A That is correct. 16:29:27

Q Does this illustration depict a front surface field? 16:29:28 16:29:35

A Yes, Regions 39 and 38 make up the front surface field. The N plus layer at the front. Or N plus region at the front of the wafer. 16:29:38 16:29:42 16:29:47

Q Okay. Let's go back to Paragraph 45 of Froitzheim. This paragraph also talked about a deep N dopant diffusion. Right? 16:29:51 16:29:54 16:29:59

A That's correct. 16:30:02

Q What is a deep N dopant diffusion? 16:30:02

A So again, in Paragraph 45 Froitzheim is not talking about a front surface field generally, but in particular the instance of a selective front surface field. So that is to say, going back to Figure 3, which you found on Page 78 of my declaration, the instances or the embodiments that 16:30:09 16:30:13 16:30:19 16:30:22 16:30:27 16:30:31

include 38 as it's labeled in that figure. 16:30:36

And what Froitzheim is saying in 16:30:43

Paragraph 45 is that the diffusion in that 16:30:45

reason -- in that region can be -- can be deep. 16:30:51

That is to say, deeper than in the surrounding 16:30:58

front surface field region. 16:31:04

So if we look on the figure, Paragraph 45 16:31:06

describes an embodiment in which 38 would extend 16:31:13

further into the wafer than 39. It's not drawn as 16:31:17

such in this figure, but that's what the words of 16:31:22

that paragraph say. 16:31:24

Q Thank you for correcting me. So let me 16:31:28

just make sure the record is clear. 16:31:30

When we're talking about in your 16:31:32

declaration on Page 78 the illustration of the 16:31:33

Froitzheim-Gan combination, that is illustrating a 16:31:38

selective front surface field. Right? 16:31:42

A Okay. That is different than what you 16:31:44

asked before. 16:31:46

Yes, this embodiment shows a selective 16:31:48

front surface field, it's 38. You'll also find 16:31:52

elsewhere in my declaration I point to and 16:31:57

reproduce Figure 1 of Froitzheim, which has a front surface field but not a selective front surface field. 16:32:03 16:32:17 16:32:19

Q Can you direct me to where you're looking at? 16:32:19 16:32:21

A Within my declaration? 16:32:23

Q Yes. 16:32:24

A Yes. You'll have to give me one moment. It might take me a minute to find it. I am looking in the table of contents. 16:32:26 16:32:30 16:32:46

I referred to Froitzheim's Figure 1 in the footnote of Page 66 of my declaration. I reproduce Froitzheim's Figure 1 on Page 98 of my declaration. 16:33:30 16:33:33 16:33:39 16:33:46

Q Froitzheim Figure 1 and Figure 3 -- 16:34:00

MR. SELWYN: Did you finish your answer? 16:34:04

Q Oh, I'm sorry. 16:34:06

A Just I was still looking. There are additional instances. Paragraph 184 on Page 116 I refer to both Figure 1 and 3 and reproduce them both on Page 117. There may be other instances, but I think I've pointed you to some. 16:34:08 16:34:09 16:34:16 16:34:19 16:34:25

Q Figures 1 and 3 illustrate different embodiments of Froitzheim. Right? 16:34:28 16:34:32

A That is correct. 16:34:38

Q And the Froitzheim-Gan combination that you propose would include either of those two embodiments? 16:34:39 16:34:41 16:34:47

A Once again, the combination, in order for it to be obvious, as I understand it, must have been obvious to a POSITA based on the teachings. The teachings aren't limited to one embodiment or another embodiment. And so the reason that I refer to both Figures 1 and 3 is that the teachings embodied in 1 and 3, when combined with Gan, meet the limitations of the '053 claims. 16:34:50 16:34:55 16:34:58 16:35:02 16:35:04 16:35:07 16:35:10 16:35:17

Q How do you perform a deep N dopant diffusion? 16:35:30 16:35:59

A As I've discussed previously, the time and temperature determine how quickly and then how far the dopants move. So a deeper diffusion is commonly achieved relative to a shallower diffusion -- excuse me -- by making the diffusion time longer or making it hotter. 16:36:02 16:36:04 16:36:11 16:36:16 16:36:23 16:36:26

Q So in the embodiment of Froitzheim Figure 3 where you have a selective front surface field, how do you perform diffusion such that there can be deep diffusion areas and shallower diffusion areas? 16:36:30 16:36:34 16:36:39 16:36:43 16:36:46

A Froitzheim describes in Paragraph 45 that if a selective front surface field is to be arranged -- used, I understand, then one diffusion is formed that results in a deep diffusion in the areas of 38, so presumably the hotter or longer diffusion. Subsequently the mask that limited that diffusion to the areas of 38 is removed and another diffusion is performed that's shallower, that is at shorter times or lower temperatures. But note that as the '053 claims do not include a limitation about selective front surface field, I have not included that in my combination explicitly. 16:36:52 16:37:01 16:37:05 16:37:16 16:37:18 16:37:23 16:37:27 16:37:34 16:37:38 16:37:44 16:37:50 16:37:57 16:37:59

Q Can you talk a little bit about this general concept of masking? 16:38:00 16:38:07

A I can talk about it within the context of what Froitzheim is describing. 16:38:14 16:38:16

Is that suitable? 16:38:18

Q Yep. 16:38:19

A Okay. Froitzheim is describing that 16:38:24

dopants may be diffused into select regions, that 16:38:28

is to say, not the full surface of the substrate, 16:38:32

by having an oxide layer, typically an undoped 16:38:39

oxide layer, that blocks or slows the diffusions 16:38:49

of dopants. 16:38:56

And these would be thick oxide layers, 16:39:01

not like tunnel oxide layers. And they would be 16:39:05

put in certain areas that they form a mask. 16:39:10

Similar concept is used for example by 16:39:15

Smith, in defining the P and N regions at the back 16:39:17

side of Smith's solar cells. Smith also makes use 16:39:22

of undoped oxide layers to achieve that. 16:39:26

MS. ZHAO: We've been going for about an 16:39:43

hour. I just have a few more questions on 16:39:44

Froitzheim. So if you're doing okay, let's power 16:39:46

through Froitzheim and then we'll take a break. 16:39:48

Is that okay? 16:39:50

THE WITNESS: Yes, it is. Thank you for 16:39:51

asking. 16:39:54

Q Let's go to Paragraph 46. 16:39:55

Would the Froitzheim-Gan combination use 16:39:59

the process described in Paragraph 46 of 16:40:01

Froitzheim? 16:40:05

A Paragraph 46 is similar to 45, but on the 16:40:08

other side of the solar cell and with the opposite 16:40:15

doping to form the emitter. 16:40:21

In my combination of Gan and Froitzheim I 16:40:22

take Gan's oxide layer and P-type polysilicon 16:40:25

emitter and I use it to replace Froitzheim's 16:40:30

emitter. So this process step, which is 16:40:33

describing a particular variation of Froitzheim's 16:40:37

P-type emitter, would not be used in the 16:40:41

combination; rather, the teachings of Gan would be 16:40:45

used to form the emitter. 16:40:49

Q What about the process described in 16:40:52

Paragraph 47; would the Froitzheim-Gan combination 16:40:53

use that? 16:40:57

A So Paragraph 47 of Froitzheim describes 16:42:14

what is generally referred to as edge isolation. 16:42:18

And it's a method to make sure that there aren't 16:42:22

any shunts, which is the word we use for 16:42:27

electrical shorts, in the positive and negative -- positive and negative regions or P-type and N-type regions inadvertently touch each other. And Froitzheim is describing a method to make sure that that doesn't happen, your edge isolation. 16:42:30 16:42:40 16:42:44 16:42:48 16:42:51

And that is not a limitation of the '053 claims. And the process of forming such an edge isolation is not a limitation of the '053 claims. So I have not specifically addressed or incorporated it in my combination. It may be included, but it is not necessary to form the combination. 16:42:56 16:43:02 16:43:08 16:43:10 16:43:11 16:43:15 16:43:19

Q Paragraph 47 says, "If required after the formation of the N plus dope layer." 16:43:22 16:43:26

Do you see that? 16:43:29

A I do. 16:43:30

Q In what situation would this if come into play? 16:43:30 16:43:35

A If the N plus doped layer or the P-type emitter layer, which in the combination comes from Gan, but in Froitzheim alone comes from Froitzheim, wraps around the edge of the wafer so 16:43:38 16:43:50 16:43:53 16:43:56

as to touch the doped region of the opposite polarity on the opposite side. 16:43:59 16:44:04

Q Is that a common situation that occurs in the manufacturing of a solar cell? 16:44:07 16:44:11

A It can be, particularly for solar cells that achieved both the N and P-type regions via diffusion processes. And so edge isolation steps were commonly used in manufacturing. They were understood. And I expect, I would guess that the reason that Froitzheim does not provide much detail here is because Froitzheim understands that a POSITA knew about edge isolation steps as of the time Froitzheim was writing. 16:44:15 16:44:20 16:44:25 16:44:30 16:44:34 16:44:39 16:44:42 16:44:45 16:44:49

Q The last word of Paragraph 47 is plasma.

Is this referring to plasma etching? 16:44:52 16:44:57

A I think that that is likely. That is how I read it. Removal of material via plasma are commonly called etching. This is one way to do edge isolation, and that's why Froitzheim introduces it with a e.g., for example. 16:45:05 16:45:07 16:45:13 16:45:16 16:45:19

Q What about the process described in Paragraph 48; would the Froitzheim-Gan combination 16:45:26 16:45:27

use that process? 16:45:31

A The Froitzheim-Gan combination can use 16:45:41
Froitzheim's teaching on metallization as 16:45:46
described in 48. Gan also teaches formation of 16:45:52
metal contacts to Gan's P-type polysilicon layer. 16:45:59
Both references teach formation of metal contacts. 16:46:06
These were common, as they're required on every 16:46:12
functioning solar cell and screen printing, which 16:46:15
Froitzheim mentions is one of the common ways of 16:46:23
forming such metal contacts. 16:46:31

Q What about the process described in 16:46:33
Paragraph 50; would the Froitzheim-Gan combination 16:46:34
use that process? 16:46:39

A Yes, the combination would make use of 16:46:55
Froitzheim's teaching, for example, in Paragraph 16:47:01
50, regarding passivation layers and 16:47:04
antireflection coatings. I describe starting on 16:47:23
Page 180 -- excuse me, Paragraph 180 of my 16:47:31
declaration I talk about the Froitzheim-Gan 16:47:36
combination and the Froitzheim's description of 16:47:42
the passivation layer and antireflection coating 16:47:45
needed for that combination. 16:47:48

Q Okay. One last question on Froitzheim, then we'll take a break. 16:47:51 16:47:55

Can you go to Paragraph 34. 16:47:56

The second-to-last line talks about a doping concentration intermediate. 16:48:03 16:48:05

Do you see that? 16:48:08

A I do see it, yes. 16:48:09

Q What is a doping concentration intermediate? 16:48:15 16:48:17

A It's -- the concentration is expressed in the number of dopant atoms per cubic centimeter. And Froitzheim is describing a concentration, a value with those units that is between the -- what he calls the N-type body layer, we recognize as the wafer, and that of the N plus doped regions 18, that refers to Figure 1 -- let me double-check that. Yes, I confirm. Or in reference to Figure 3. No, that's referring to something else. 16:48:22 16:48:26 16:48:34 16:48:36 16:48:41 16:48:45 16:48:58 16:49:02 16:49:13

So what Froitzheim is saying there is that dopant concentration that is between two other dopant concentrations. 16:49:25 16:49:27 16:49:30

Q Okay. The dopant concentration that is 16:49:39

between two other dopant concentrations, what would be those two other dopant concentrations? 16:49:41 16:49:44

A Okay. I have to back up a little bit. I previously said Froitzheim is referring to Figure 1, and I am incorrect about that. I was incorrect about that. In this paragraph Froitzheim is contrasting his previous discussion of Figure 1 with a new discussion of Figure 3. And Froitzheim is saying that Regions 38, those are the selective front surface field that we described previously, have heavier doping or higher doping, that is to say, a larger doping concentration. Regions 39 is a weaker doping concentration. And what he means by "weaker" is that it is intermediate between that of Region 38 and the wafer. Yes, and the wafer. 16:50:17 16:50:21 16:50:24 16:50:27 16:50:31 16:50:35 16:50:40 16:50:49 16:50:52 16:50:55 16:51:00 16:51:04 16:51:08 16:51:20

So what Froitzheim is saying is wafer is doped the lowest N-type, 39 is the next highest N-type, and 38 has the highest dopant N-type, in the configuration of Figure 3, which there's a selective front surface field. 16:51:20 16:51:26 16:51:29 16:51:33 16:51:36

MS. ZHAO: Okay. Shall we take a break? 16:51:41

MR. SELWYN: Sure. 16:51:43

MS. ZHAO: Five minutes? 16:51:43

MR. SELWYN: Yeah. 16:51:44

(A recess was taken.) 16:51:45

BY MS. ZHAO: 16:57:46

Q Let's go to Exhibit 1005, Gan. 16:57:47

On Page 246 of Gan, I am looking at the 16:57:56

first paragraph on the left. 16:58:02

(Exhibit 1005, previously marked, not 16:58:02

attached.) 16:58:08

A I am as well. 16:58:08

Q The second sentence begins with, "Because 16:58:09

high bulk lifetime is needed for such a 16:58:13

measurement, the samples were prepared with high 16:58:16

resistivity FZ wafers." 16:58:19

Do you see that? 16:58:22

A Yes, I do. 16:58:23

Q Here the term "such a measurement" refers 16:58:24

to J naught. Right? 16:58:29

A That is correct. 16:58:35

Q Can you help me understand the sentence 16:58:35

generally. 16:58:37

What is "high bulk lifetime"? 16:58:38

A High bulk lifetime means that there are comparatively low amounts of nonradiative recombination within the wafer itself, such that an electron that is excited from the valence band to the conduction band of the silicon wafer will remain in the conduction band for a comparatively long period of time, its lifetime, before recombining with a hole and returning to the valence band. And I describe these basic semiconductor physics in my background section. 16:58:46 16:58:49 16:58:53 16:59:00 16:59:03 16:59:07 16:59:13 16:59:17 16:59:22 16:59:24

Q Why is high bulk lifetime needed to measure J naught? 16:59:29 16:59:33

A Because J naught is a measurement of recombination at the surface of the wafer. And one wants to measure that instead of recombination within the wafer itself. So for this particular measurement to learn about a new emitter, which is the point of Gan's work, it's important to make sure that you're not instead being limited by the wafer. 16:59:36 16:59:46 16:59:51 16:59:55 16:59:59 17:00:03 17:00:06 17:00:09

Q And what are FZ wafers? 17:00:11

A FZ stands for float zone. It's a particular method of making a wafer. 17:00:19 17:00:22

Q So are FZ wafers made out of silicon as well? 17:00:31 17:00:34

A Yes. Yes, Gan is using a silicon wafer made with a process called float zone. 17:00:35 17:00:39

Q Would the wafer in Froitzheim also be an FZ wafer? 17:00:46 17:00:50

A Likely not. Float zone wafers are very good for learning new things, like the performance of a new emitter as Gan is doing, but they are expensive. And the solar industry -- sorry, there is a phone in here that's ringing. We will make sure that stops. My apologies. 17:01:14 17:01:17 17:01:21 17:01:26 17:01:33 17:01:36

The solar industry has historically tried to enhance efficiency while keeping costs low, and so has most commonly used multicrystalline wafers for Czochralski-grown monocrystalline wafers. 17:01:39 17:01:46 17:01:51 17:02:02

So if you look at Paragraph 24 of Froitzheim, Froitzheim says that the silicon body layer is made from crystalline silicon and then can be of the mono, multi, or polycrystalline 17:02:03 17:02:07 17:02:11 17:02:14

type, preferably Czochralski-grown silicon is used. 17:02:17 17:02:21

So Froitzheim allows for different possibilities that would be inclusive of float zone wafers. That was not common because of their high cost. And Froitzheim gives a specific example of Czochralski wafers. 17:02:22 17:02:24 17:02:27 17:02:30 17:02:35

And Czochralski wafers, grown wafers, are typically abbreviated CZ, as opposed to FZ for float zone. 17:02:39 17:02:43 17:02:47

If we turn back to Page 246 of Gan, you can see that the contact resistive measurements that Gan did were on CZ wafers instead. 17:02:48 17:02:53 17:02:57

Q Why is Gan using different wafers to measure different things? 17:03:02 17:03:04

A Because Gan's purpose is to learn about polysilicon oxide contacts to silicon. And he's using two techniques to learn the most relevant parameters, which are contact resistivity, that tells you about how much resistive losses you're going to have; J naught, which tells you about how much surface recombination losses you're going to 17:03:10 17:03:11 17:03:15 17:03:20 17:03:24 17:03:26 17:03:30

have. And the techniques to use -- to measure those two things require something different of the wafers. 17:03:32 17:03:34 17:03:39

These techniques were introduced long ago. I believe the J naught technique that Gan is using was introduced in 1985, in his Reference 10. And the contact resistivity techniques date back even before that. I regularly refer to a paper written in 1984. And yet these are still even today the most common and best-known techniques for measuring contact resistivity and J naught. We use both of them in my own research lab. 17:03:40 17:03:47 17:03:53 17:04:03 17:04:08 17:04:10 17:04:15 17:04:18 17:04:22

So the measurement techniques to learn about the emitter require something of the substrate. 17:04:25 17:04:27 17:04:31

Q Below this paragraph we just looked at there are 12 steps in Gan. 17:04:34 17:04:39

Do you see that? 17:04:42

A I do. 17:04:43

Q Can you tell me which of these steps would be used in the Froitzheim-Gan combination? 17:04:43 17:04:46

A Yes. As I described previously, it's not 17:04:52

required for a POSITA to make a one-to-one copying of steps for particular instances but, rather, to take the teachings of a whole to implement them. 17:04:55 17:05:01 17:05:09

But as an example, Step 3, Thin thermal oxide growth, that's referring to the formation of Gan's tunnel oxide. That tunnel oxide is used in my combination of Froitzheim and Gan. That's important. 17:05:14 17:05:18 17:05:22 17:05:28 17:05:32

The fourth step, polysilicon deposition, it's also important to -- or is required in my Froitzheim-Gan combination. 17:05:34 17:05:38 17:05:43

And then some subsequent steps, such as Step 9 and Step 10, are about doping that polysilicon layer to turn it into an emitter. And as I say in my declaration, my combination is Gan's oxide and polysilicon emitter. And so those steps teach how to dope the polysilicon to make an emitter. 17:05:47 17:05:54 17:05:59 17:06:04 17:06:07 17:06:13 17:06:17

As we discussed previously, Froitzheim also teaches steps about how to make a P-type diffusion. 17:06:20 17:06:22 17:06:28

Q Am I understanding you correctly, Steps 17:06:29

3, 4, 9, and 10 are the required steps in your Froitzheim-Gan combination? 17:06:36 17:06:42

A As I discussed previously, there are teachings that Gan has about forming the oxide, the polysilicon, and the doping are what we need. These steps here embody that teaching, but the teaching isn't limited to that. Right? 17:06:45 17:06:52 17:06:54 17:06:59 17:07:04

If you look at Figure 3 as an example, you can see that the time of a first step anneal, that's Step 5, is varied. But the five -- the 12 steps don't show the variation in time. 17:07:06 17:07:14 17:07:19 17:07:27

So Gan's teaching is bigger than just those -- that's what's written in those steps. And I guess in my list I didn't mention Step 5, that first step anneal. Gan -- excuse me. No. It's incorporated in Step 4. 17:07:29 17:07:33 17:07:38 17:07:41 17:07:46

Q What about Steps 6 to 7 -- I'm sorry, 6 to 8; would those not be required in the Froitzheim-Gan combination? 17:07:58 17:08:01 17:08:03

A Step 6 is particular to a contact resistivity structure and isn't required in making a solar cell, a finished solar cell incorporating 17:08:18 17:08:20 17:08:27

Froitzheim's, for example. Step 7 is also required to make the contact resistivity measurements, what wouldn't be required in Froitzheim's solar cell. And similarly with Step 8. 17:08:34 17:08:43 17:08:46 17:08:50 17:09:00

So these are -- these are steps that Froitzheim has in order to make his measurements that teach us about the properties of oxide polysilicon emitters, but aren't required in Froitzheim's solar cell to make a functioning solar cell. 17:09:00 17:09:02 17:09:07 17:09:10 17:09:14 17:09:16

Q Step 9 discloses doped glass deposition on both sides of the wafer. Right? 17:09:16 17:09:26

A That's correct. 17:09:30

Q What does "doped glass deposition" mean to you? 17:09:30 17:09:33

A It's the same as Froitzheim's dopant source layers. It means PSG, or BSG, that's how I understand it. 17:09:38 17:09:44 17:09:51

Q And what does "deposition on both sides of the wafer" mean to you? 17:09:55 17:09:57

A Its front and back surface. In 17:09:59

particular when making J naught measurements, the best way to do them and the measurement method, requires that you have the same surface passivation on both sides. If you have different surface passivation or different layers on both sides, then what you'll measure will end up being a interpolation of the recombination at someone surface versus the other surface. But if you're interested in a new oxide emitter structure, put it on both sides in order to do a J naught measurement. And that's why that step is one of the ones marked with the asterisk. And the next step -- excuse me, the next sentence indicates that the steps marked with an asterisk are for J naught measurement samples. 17:10:02 17:10:07 17:10:11 17:10:13 17:10:16 17:10:19 17:10:23 17:10:29 17:10:32 17:10:36 17:10:42 17:10:46 17:10:48 17:10:50 17:10:54

Q Would the deposition on both sides of the wafer occur at the same time? 17:10:55 17:10:58

A Very likely. For example, if Gan put the wafer into the furnace and inserted POCl3 vapor, that vapor would form a glass on both sides of the surface, both sides of the wafer, unless one side was blocked with something else, was masked with 17:11:04 17:11:10 17:11:24 17:11:27 17:11:30

something else. 17:11:37

Gan doesn't teach that. It doesn't have 17:11:37

to be that the dopant source is added to both 17:11:40

sides at the same time. But it could be. 17:11:43

Q Do you understand Step 9 to mean 17:11:50

deposition of the same dopant source to both sides 17:11:56

of the wafer? 17:12:00

A Yes. 17:12:04

Q And in the Froitzheim-Gan combination, 17:12:04

would you also be applying Step 9 in the way Gan 17:12:08

describes it? 17:12:14

A Not to both sides of the wafer. You 17:12:18

would apply it to the side on which the 17:12:20

polysilicon emitter is formed. Just like Gan 17:12:26

doesn't add doped glass on both sides of the wafer 17:12:36

for the -- let me back up. 17:12:41

For the combination I would take the 17:12:50

teachings of Gan about his oxide and polysilicon 17:12:52

emitter, and I would apply it to one side of the 17:12:56

wafer; namely, to the back side of Froitzheim's 17:12:59

wafer, as that's where I'm trying to form the 17:13:02

emitter. 17:13:06

Gan here is using test structures, solar cell-like structures, in order to measure these important properties of the contact -- excuse me, of an emitter that he shows with these structures, that this emitter has very good surface passivation as seen in J naught and very good contact resistance as seen in rho C, such that a POSITA would recognize the excellent performance of this contact and be motivated to implement it in Gan. 17:13:07 17:13:12 17:13:15 17:13:18 17:13:22 17:13:27 17:13:32 17:13:36 17:13:38 17:13:41

Q Earlier we talked about retaining some of Froitzheim's manufacturing steps. Right? 17:13:42 17:13:51

MR. SELWYN: Objection. Form. 17:13:56

A We previously talked about Froitzheim's teachings to make a solar cell, yes. 17:13:57 17:13:59

Q Where in Froitzheim's manufacturing steps would you insert Steps 3, 4, 5, 9, and 10 of Gan? 17:14:02 17:14:06

MR. SELWYN: Objection. Form. 17:14:12

A So there are multiple ways in which this could be done. But one that a POSITA would be motivated to do would be, after etching the surface of the wafer to texture it, which 17:14:31 17:14:34 17:14:42 17:14:52

Froitzheim describes, instead of proceeding to Froitzheim's diffusion of boron into the back of the wafer to form a diffused emitter, one would follow Gan's teaching to form an oxide layer and a polysilicon boron-doped emitter on the back side. 17:14:55 17:14:58 17:15:03 17:15:08 17:15:16

And subsequently one would finish the front side of the solar cell and the metallization per Froitzheim's teachings, for example, in 43, 49 -- excuse me, 43, 48, 49, and 50. 17:15:20 17:15:25 17:15:30 17:15:47

Q Okay. When you say a POSITA would be motivated to do, would be after etching the surface of the wafer to texture it, what paragraph are you referring to in Froitzheim? 17:16:05 17:16:14 17:16:22 17:16:24

A Froitzheim describes texturing the silicon wafer in Paragraph 39. 17:16:27 17:16:36

Q Okay. Okay. I see what you're talking about. Thank you. 17:16:41 17:16:48

Looking at Gan, Figure 1, Gan's device would have a PN junction that is on the front side of the cell. Right? 17:16:52 17:17:00 17:17:03

A No. Figure 1 is Gan's contact resistivity test structure. But while Gan's work 17:17:07 17:17:12

is all about understanding and showing the great performance of polysilicon oxide contacts, Gan also places their performance in the context of solar cells. And when Gan does so, he teaches that it can be implemented in a back-contact solar cell. And back-contact solar cells, both their N and their P regions on the back side, that is to say they have their emitters on the back side. 17:17:18 17:17:22 17:17:26 17:17:32 17:17:52 17:17:57 17:18:00 17:18:06

So Gan teaches implementing Gan's emitter on the back side of a solar cell, which is where it would be sensible to locate it to replace Froitzheim's diffused emitter, particularly because Froitzheim is motivated to have the emitter on the back side in the first place to avoid parasitic absorption. 17:18:09 17:18:13 17:18:17 17:18:23 17:18:28 17:18:30 17:18:34

So Gan's deposited emitter on the back side as taught by Gan would retain this beneficial function of the arrangement taught by Froitzheim. 17:18:37 17:18:43 17:18:47

Q But Figure 1 of Gan, is that depicting a back side PN junction? 17:18:51 17:18:55

A No. Figure 1 of Gan isn't depicting solar cell. Figure 1 of Gan is depicting, as it 17:18:59 17:19:01

says in the figure caption, the device structure for the specific contact resistivity measurement. 17:19:07 17:19:09

So as we discussed, Gan implemented the oxide polysilicon emitter in two different structures, one for measuring J naught, one for measuring contact resistivity -- that's the one depicted -- from which Gan determines important performance values of the emitter from which Gan goes on to say using this emitter in solar cells, back-contact solar cells, would improve their performance. I believe he says that one might expect a 1 percent increase in performance if implemented in a back-contact solar cell. 17:19:14 17:19:16 17:19:22 17:19:26 17:19:28 17:19:33 17:19:36 17:19:41 17:19:44 17:19:46 17:19:49

Q So is there no PN junction depicted in Figure 1 at all? 17:19:51 17:19:57

A Figure 1, no, there is not a PN junction depicted in Figure 1. There is an emitter on an oxide, metal oxide polysilicon layer on a wafer, for contact resistivity measurements. 17:20:10 17:20:16 17:20:24 17:20:31

Q Figure 1 depicts an emitter. Right? 17:20:34

A Yes, Figure 1 depicts this oxide and polysilicon emitter, in this case implemented on a 17:20:53 17:21:00

wafer for the purpose of contact resistivity measurements. 17:21:03 17:21:06

This isn't -- this isn't a solar cell; it's a measurement test structure for learning about emitters for use in solar cells. 17:21:07 17:21:10 17:21:13

Q I thought earlier you said emitters are oppositely doped as the wafer. 17:21:17 17:21:20

Is that right? 17:21:23

A When used in solar cells, that is correct. 17:21:25 17:21:26

Q So wouldn't an oppositely doped layer on top of a wafer form a PN junction? 17:21:28 17:21:32

A Yes, it would. These contact resistance measurements, the way in which they're done, they are done on wafers of the same doping polarity. That's just for the contact resistance measurement. This is a known way to measure contact resistance from, as I mentioned, I usually cite a paper from the 1980s that's still used that tells you about the contact resistance that that will have when used in a solar cell, which is what Gan plots, for example, on the Y axis of Figure 6. 17:21:37 17:21:44 17:21:46 17:21:51 17:21:54 17:21:56 17:21:59 17:22:02 17:22:07 17:22:11

Q So in Figure 1 the emitter and the wafer are not oppositely doped? 17:22:16 17:22:26

A In Figure 1 in the contact resistivity structure, the polysilicon layer and the substrate will have the same doping polarity for the purposes of that measurement. When implemented in a solar cell as an emitter, then the layer would be on a wafer of the opposite doping polarity. 17:22:31 17:22:35 17:22:40 17:22:43 17:22:46 17:22:50

This is how we routinely measure contact resistance in this field and in microelectronics. 17:22:59 17:23:02

Q Gan's device structure for measuring J naught -- I'm sorry, let me back up. 17:23:08 17:23:17

Figure 1 depicts Gan's device structure for measuring rho C. Right? 17:23:18 17:23:21

A Correct. 17:23:25

Q And Gan has a device structure for measuring J naught. Right? 17:23:25 17:23:30

A Correct. 17:23:32

Q Would the device structure for measuring J naught look similar to the device structure for measuring rho C? 17:23:33 17:23:36 17:23:41

MR. SELWYN: Objection. Form. 17:23:43

A It would have some similarities, but it would look different. It would look like a silicon wafer with oxide polysilicon on one side and the same oxide polysilicon on the other side to make this symmetric structure that I talked about before. 17:23:47 17:23:49 17:23:52 17:23:55 17:23:59 17:24:02

This is the standard measurement since 1985 for measuring J naught. 17:24:03 17:24:05

Q So -- 17:24:09

A J naught values for use of an emitter in solar cells. 17:24:10 17:24:16

Q So would the device structure for measuring J naught have a PN junction? 17:24:16 17:24:19

MR. SELWYN: Objection. Form. 17:24:27

A The wafer doping polarity isn't specified that Gan used. He says that he uses a high-resistivity wafer, which is a nearly intrinsic wafer. 17:24:28 17:24:31 17:24:34 17:24:37

Q What do you mean by "intrinsic"? Sorry. 17:24:40

A Oh, excuse me. Intrinsic in the solar field or the semiconductor field means undoped. So the wafer has very low doping or -- yeah, very 17:24:43 17:24:46 17:24:49

low, low doping for a J naught measurement. That's standard -- standard procedure at this time. 17:24:53 17:24:58 17:25:05

Q So if I put a P-type doped polysilicon emitter on an intrinsic wafer, would that form a junction? A PN junction, sorry. 17:25:05 17:25:11 17:25:23

MR. SELWYN: Objection. Form. 17:25:24

A If the wafer was truly intrinsic, then, no, it wouldn't form a PN junction. It would form an intrinsic N junction or intrinsic P junction. We oftentimes represent intrinsic layers or wafers with an I. These structures are being used to measure the contact resistivity and the J naught for Figure 6. And we're a standard -- and still are the standard methods for determining how an emitter will perform in a solar cell when it is used to form a PN junction. 17:25:25 17:25:29 17:25:34 17:25:37 17:25:42 17:25:47 17:25:52 17:25:57 17:25:59 17:26:03

As I said previously, these measurement techniques are very powerful. They use -- they require different wafers from each other and also different wafers than might be used in the solar cells in order to do the measurement techniques. 17:26:06 17:26:09 17:26:13 17:26:20 17:26:24

They are routine, accepted by the industry, and used for about as long as I have been on this earth. 17:26:25 17:26:28 17:26:32

Q Do concentrator cells have PN junctions? 17:26:33

A Concentrator solar cells, yes, they have PN junctions. 17:26:43 17:26:45

Q And typically in concentrator solar cells would you find that PN junction to be on the front side or the back side of the substrate? 17:26:46 17:26:50 17:26:53

MR. SELWYN: Objection. Form. 17:26:57

A It could be either. 17:26:59

Q Is one more common than the other? 17:27:03

MR. SELWYN: Objection. Form. 17:27:05

A Are you referring to silicon concentrator solar cells in particular or any type of concentrator solar cell? 17:27:12 17:27:14 17:27:17

Q Let's say any type of concentrator solar cell. 17:27:19 17:27:22

MR. SELWYN: Objection. Form. 17:27:23

A I can't definitively answer the question for all -- for any type of solar cell. For example, for 35 -- for multijunction solar cells 17:27:34 17:27:36 17:27:41

based on gallium arsenide, for instance, I believe it's more common to have the junction on the front. For silicon concentrator solar cells, you find both -- you found really previous to 2008, there aren't a lot of them made anymore -- junctions on front side or back side. And I don't know offhand which was more common or how you want to measure, quantify "more common." 17:27:44 17:27:49 17:27:57 17:28:01 17:28:06 17:28:11 17:28:14 17:28:18

Q Let's go back to Exhibit 1003, the '053 declaration. We were on Paragraph 122. 17:28:24 17:28:27

A There we go. 17:28:39

Q Actually, if you could, go to the next page. That would be Page 78, to the illustration of the Froitzheim-Gan combination. 17:28:44 17:28:46 17:28:48

A Okay, I'm there. 17:28:51

Q Is this Froitzheim-Gan combination a silicon solar cell? 17:28:52 17:28:57

A Yes, it is. 17:28:58

Q Would you call it a heterojunction solar cell? 17:28:58 17:29:07

A No, I would not. 17:29:07

Q So it would be a homojunction solar cell? 17:29:08

A As I mentioned, as of 2008 at least it would be more common just to call it a silicon solar cell. But technically, yes, we have a junction between a crystalline silicon wafer that's N-type and a polysilicon emitter that's -- it's P-type, both of them being crystalline silicon. 17:29:14 17:29:17 17:29:20 17:29:22 17:29:25 17:29:30 17:29:33

Q So technically it would be a homojunction solar cell? 17:29:34 17:29:37

MR. SELWYN: Objection. Form. 17:29:38

A Yes, I would be most comfortable calling it that if the silicon wafer was also multicrystalline or polycrystalline, as Froitzheim allows. Because then I have polycrystalline silicon on both sides of the junction. 17:29:47 17:29:49 17:29:52 17:29:55 17:29:59

Q And is this Froitzheim-Gan combination a concentrator solar cell? 17:30:01 17:30:05

A The combination? 17:30:09

Q Yes. 17:30:10

A The combination is taken from the teachings of Froitzheim and of Gan. And Froitzheim does not provide any limitations about 17:30:10 17:30:13 17:30:20

the intended use of his solar cell. And Gan, while Gan is interested in concentrator applications, Gan's teachings about emitters with low J naught or low contact resistivity could be applied to either concentrator or nonconcentrator solar cells. It was common at the time for POSITAs to take learnings from one and apply it to the other, and vice versa. 17:30:25 17:30:34 17:30:36 17:30:41 17:30:44 17:30:50 17:30:52 17:30:55

So the combination, the solar cell shown on Page 78, could be used under concentration or it could be used under one sun, and it would function in both instances. 17:30:58 17:31:00 17:31:04 17:31:07

Q Let's go to Paragraph 129 of your declaration. 17:31:09 17:31:17

A Okay, I'm there. 17:31:24

Q On Page 83 in the middle of the paragraph you state, "Gan notes that this combination, polysilicon emitter and oxide layer on the wafer surface, has less recombination and lower contact resistance as compared to that of diffused emitters." 17:31:25 17:31:31 17:31:36 17:31:39 17:31:43 17:31:45

Do you see that? 17:31:45

A I do. 17:31:46

Q The result of less recombination and 17:31:47

lower contact resistance, that is the benefit that 17:31:52

Gan brings to the Froitzheim-Gan combination. 17:31:56

Right? 17:31:59

MR. SELWYN: Objection. Form. 17:32:00

A That is a benefit that Gan brings, that's 17:32:02

correct, is this oxide polysilicon emitter 17:32:07

structure has low recombination and low contact 17:32:13

resistivity, and these things will lead to an 17:32:16

enhancement, an increase in the efficiency of the 17:32:21

solar cell. 17:32:24

Q And Gan achieves this benefit through a 17:32:24

combination of polysilicon emitter and oxide 17:32:29

layer. Right? 17:32:33

A That's correct. Gan's paper, his 17:32:34

investigation is with the structure having both 17:32:38

the oxide and the polysilicon. 17:32:41

Q And you're not claiming here that just 17:32:44

implementing Gan's polysilicon emitter would lead 17:32:47

to the same benefits. Right? 17:32:51

A I am not making that claim, as those 17:32:53

experiments are not covered in Gan's paper. Gan doesn't show data for a polysilicon emitter without the oxide layer. 17:32:55 17:33:01 17:33:04

There are other previous papers and publications that cover that structure. Gan focuses on the oxide layer and polysilicon emitter together. 17:33:06 17:33:08 17:33:10 17:33:15

Q Let's go to Page 97 of your declaration. 17:33:15

A Okay, I am there. 17:33:32

Q I have some questions about your discussion of Claim 9 generally, which spans from Page 97 to Page 109. So feel free to look through those pages or any part of your declaration as you answer my questions. 17:33:34 17:33:36 17:33:38 17:33:42 17:33:45

And my question is, you do not mention Gan's oxide layer in your discussion of Claim 9. 17:33:49 17:33:50

Do you agree? 17:33:53

A I agree. An oxide layer is not amongst the limitations of Claim 9. I believe it appears in Claim 16 as a limitation. 17:34:24 17:34:26 17:34:29

Q In Paragraph 148 of your declaration you talk about the combination of Froitzheim and Gan. 17:34:31 17:34:37

Do you see this? 17:34:41

A Yes. 17:34:45

Q Is this still referring to the Froitzheim-Gan combination we discussed earlier? 17:34:46 17:34:47

A Yes. 17:34:49

Q So that combination would include Gan's oxide layer. Right? 17:34:54 17:34:56

A Yes, I describe the inclusion of Gan's oxide layer in subsequent claims that have an oxide layer as a limitation. This claim does not. And I haven't described it here in describing the combination. 17:35:07 17:35:12 17:35:16 17:35:25 17:35:28

Q So in Paragraph 148 when you talk about the combination of Froitzheim and Gan, do you envision a combination that includes Gan's oxide layer? 17:35:30 17:35:32 17:35:36 17:35:39

MR. SELWYN: Objection. Form. 17:35:42

A A combination that includes Gan's oxide layer would also meet the limitation of the claim, as would one in which it was not omitted. Because in both cases the combined teachings of Froitzheim and Gan include forming a layer of polysilicon 17:35:43 17:35:46 17:35:49 17:35:52 17:35:57

over a back surface of a silicon substrate. 17:36:00

Q Are you saying in this paragraph when you talk about the combination of Froitzheim and Gan you mean -- you could mean a combination that does not include Gan's oxide layer? 17:36:03 17:36:09 17:36:12 17:36:16

MR. SELWYN: Objection. Form. 17:36:21

A This claim, which is directed towards a method of manufacture of the structure, is about forming a layer of polysilicon over a back surface of a silicon substrate. And as I describe here, Gan teaches forming a layer over a polysilicon over a back surface of a silicon substrate, and the combination of Gan and Froitzheim teaches that. 17:37:02 17:37:05 17:37:09 17:37:13 17:37:19 17:37:25 17:37:30 17:37:34

Gan also then teaches -- teaches an oxide layer. That oxide layer is not required to meet this claim limitation. 17:37:34 17:37:42 17:37:45

Q I'm just trying to understand what you mean by "the combination of Froitzheim and Gan" in Paragraph 148. This combination that you write about here, does it include Gan's oxide layer or not? 17:37:46 17:37:56 17:37:59 17:38:03 17:38:08

MR. SELWYN: Objection. Form. 17:38:09

A The combination of Froitzheim and Gan 17:38:14
that -- combining the teachings of Froitzheim and 17:38:20
Gan, Froitzheim -- excuse me, Gan teaches an oxide 17:38:23
layer. Gan teaches a polysilicon layer. This 17:38:27
claim requires a polysilicon layer. Gan teaches 17:38:32
that. 17:38:36

And if one combined the teachings of Gan 17:38:37
and polysilicon, one has all of the elements of 17:38:40
the claim limitation, in particular forming a 17:38:46
layer of polysilicon over a back surface of a 17:38:50
silicon substrate. 17:38:52

Q So is that a no to my question? 17:38:59

A Can you ask your question one more time 17:39:01
for me, please. 17:39:03

Q Yep. My question was, I'm just trying to 17:39:03
understand what you mean by "the combination of 17:39:06
Froitzheim and Gan" in Paragraph 148. This 17:39:09
combination that you write about here, does this 17:39:13
include Gan's oxide layer or not? 17:39:15

MR. SELWYN: Objection. Form. 17:39:18

A What I'm combining is the teachings of 17:39:27

Gan and Froitzheim. And that's what's required, as I understand it, for a POSITA to make a combination when one is considering the obviousness of a claim. And Gan teaches a polysilicon layer. Gan also teaches an oxide layer. But combining Gan's teachings with Froitzheim, if the oxide layer is present or not, Gan teaches forming -- Gan with Froitzheim teaches forming a layer of polysilicon over a back surface of a silicon straight. 17:39:32 17:39:38 17:39:44 17:39:46 17:39:51 17:39:54 17:39:58 17:40:03 17:40:08 17:40:09

Q I am still not understanding when you say "the combination of Froitzheim and Gan" in Paragraph 148, do you envision a combination that has Gan's oxide layer, or does it not have Gan's oxide layer? 17:40:15 17:40:35 17:40:38 17:40:43 17:40:46

MR. SELWYN: Objection. Form. 17:40:48

A In order to meet the claim limitation, I don't believe that I have to envision one or the other. I believe that Gan and Froitzheim have teachings that meets the claim limitation with or without the oxide layer present here, because Gan teaches forming a layer of polysilicon over a 17:41:06 17:41:09 17:41:12 17:41:17 17:41:23 17:41:29

silicon substrate. Froitzheim teaches an emitter on the rear side of the back surface of a -- of a solar cell. And so the combination of Gan with Froitzheim would teach the polysilicon -- forming a layer of polysilicon over a back surface of a silicon substrate. 17:41:33 17:41:36 17:41:42 17:41:45 17:41:49 17:41:52

Q When you say "the combination of Froitzheim and Gan," are you contemplating an embodiment that would not include Gan's oxide layer? 17:41:53 17:41:58 17:42:03 17:42:05

MR. SELWYN: Objection. Form. 17:42:09

A I think that's similar if not the same to the question that you just asked. And so my answer remains the same, that I think that Gan teaches the formation of a layer of polysilicon. Gan also teaches an oxide. Whether you take the oxide or not, Gan's teachings when combined with Froitzheim meet the limitation of this claim. 17:42:11 17:42:13 17:42:18 17:42:21 17:42:29 17:42:32 17:42:35

Q But when you propose to combine Gan with Froitzheim, are you saying you don't necessarily need to take the oxide of Gan? 17:42:40 17:42:42 17:42:44

MR. SELWYN: Objection. Form? 17:42:47

A I think that's the same question. My answer is the same, which is that I think that Gan teaches a polysilicon layer formed over a silicon substrate. And Froitzheim teaches an emitter on the back side of a solar cell. And so implementing Gan and Froitzheim, one would put a polysilicon layer formed over a back surface of the silicon substrate, and those teachings are present regardless or with or without the teachings of Gan's oxide layer. 17:42:53 17:42:54 17:43:00 17:43:03 17:43:09 17:43:11 17:43:15 17:43:18 17:43:22 17:43:25

Gan teaches all of the elements of the claim when combined with Froitzheim. 17:43:30 17:43:33

Q But Gan teaches all of the elements of the claim when combined with Froitzheim how? 17:43:41 17:43:43

MR. SELWYN: Objection. 17:43:47

Q Are you combining Gan's oxide layer with Froitzheim here? 17:43:47 17:43:50

MR. SELWYN: Objection. Form. 17:43:55

A Per my previous answers, if the oxide layer is included, one still has a polysilicon layer over a back surface of a silicon substrate. The oxide layer is not included. One still has a 17:44:03 17:44:07 17:44:12 17:44:15

polysilicon layer formed over the back surface of the silicon substrate. So Gan's teachings in both cases, when combined with Froitzheim, Froitzheim provides motivation for implementing Gan on the back surface meet the -- meet the limitations of the claim. 17:44:19 17:44:21 17:44:24 17:44:28 17:44:30 17:44:35

Gan also has many other features, for example, that I'm not being asked about. So I don't think that one -- I don't think that the requirement for obviousness is that everything from one reference be mechanically included in everything from another reference; but rather, the teachings of one reference with the ordinary skill of a POSITA, when incorporated in another reference, provide a likely chance of success, and the POSITA would have motivation to make the combination. 17:44:38 17:44:44 17:44:47 17:44:53 17:44:58 17:45:01 17:45:04 17:45:07 17:45:11 17:45:18 17:45:21

Q Would a POSITA have motivation to make a combination of Gan and Froitzheim without Gan's oxide layer? 17:45:21 17:45:28 17:45:33

A Gan teaches that with the oxide layer, the J naught and rho C of the resulting 17:45:39 17:45:45

oxide-polysilicon-emitter combination are very good. 17:45:54 17:45:55

Gan references previous work in which oxide is omitted. Gan also describes work that Gan did and others have done in which an oxide layer is unintentionally grown, not thermally grown, and describes those results. 17:45:55 17:45:57 17:46:03 17:46:05 17:46:09

So Gan provides, I would say, clear motivation or explicit motivation for a POSITA to make the combination with the oxide. The same explicit motivation is not provided with the oxide. 17:46:15 17:46:20 17:46:25 17:46:30 17:46:34

But if you look at the -- my understanding of motivation to combine as presented in my declaration, it doesn't require -- just that there is no rigid requirement of finding an expressed teaching suggestion or motivation combined within the references in order to find a motivation; but rather that a person of ordinary skill in the art would have had reason to combine references or add missing features. 17:46:34 17:46:38 17:46:43 17:47:33 17:47:36 17:47:38 17:47:40 17:47:43 17:47:46

Q Does your declaration talk about a 17:47:52

POSITA's motivation to combine Froitzheim and Gan's polysilicon emitter without Gan's oxide layer? 17:47:57 17:48:02 17:48:06

A No. My combination focuses on -- excuse me. My declaration focuses on the combination with the oxide layer and the motivation to combine being provided by the excellent J naught and rho C values that that oxide and polysilicon emitter provides as I described previously from Gan, and the expected efficiency enhancement of that. 17:48:15 17:48:21 17:48:28 17:48:34 17:48:41 17:48:44 17:48:48

You can find that starting on Paragraph 121 of my declaration and extending through -- extending to 135. 17:48:52 17:49:00 17:49:27

MS. ZHAO: I'm about to start a new section. How are you doing? Do you need a break? 17:49:33 17:49:35

MR. SELWYN: Why don't we take five minutes. 17:49:37 17:49:39

MS. ZHAO: Okay. 17:49:39

THE WITNESS: Yeah, that would be nice. Thank you. 17:49:40 17:49:41

(A recess was taken.) 17:49:42

BY MS. ZHAO: 17:54:47

Q Let's go to Paragraph 199 of the '053 declaration. 17:54:48 17:54:51

A Okay. 17:55:12

Q In the middle of the paragraph you talk about a person of ordinary skill in the art would have understood that the combination of Froitzheim's manufacturing of a back-junction solar cell, Gan's manufacturing of a polysilicon emitter and oxide layer structure, and Smith's solar cell manufacturing techniques, and so on. 17:55:12 17:55:15 17:55:18 17:55:21 17:55:24 17:55:27 17:55:30

Do you see that? 17:55:33

A Yes. 17:55:35

Q I'm going to refer to this combination as the Froitzheim-Gan-Smith combination. 17:55:35 17:55:38

Is that okay? 17:55:46

A Yes, it is. 17:55:47

Q Let's go to Paragraph 205. 17:55:48

A Okay. 17:56:00

Q At the top of Page 129 you state that "Smith teaches depositing dopant source layers, such as BSG, using APCVD." 17:56:01 17:56:04 17:56:07

Do you see that? 17:56:12

A Yes, I do. 17:56:13

Q Is this a technique you are proposing to add to the Froitzheim-Gan-Smith combination? 17:56:14 17:56:17

MR. SELWYN: Objection. Form. 17:56:22

A Did you mean add to the Froitzheim -- I think I understand your question. 17:56:28 17:56:32

Q Let me ask it -- 17:56:33

A Included in the Froitzheim-Gan-Smith combination? 17:56:35 17:56:37

Q Thank you. Yes. 17:56:37

A I'm proposing here that Smith teaches certain advantages in manufacturing techniques that would motivate a POSITA to implement some of Smith's teachings in the Froitzheim-Gan device combination. That's what I'm suggesting. 17:56:43 17:56:49 17:56:54 17:57:02 17:57:07

Q This APCVD process, is that a manufacturing technique that a POSITA would have been motivated to implement in the Froitzheim-Gan device? 17:57:14 17:57:20 17:57:23 17:57:25

A So on Page 136, going on to Page 137, Paragraph 220, I discuss that a POSITA would have been motivated to modify the Froitzheim-Gan 17:58:00 17:58:15 17:58:21

combination to implement Smith's diffusion methods. And one thing that Smith teaches is the formation of a borosilicate glass as a source of a -- a dopant source, a P-type dopant source. Deposited by APCVD. I'm sorry, I'm not sure if I said that or not. 17:58:26 17:58:33 17:58:35 17:58:44 17:58:57 17:59:01

Q Okay. Let's look at Exhibit 1007, Smith. 17:59:04

(Exhibit 1007, previously marked, not attached.) 17:59:04 17:59:04

A Okay, I'm there. 17:59:19

Q Let me direct you to Column 2, Lines 44 to 49. 17:59:20 17:59:25

A Column 2, 42 to 49? 17:59:38

Q Forty-four to 49. 17:59:41

A Got it. Yes. 17:59:47

Q These lines talk about a boron-doped silicon dioxide labeled as 104, deposited on the back side of a wafer. Right? 17:59:49 17:59:53 17:59:58

A Yes. 18:00:00

Q The Froitzheim-Gan-Smith combination that you propose, would it also have a boron-doped silicon dioxide? 18:00:00 18:00:08 18:00:11

A Yes. And in fact, Smith already -- excuse me, Froitzheim already teaches forming such a dopant source, boron dopant source. And Gan also teaches forming boron sources. Smith teaches an improved method using APCVD of forming this boron dopant source. 18:00:20 18:00:26 18:00:33 18:00:38 18:00:45 18:00:52

Q Going to Lines 53 to 60. They talk about an undoped silicon dioxide labeled as 106 being deposited over the boron-doped silicon dioxide. 18:00:54 18:00:59 18:01:05

Right? 18:01:08

A Yes, I see that. 18:01:09

Q Does the Froitzheim-Gan-Smith combination have an undoped silicon dioxide, too? 18:01:10 18:01:14

A It can. And that is not a limitation of the claims that we were looking at, but comes in in Claim 1C, which is discussed in Paragraph 159 -- excuse me, Page 159 of my declaration. 18:02:28 18:02:33 18:02:39 18:02:43

One of the advantages that Smith teaches about his manufacturing method is that these undoped silicon dioxide capping layers can prevent dopants from diffusing in undesirable directions. And those teachings of Smith can be implemented in 18:02:51 18:02:55 18:03:01 18:03:09 18:03:14

the Froitzheim-Gan combination, and are implemented in that combination. In particular to arrive at Element 1C of Claim 1 on Page 159 of my declaration. 18:03:19 18:03:24 18:03:32 18:03:39

Q The next paragraph in Smith, starting in Column 2, on Line 65, talks about forming a mask, and going into Column 3, paragraph starting on Line 11, the mask is used to pattern the silicon dioxide stack comprising Components 104 and 106. 18:03:40 18:03:44 18:03:49 18:03:53 18:03:56

Do you see that? 18:04:04

A Yes, I do. 18:04:08

Q Does the Froitzheim-Gan-Smith combination include the process described in Column 2, Lines 65 to Column 3, Line 18? 18:04:09 18:04:12 18:04:16

A Make sure I get that right. Column 2, 65; Column 3, 18. 18:04:22 18:04:27

Is that correct? 18:04:28

Q Yep. 18:04:30

A Thank you. 18:04:31

This portion of Smith -- this portion of Smith is teaching a method to pattern the emitter and back surface field layer at the rear side of 18:05:22 18:05:33 18:05:39

Smith's solar cell to make a back-contact solar cell. No such patterning is required by the limitations of the '053 patent, and consequently I have not drawn from these teachings of Smith in my combination. 18:05:42 18:05:47 18:05:50 18:05:57 18:05:59

Q Going to Column 3, paragraph starting on Line 19. This paragraph starts with a phosphorous doped silicon dioxide being deposited over the sample of Figure 4. 18:06:03 18:06:05 18:06:14 18:06:17

Do you see that? 18:06:19

A Yes, I do. 18:06:19

Q Does the Froitzheim-Gan-Smith combination include a phosphorous doped silicon dioxide? 18:06:20 18:06:24

A It does. The Froitzheim-Gan-Smith combination includes a phosphorous diffusion at the front surface of the wafer to form the N plus layer that Froitzheim has in his solar cell. And in the formation of that N plus layer, a phosphorous dopant source, phosphorous glass, for instance, would be formed at the front side of the wafer. 18:07:04 18:07:08 18:07:16 18:07:20 18:07:27 18:07:33 18:07:36 18:07:38

Q Then the paragraph talks about an undoped 18:07:38

silicon dioxide deposited over the phosphorous doped silicon dioxide. 18:07:45 18:07:50

Do you see that? 18:07:51

A Yes, I do. 18:08:06

Q Does the Froitzheim-Gan-Smith combination include this undoped silicon dioxide? 18:08:06 18:08:10

A This teaching of Smith, while required for Smith's back-contact solar cell and its patent therein, is not required for the Froitzheim-Gan-Smith combination. And I have not, if I remember correctly, included Smith's teachings on an undoped silicon oxide over an N-type silicon -- phosphorous doped silicon oxide glass in my combination. It's not required and not part of the claim limitations. 18:09:00 18:09:06 18:09:12 18:09:19 18:09:39 18:09:45 18:09:52 18:09:57 18:10:02

Q Column 3, starting on Line 40, Smith goes into the in situ steps. Right? 18:10:10 18:10:13

A Just one moment, please. 18:10:21

Can you repeat that for me one more time? 18:10:31

Q Column 3, starting on Line 40, is where Smith starts to talk about the in situ steps. 18:10:34 18:10:39

Right? 18:10:43

A That is correct. 18:10:43

Q Is the in situ diffusion process also a technique you are proposing to implement in the Froitzheim-Gan-Smith combination? 18:10:43 18:10:49 18:10:54

A Yes, it is. Smith teaches that one of the advantages of his methods is this in situ procedure in which multiple -- multiple diffusions are performed with one loading of -- of the wafer. And I describe this beginning on Page 149 of my declaration. 18:11:03 18:11:08 18:11:21 18:11:27 18:11:38 18:11:44

And this, in fact this in situ process in which the substrate in the one loading of the tool is heated up to perform the diffusion that forms Gan's P-type polysilicon emitter, and then without removal from the tool per Gan's teachings with the flow of POCl3, forms the N plus front surface field at the -- at the front of -- front of the wafer. And this, in fact, is why Gan -- excuse me, Smith's undoped oxide layer over a thin type glass, your previous question, is not required. Because the doping of the front surface to achieve Froitzheim's N plus front surface field layer can 18:11:47 18:11:54 18:12:04 18:12:08 18:12:13 18:12:20 18:12:32 18:12:34 18:12:42 18:12:48 18:12:50 18:12:55

occur via this in situ step that I describe beginning on Page 139. 18:12:59 18:13:04

Q So Smith talks about a first in situ step where the wafer is heated to about 1000 degrees C. Right? 18:13:12 18:13:14 18:13:18

A Correct. 18:13:20

Q And in the Froitzheim-Gan-Smith combination, would you be heating the wafer to 1000 degrees C as well? 18:13:20 18:13:26 18:13:28

A Once again, the particular numbers of a method are not required in making an obvious combination. A POSITA has ordinary ingenuity in learning from the teachings and making the combination. 18:13:33 18:13:37 18:13:41 18:13:46 18:13:49

But Smith teaches 1000 degrees Celsius for one hour for this diffusion. Gan teaches 900 degrees to 1000 degrees and shows both values for a diffusion to form his P-type polysilicon emitter, and shows times that are consistent with that one hour. Froitzheim teaches a temperature range of 900 to 1200 degrees C. All of these are consistent. A POSITA would be able to look at 18:13:49 18:13:54 18:13:59 18:14:03 18:14:08 18:14:10 18:14:15 18:14:19

these and recognize that these processes would work together. 18:14:21 18:14:25

Q Is it accurate to say that a temperature within the range disclosed by Smith or Gan or Froitzheim would work, for the Froitzheim-Gan-Smith combination? 18:14:28 18:14:33 18:14:39 18:14:45

A Yes, if I understood your statement correctly, the teachings of Gan, Smith, and Froitzheim are consistent regarding diffusion temperatures, and a diffusion temperature consistent with their teachings would work for the combination. 18:14:49 18:14:54 18:15:00 18:15:05 18:15:12 18:15:15

Q And in the Froitzheim-Gan-Smith combination, this heating would diffuse both the boron-doped silicon dioxide and the phosphorous-doped silicon dioxide. 18:15:18 18:15:26 18:15:29 18:15:33

Is that right? 18:15:36

A There are multiple ways that this could be implemented. A POSITA can -- can learn from the teachings within Smith. 18:15:41 18:15:44 18:15:52

So in the first step it is important, it is necessary that the P-type emitter become doped, 18:15:56 18:15:59

the N diffusion of boron that needs to happen in the first step. And a possible second step as taught by Smith dopes the front side of the wafer N-type, as I describe on Page 153. This all would happen within one loading of the wafer into the tool, per Smith's teachings about the manufacturing value of in situ diffusion. 18:16:15 18:16:18 18:16:23 18:16:33 18:16:38 18:16:40 18:16:46

Q Is it possible to only dope the P-type emitter in the first step but not the N-type -- 18:16:50 18:16:59

MR. SELWYN: Objection -- 18:17:02

Q (Inaudible.) 18:17:02

MR. SELWYN: Objection. Form. 18:17:03

A Yes, consistent with the teachings of Froitzheim, Gan, and Smith, this is possible. For example, adding the doped -- boron-doped glass on the back of Gan's polysilicon emitter, loading the wafer into the tool, performing Smith's first step to diffuse the dopants into the polysilicon emitter, and then switching to Smith's second step, which flows POCl. And in so doing forms the phosphorous glass and drives that phosphorous glass -- the dopants from that phosphorous glass 18:17:08 18:17:10 18:17:15 18:17:23 18:17:30 18:17:34 18:17:38 18:17:41 18:17:51 18:17:54

into the wafer, and then removing the wafer from the tool. That's one implementation of Smith's teachings into the Froitzheim-Gan combination, as I think I described in this section of my declaration. 18:17:58 18:18:02 18:18:05 18:18:09 18:18:12

Q If you were to do that, would phosphorous glass also form on the P-type dopant side of the wafer? 18:18:12 18:18:20 18:18:23

A One moment, please. 18:18:35

Your question was would an oxide be formed on both surfaces of the wafer during Smith's second step. Correct? 18:19:48 18:19:50 18:19:56

Q I said would phosphorous glass also form on the P-type dopant side of the wafer? Because I thought in your answer you talked about how performing Smith's first step to diffuse the dopant into polysilicon emitter and then switching to Smith's second step which flows POCl and in doing so forms the phosphorous glass. So I just want to know, would that phosphorous glass also be formed on the P-type dopant side of the wafer. 18:20:01 18:20:06 18:20:15 18:20:19 18:20:23 18:20:26 18:20:30 18:20:33 18:20:37

A I understand. 18:20:40

So it will certainly be formed on the front of the wafer because the POCl can react with the silicon surface on the back side of the wafer from the diffusion that already occurred into Gan's polycrystalline emitter, there was -- there would be presence of boron-doped glass and potentially an undoped oxide layer per Smith, as we've discussed previously. 18:20:41 18:20:43 18:20:51 18:20:54 18:20:58 18:21:03 18:21:06 18:21:12

The POCl may react some with those existing oxide layers. I don't think it would grow as much of the glass, if any, as it would on the front side where it can react with the -- with the silicon. 18:21:14 18:21:19 18:21:28 18:21:32 18:21:35

But what you're -- what we're describing here is common to both Froitzheim and Smith. Both of them envision forming a P-type diffusion and subsequently doping the front of their wafers N-type through a POCl process. Both have that. 18:21:39 18:21:41 18:21:47 18:21:54 18:21:59

Q So in the Froitzheim-Gan-Smith combination, we talked about how in the first step of the in situ -- the first in situ step you could diffuse both P-type dopant and N-type dopant, or 18:22:02 18:22:12 18:22:15 18:22:20

you could in the first step diffuse one and in the second step diffuse the other. Right? 18:22:25 18:22:28

MR. SELWYN: Objection. Form. 18:22:36

A Yes, we talked mostly about the second of what you described. But both could be possible. 18:22:52 18:22:55

Q Is one process more preferable than the other? 18:23:01 18:23:04

MR. SELWYN: Objection. Form. 18:23:10

A In my declaration I have -- I have described -- is one preferable to the other? I expect that there are trade-offs that a POSITA would consider when making a design choice between one and the other. 18:23:12 18:23:18 18:23:39 18:23:44 18:23:47

Q Can you talk about that trade-off a bit more? 18:23:50 18:23:52

A For example, there could be cost trade-offs in forming the -- an N-type glass first and then diffusing it, versus forming the N-type glass -- diffusing it in the first step with the P-type dopants versus diffusing it in a second step. 18:24:16 18:24:19 18:24:34 18:24:38 18:24:41 18:24:46

If one were interested in implementing 18:24:51

other aspects of Froitzheim, like Froitzheim's selective front surface field, which has two different dopings, one might even implement both the phosphorous glass diffusion selectively at the front and -- sorry, one might implement both the co-diffusion in the first step and the second step POCl diffusion. Recall that Froitzheim talks about forming this selective front surface field in a manner similar to that, a manner which would be advantaged by implementing Smith's combinations. 18:24:53 18:24:56 18:25:00 18:25:05 18:25:10 18:25:16 18:25:22 18:25:25 18:25:30 18:25:33 18:25:36

I don't go into these details in my declaration because it's not described by the limitations of the -- of the claim. But there are possibilities that a POSITA could consider when making a design trade-off. 18:25:37 18:25:40 18:25:45 18:25:52 18:25:55

Q You said there are cost trade-offs in forming an N-tech glass first and then diffusing it versus forming the N-type glass, diffusing it in the first step with the P-type dopants, versus diffusing in a second step. 18:25:57 18:26:09 18:26:12 18:26:15 18:26:20

Can you talk about what that cost 18:26:21

trade-off is? Is one cheaper than the other, is that what you mean? 18:26:24 18:26:28

MR. SELWYN: Objection. Form. 18:26:28

A Yes, in reality, every change made in solar cell manufacturing implies a cost trade-off. And so POSITAs, when implementing a manufacturing sequence, are always asking questions about, Hey, does this enhance the efficiency, is there an associated change in cost, et cetera. 18:26:30 18:26:34 18:26:39 18:26:46 18:26:51 18:26:54

So without knowing details, I couldn't tell you which one was more expensive or less expensive. It depends on the particular implementations. But cost trade-offs would be one example that a POSITA would consider when making design choices about how to implement particular teachings. 18:26:58 18:27:00 18:27:03 18:27:05 18:27:11 18:27:18 18:27:28

Q Smith also talks about a second in situ step. Right? 18:27:28 18:27:34

A Smith? 18:27:36

Q Yes. 18:27:36

A Yes, that's correct. 18:27:41

Q Would the Froitzheim-Gan-Smith 18:27:42

combination use the second in situ step? 18:27:46

A I'm sorry, I'm confused. We were just 18:27:53

talking about the second in situ step. So as I 18:27:55

describe in particular Page 151, 152, and 153, one 18:27:59

implementation of Smith's teachings into the 18:28:09

Gan-Froitzheim combination would be to, in the 18:28:14

first step, diffuse boron from the glass into 18:28:18

Gan's polysilicon emitter. And Smith's second 18:28:25

step, second in situ step, to change the diffusion 18:28:31

conditions to diffuse phosphorous into the front 18:28:38

of the wafer and form N plus front surface field. 18:28:40

Q In the scenario where you diffuse both 18:28:44

dopants in the first step, would you still need 18:28:49

the second step? 18:28:52

A Not necessarily, but you could. As I 18:28:57

described a moment ago, if, for example, you 18:29:01

wanted to implement Froitzheim's selective front 18:29:03

surface field, this would be a great way to do it. 18:29:08

But I don't address that in my combination because 18:29:15

it's not one of the limitations of the claim. 18:29:17

Q Are you saying the Froitzheim-Gan-Smith 18:29:19

combination that you propose does not include 18:29:33

Froitzheim's selective front surface field? 18:29:36

A I'm saying that the combination that I 18:29:43

propose is silent on the matter of whether there's 18:29:47

a front surface field because it's -- a selective 18:29:49

front surface field, because a selective front 18:29:54

surface field is not required to meet the 18:29:57

limitations of the claim. 18:30:00

One could use Froitzheim's selective 18:30:04

front surface field if one so desired; the 18:30:09

resulting device would still meet the limitations 18:30:13

of the claim. One could omit it; the resulting 18:30:15

device and process would still meet the 18:30:18

limitations of the claim. 18:30:21

Q If one were to omit the selective front 18:30:21

surface field in the Froitzheim-Gan-Smith 18:30:24

combination and if one were to diffuse both dopant 18:30:28

in the first in situ step, would you still need 18:30:34

the second in situ step? 18:30:39

MR. SELWYN: Objection. Form. 18:30:43

A There -- in the hypothetical that you 18:30:53

have created, I believe it could be possible to 18:30:56

achieve the device with one -- one diffusion, 18:31:02

so-called co-diffusion. 18:31:08

This still meets Smith's teachings of in situ because Smith teaches that in situ -- the steps are in situ, in that they are performed in one loading of Wafer 102 into the wafer processing. So that would still be the case for the hypothetical that you've described. But I believe it would be one diffusion rather than Smith's two-step diffusion in that case. 18:31:11 18:31:17 18:31:26 18:31:29 18:31:36 18:31:38 18:31:41 18:31:43

Q On Line 59 of Smith, in Column 3 -- just make sure that's the right one. Yes. Smith says to diffuse phosphorous as an N-type dopant into Wafer 102 and to grow a thin layer of silicon dioxide on both sides of the wafer. 18:31:45 18:32:01 18:32:05 18:32:09 18:32:13

Do you see that? 18:32:16

A Yes, I do. 18:32:24

Q In the Froitzheim-Gan-Smith combination, if you were to use a second in situ step, would there also be a thin layer of silicon dioxide on both sides of the wafer? 18:32:25 18:32:30 18:32:33 18:32:39

MR. SELWYN: Objection. Form. 18:32:42

A I think we talked about this previously, 18:34:21

and my answer is the same. I see the lines that you're pointing out. I see between Figure 6 and Figure 7 of Smith that Smith shows this oxide growth on the front surface of the wafer where the POCl can react with the silicon, as I was describing previously. And Smith draws this as 101B in Figure 7. That appears it wasn't present in Figure 6, the back side of the wafer is not drawn as having any change between Figure 6 and Figure 7. Although Smith's text, the region that you read, describes a thin layer of oxide on the back as well. So it may be that Smith is observing what I described previously, where there's some oxide growth on the back, not as much on the front where the silicon is exposed. 18:34:25 18:34:29 18:34:35 18:34:42 18:34:45 18:34:49 18:34:52 18:34:58 18:35:02 18:35:05 18:35:11 18:35:15 18:35:18 18:35:19 18:35:25

I also look to Froitzheim in answering your question. And as I mentioned previously, Froitzheim's process similarly puts a wafer into a POCl diffusion furnace after diffusing the P-type emitter. And Froitzheim describes this diffusion in Paragraph 44. 18:35:27 18:35:31 18:35:40 18:35:43 18:35:52 18:36:10

Froitzheim doesn't describe whether or 18:36:17

not there's an oxide layer that is grown on the back side, for example, during that process, and whether there are any consequences of that. 18:36:19 18:36:24 18:36:26

Q Let's go to Paragraph 281. 18:36:32

A Of my deposition. 18:36:42

Q Of your '053 declaration. 18:36:43

A The declaration. 281? 18:36:46

Q 281, Page 168. 18:36:49

A Okay, I have arrived. 18:36:59

Q We're now in the section with Li, Gan, and Smith. So I'm going to call the structure you are proposing in this section the Li-Gan-Smith combination. 18:37:00 18:37:03 18:37:06 18:37:09

Is that okay? 18:37:10

A Yes, it is. 18:37:10

Q In this paragraph, 281, you talk about, three lines in, "replacing these deposited silicon thin film with Gan's deposited polysilicon emitter and implementing an oxide layer." 18:37:11 18:37:17 18:37:21 18:37:25

Do you see that? 18:37:28

A Yes, I do. 18:37:32

Q In this Li-Gan-Smith combination, are we 18:37:32

still implementing Gan's Steps 3, 4, 5, 9, and 10 that we discussed earlier? 18:37:38 18:37:44

A We are certainly implementing Gan's teaching for oxide layer and P-type polysilicon emitter. And those teachings are -- one embodiment of those teachings are shown in Gan's 3, 4, 9, 10. Were those the numbers that you mentioned? 18:37:49 18:37:52 18:38:00 18:38:06 18:38:10 18:38:21

Q I believe you also included Step 5. 18:38:22

A I did. And then -- and then backed away from that because I had forgotten that Step 4 in fact says, first step anneal. So that's not really required. I apologize for confusion there. 18:38:26 18:38:30 18:38:33 18:38:39

Q Okay. 18:38:42

A So those Steps 3, 4, 9, 10, from -- from Gan are some of Gan's -- an embodiment of Gan's teaching for oxide layer growth and polysilicon deposition and dopant drivant on the emitter. 18:38:43 18:38:49 18:38:52 18:38:56

Q Let's look at Exhibit 1008, Li. 18:39:03

(Exhibit 1008, previously marked, not attached.) 18:39:07 18:39:13

Q Now, on Page 4, Section 5, titled 18:39:13

Detailed Description of Embodiment. 18:39:19

A Yes. 18:39:21

Q The first paragraph under this section talks about how to construct Li's solar cell. 18:39:21 18:39:26

Right? 18:39:32

A Yes. 18:39:32

Q Li starts with a high-quality N-type monocrystalline silicon wafer. Right? 18:39:32 18:39:36

A Yes. 18:39:42

Q Would this be the type of wafer used in the Li-Gan-Smith combination? 18:39:43 18:39:47

A Li is the primary reference here. And Li teaches this wafer is suitable for making Li's device. So this is an appropriate wafer as taught by Li to use, including in the combination. 18:40:02 18:40:08 18:40:12 18:40:17

Q Then Li talks about cleaning the surfaces of the wafer and texturing it. Right? 18:40:22 18:40:24

A Yes. 18:40:27

Q The Li-Gan-Smith combination, would it have these processes, too? 18:40:27 18:40:33

A Yes. And Smith as well describes texturing and cleaning of wafers. These are 18:40:34 18:40:43

standard processing steps done on nearly all silicon solar cells. 18:40:47 18:40:51

Q Next Li talks about a highly doped N plus layer being diffused on the front surface. Right? 18:40:53 18:40:58

A Correct. 18:41:01

Q Is this step retained in the Li-Smith-Gan combination? 18:41:02 18:41:10

A This is required to make Li's solar cell to have an N plus layer on the front side. Li teaches that it's diffused. This teaching tells you how to do it. This is appropriate to include in the combination. 18:41:11 18:41:12 18:41:15 18:41:21 18:41:25

Q Then Li talks about a thin film having antireflection effect being deposited or grown on the N plus layer. Right? 18:41:26 18:41:31 18:41:34

A That's correct. 18:41:39

Q Is this step retained in the Li-Gan-Smith combination? 18:41:39 18:41:43

A It is required to have an antireflection coating to make Li's device in the combination. Li teaches how to do it. Smith also teaches how to do it. 18:41:44 18:41:47 18:41:52 18:41:54

Q And Li talks about a silicon thin film being deposited on the back surface of the wafer. Right? 18:41:55 18:41:58 18:42:01

A Yes. 18:42:04

Q Is this what you're replacing with Gan's steps? 18:42:04 18:42:06

A Yes, I am replacing in this combination Li's silicon thin film deposited emitter with Gan's oxide polysilicon deposited emitter. 18:42:12 18:42:14 18:42:18

Q Li also talks about preparing a positive electrode on the antireflection layer. Right? 18:42:23 18:42:26

A Yes. 18:42:31

Q Is this step retained in the Li-Gan-Smith combination? 18:42:32 18:42:37

A The solar cell must have two metal contacts, also called electrodes, in order to successfully extract electricity, electrical power. Li teaches how to do it. Smith also teaches how to do it. 18:42:38 18:42:43 18:42:46 18:42:50 18:42:54

Q By the way, is the cell structure disclosed in Li a silicon solar cell? 18:43:00 18:43:04

A Yes, it is. 18:43:07

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Maxeon Exhibit 2029

Q Would you call it a heterojunction solar cell? 18:43:08 18:43:11

A Li teaches that Li's emitter can be amorphous silicon. And if it is amorphous silicon, I would certainly call it a heterojunction solar cell. 18:43:14 18:43:20 18:43:23 18:43:24

Li teaches that Li's emitter can also be crystalline silicon, and more particularly microcrystalline or nanosilicon, nanocrystalline silicon. And in this case, similar to your questions before about a polycrystalline silicon emitter, one would normally just call this a silicon solar cell as of 2008, as opposed to identifying it as a homojunction. And it definitely would not normally be called a silicon heterojunction as I described this morning that that term was used for amorphous silicon crystalline silicon heterojunctions. 18:43:27 18:43:35 18:43:41 18:43:45 18:43:47 18:43:54 18:43:57 18:44:00 18:44:04 18:44:07 18:44:10 18:44:13

Q I would like to go over the steps in Smith again, this time in the context of Li, Gan, and Smith. So earlier we talked about Smith disclosing a boron-doped silicon dioxide on the 18:44:16 18:44:23 18:44:27 18:44:29

back side of the wafer. Right? You can find that in Smith Column 2, Line 44. 18:44:33 18:44:44

A Yes, we discussed that previously. That's correct. 18:44:46 18:44:50

Q Does the Li-Gan-Smith combination have a boron-doped silicon dioxide? 18:44:51 18:44:55

A Yes; both Gan and Smith teach the formation of a dopant source layer, as is required to dope Gan's polysilicon emitter. 18:45:02 18:45:04 18:45:09

Q And Smith also discloses an undoped silicon dioxide being deposited over the boron-doped silicon dioxide. Right? 18:45:11 18:45:16 18:45:20

A Yes, that is correct. Smith teaches that. 18:45:24 18:45:26

Q Does the Li-Gan-Smith combination have an undoped silicon dioxide too that is deposited over the boron-doped silicon dioxide? 18:45:27 18:45:31 18:45:36

A Just one moment. Sorry for the delay. 18:46:29

Okay. That undoped layer could be included. I have not included it in my combination, as my Ground 3 that uses Li as the primary reference covers Claims 9 through 20, and 18:47:23 18:47:27 18:47:31 18:47:34

those claims do not have as a limitation an undoped capping layer. But that's found in Claim 1. And so I have not included it here. Smith does teach it. It and other teachings could, of course, be included. They weren't required for my combination. 18:47:40 18:47:44 18:47:49 18:47:54 18:48:00 18:48:02

Q Smith also talks about a phosphorous-doped silicon dioxide. Right? 18:48:03 18:48:09

A That is correct. 18:48:13

Q Does the Li-Gan-Smith combination includes a phosphorous-doped silicon dioxide? 18:48:15 18:48:18

A Li as the primary reference as an N plus layer at the front, similar to Froitzheim, a front surface field, and it is diffused. And so one can follow -- well, both Li and Smith have teachings about how to form an N plus layer. And Smith gives you two teachings, as we discussed in the previous combination. One in which an oxide is formed and then it goes into a furnace, and another in which the oxide is formed by flowing POCl during a furnace step. 18:48:23 18:48:26 18:48:32 18:48:37 18:48:45 18:48:51 18:48:55 18:48:58 18:49:00 18:49:04

Q Does -- 18:49:07

A Pardon me. Go ahead. 18:49:09

Q No. Please. 18:49:10

A Go ahead. I'm finished. 18:49:12

Q Smith also talked about an undoped silicon dioxide being deposited over the phosphorous-doped silicon dioxide. Right? 18:49:13 18:49:16 18:49:19

A Correct. 18:49:22

Q Would the Li-Gan-Smith combination include an undoped silicon dioxide deposited over the phosphorous-doped silicon dioxide? 18:49:23 18:49:26 18:49:30

A Similar to my previous answer, one could use this. It is a teaching of Smith. It's not a teaching of Smith that is required to meet the limitations of any of Claims 9 through 20, which are the claims addressed by my Ground 3 combination with Li. 18:49:39 18:49:41 18:49:44 18:49:48 18:49:51 18:49:54

Q Does that mean your combination does not include it? 18:49:55 18:50:03

A My combination does not require it. 18:50:04

Q Going back to Smith's first in situ step, where the wafer is heated to about 1000 degrees C. In the Li-Gan-Smith combination, would you be 18:50:07 18:50:15 18:50:20

heating the wafer to 1000 degrees C as well? 18:50:22

A Yes, I describe on Page 191 implementing 18:50:52

in Smith's in situ teachings into -- into Li. And 18:50:57

that would include Li and Gan -- excuse me, that 18:51:04

would include diffusing dopants into Gan's emitter 18:51:10

at the back of Li's solar cell. 18:51:17

One thing to note is that that step is a 18:51:23

high-temperature processing step, would be done 18:51:29

naturally -- a natural place to do it would be 18:51:36

after the surfaces are cleaned and textured by 18:51:38

standard industrial process, as described by Li, 18:51:41

and not -- not at the point in the process in 18:51:48

which Li describes depositing an emitter. That is 18:51:53

to say, we are replacing structurally Li's emitter 18:51:56

with Gan's emitter using Smith's manufacturing 18:52:01

methods. But a POSITA, with his or her normal 18:52:04

ingenuity, would understand that higher 18:52:08

temperature processing steps usually precede lower 18:52:10

temperature processing steps in fabrication, and 18:52:15

so would make adjustments to the order in which 18:52:19

the -- the fabrication order. 18:52:22

Q What is the lower temperature processing 18:52:28

steps in Li? 18:52:30

A Li teaches, for example, a thin film having an antireflection effect such as silicon nitride or silicon dioxide. It's deposited or grows on the N plus layer. 18:52:36 18:52:40 18:52:44 18:52:47

As you will find in other references, Froitzheim, Smith -- Smith is a great example since it's used in the combination, that antireflection coating in the metal contact steps typically occur at the end. 18:52:50 18:52:56 18:53:00 18:53:03 18:53:07

Q So is it accurate to say that in the Li-Gan-Smith combination you would not be diffusing both types of dopants during the first step of -- during the first in situ step. Right? 18:53:15 18:53:17 18:53:19 18:53:24

A I don't think I said anything to that effect. Similar to the combination of Froitzheim-Gan and Smith, Li has a diffusion step already described to form the N plus front surface field. That step still needs to happen. And it could happen using Smith's in situ teachings either in a one two-step, where the first step is the boron diffusion of the emitter and the second 18:53:30 18:53:32 18:53:38 18:53:41 18:53:47 18:53:51 18:53:57 18:54:02

step is the phosphorous diffusion of the front surface field, per Smith's teachings. Or the two could happen together in a co-diffusion, which would still meet Smith's intent or definition of in situ. 18:54:05 18:54:07 18:54:12 18:54:15 18:54:19

I think either of these is possible. 18:54:20

Q I thought earlier you said the N-type layer requires a lower temperature, or did I misunderstand you? 18:54:26 18:54:31 18:54:34

A I didn't. Or if I did, I didn't mean to. I tried to say that the antireflection coating and the metal contact layers are typically done after high-temperature diffusion steps, as for example you would find in Smith. 18:54:38 18:54:42 18:54:45 18:54:49 18:54:53

Q So Smith's second in situ step involves the heating to 750 degrees and then to 975 degrees. Right? 18:54:55 18:55:21 18:55:27

A It does. 18:55:29

Q So the Li-Gan-Smith combination, would it also use the second in situ step? 18:55:29 18:55:34

A As I mentioned, it could. That's part of Li -- excuse me, Smith's teachings. And it is a 18:55:38 18:55:41

way of forming an N plus layer at the surface. Li describes an N plus layer at the surface. It doesn't say how to make it beyond that it's a diffusion. 18:55:46 18:55:50 18:55:54 18:56:01

And alternatively, as we were just discussing, another method would be to use Smith's teachings of forming phosphorous glass and then co-diffusing that phosphorous at the front side at the same time the boron is diffused at the back side. 18:56:02 18:56:05 18:56:11 18:56:19 18:56:22 18:56:25

In Smith's teachings those two regions are adjacent on the back side of the wafer, but the same teachings can be implemented trivially with the phosphorous layer at the front. So either of these is consistent with -- or is within Smith's teachings and is in situ diffusion as defined by Smith. 18:56:25 18:56:29 18:56:34 18:56:38 18:56:40 18:56:43 18:56:49

MS. ZHAO: Okay. I'm done with the '053 declaration. Shall we take a five-minute break? 18:56:50 18:56:55

MR. SELWYN: Sure. 18:56:58

THE WITNESS: Yes, please. 18:56:59

(A recess was taken.) 18:57:00

IPR2024-01199
Maxeon Exhibit 2029

BY MS. ZHAO: 19:06:56

Q Dr. Holman, the other IPR you are testifying on today is IPR2024-01203. 19:06:58 19:07:02

Is that right? 19:07:09

A Yes. 19:07:11

Q You submitted a declaration for that IPR? 19:07:12

A I did. 19:07:17

Q And you have that declaration in one of your binders. Right? 19:07:17 19:07:20

A Yes. 19:07:22

Q And for the record, I am referring to Exhibit 1003. 19:07:22 19:07:26

(Exhibit 1003, IPR2024-01203, previously marked, not attached.) 19:07:26 19:07:26

Q This declaration relates U.S. Patent Number 8,222,516. 19:07:28 19:07:30

Is that right? 19:07:32

A Yes. 19:07:37

Q You call this patent the '516 patent. 19:07:37

Right? 19:07:40

A Correct. 19:07:41

Q So I'll refer to your declaration as the 19:07:41

'516 declaration. 19:07:45

Is that okay? 19:07:46

A Yes. 19:07:53

Q Did you prepare the '516 declaration all by yourself? 19:07:54 19:07:56

A The '516 declaration represents my opinions, my ideas, and my opinions and ideas only. I didn't type all of the words into word-processing software myself. But I have reviewed, edited every word and signed the declaration accordingly. 19:07:56 19:07:59 19:08:02 19:08:06 19:08:09 19:08:13

Q How many hours have you spent on preparing the '516 declaration? 19:08:14 19:08:18

A I think I did this estimate before. Approximately 60 hours between the -- split between the '516 and '053. There is a fair amount of overlap between them. 19:08:26 19:08:32 19:08:34 19:08:40

Q Sitting here today, do you still agree with all the statements you made in the '516 declaration? 19:08:43 19:08:46 19:08:48

A Yes. 19:08:48

Q Is there anything you wish to alter in 19:08:48

the '516 declaration? 19:08:51

A No. 19:08:55

Q Is there anything you wish to add to the '516 declaration? 19:08:56 19:08:57

A No. 19:08:59

Q Let's take a look at the table of contents. 19:08:59 19:09:05

A Okay. 19:09:05

Q I am on Page 2 of the table of contents. 19:09:09

Ground 1 involves a combination of Froitzheim and Gan. 19:09:14 19:09:18

Do you see that? 19:09:18

A Yes. 19:09:20

Q Earlier with, respect to the '053 declaration, we discussed a Froitzheim-Gan combination that would retain certain manufacturing steps from Froitzheim. Correct? 19:09:20 19:09:25 19:09:27 19:09:31

A Correct. 19:09:35

Q Now, the combination of Froitzheim and Gan in the '516 declaration, does it involve the same manufacturing steps from Froitzheim? 19:09:35 19:09:38 19:09:42

A The '516 declaration is aimed at 19:09:49

evaluating the obviousness of the claims of the '516 patents, which are not a method claim. They're not about manufacturing steps, but rather about the structure that's made. 19:09:53 19:09:55 19:09:59 19:10:02

Q So are we talking about a different combination of Froitzheim-Gan here in the '516 declaration? 19:10:06 19:10:08 19:10:12

MR. SELWYN: Objection. Form. 19:10:15

A We are talking about a combination of the teachings of Froitzheim and Gan. The same Froitzheim as in the '053 declaration and the same Gan as in the '053 declaration, but we are looking to their teachings of structure; whereas the '053 declaration is focused on their teaching of method because the '053 claims are method claims. 19:10:16 19:10:17 19:10:20 19:10:24 19:10:28 19:10:36 19:10:41

Q If I can have you go to Gan real quick. 19:10:44

Would the combination of Froitzheim and Gan in the '516 declaration still use Steps 3, 4, 9, and 10 of Gan? 19:10:50 19:10:53 19:11:00

A Again, the '516 declaration is evaluating the obviousness of claims that are structure claims, or describing a particular device. The 19:11:23 19:11:27 19:11:34

teachings of Gan and Froitzheim include teaching how to make such a device. But in the '516 declaration I'm focusing on the devices that are made and the teaching of those -- those devices. So I haven't specifically addressed which of Gan's processing steps, for example, would be included in the combination. But Gan does teach -- teaches the combination -- Gan and Froitzheim teach the combination and how to make it. 19:11:40 19:11:46 19:11:52 19:11:57 19:12:02 19:12:07 19:12:12 19:12:16 19:12:21

Q Would a POSITA know how to make a Gan and Froitzheim combination of the '516 declaration based on reading your declaration? 19:12:23 19:12:37 19:12:42

A Yes. As I described in my declaration, Gan's teaches an oxide layer and a polysilicon layer, and oxide layers have been known in microelectronics and then in solar cells for decades. Similarly with polysilicon layers. And teachings of how to make those do appear in Gan, but also can be found in the literature for decades. And I review other references, ways to make oxide and polysilicon layers in my background section that include other references that teach 19:12:47 19:12:51 19:12:58 19:13:03 19:13:06 19:13:10 19:13:14 19:13:20 19:13:25 19:13:30

how to make them. 19:13:32

So the structure that Gan describes, and it's how it would be incorporated into Froitzheim, are things that a POSITA would already understand, but are also taught in those references. 19:13:33 19:13:39 19:13:44 19:13:47

Q Would a POSITA making the Gan and Froitzheim combination of the '516 declaration, would that POSITA understand that Gan Step 3 must be used? 19:13:49 19:13:56 19:14:00 19:14:05

A Gan's Step 3 teaches the growth of a thermal oxide. Thermal oxides have been described in the literature back to at least the 1950s. And a POSITA would understand that to form Gan's structure an oxide must be -- must be formed. 19:14:17 19:14:19 19:14:25 19:14:31 19:14:36

A POSITA would understand that one method of forming it is thermal oxide growth, which is described in Gan's Step 3. Although other methods are also possible and were well known. 19:14:43 19:14:45 19:14:50 19:14:54

Q Is it your position then that a POSITA making the Gan-Froitzheim combination of the '516 declaration would not necessarily need to use Gan's oxide layer? 19:14:57 19:15:04 19:15:09 19:15:14

MR. SELWYN: Objection. Form. 19:15:20

A No. I'm referring -- I'm relying on Gan's oxide layer and Gan's teaching to form the structure, the Froitzheim-Gan combination. I'm simply saying that Gan's teachings of making an oxide layer and making a polysilicon layer were well known. It was well known in the microelectronics and solar industry how to make tunnel oxide layers and polysilicon layers. 19:15:22 19:15:27 19:15:33 19:15:39 19:15:42 19:15:45 19:15:48 19:15:51

So a POSITA would not be limited to the teachings of Gan and Froitzheim in a method of implementing the combination. They would have other knowledge as well. 19:15:55 19:15:58 19:16:06 19:16:09

And I have referred in my declaration to many references for both the formation of oxides and the formation of polysilicon. For example, Paragraph 133 -- 136 of my declaration says, "A person of ordinary skill in the art would have known how to add oxide layers to silicon surfaces, as doing so was well known and routine by 2008." 19:16:17 19:16:19 19:16:22 19:16:35 19:16:39 19:16:41 19:16:44

And similarly, "A person of ordinary skill in the art would have also readily 19:16:49 19:16:50

understood how to manufacture a polysilicon emitter," as those were well known and routine. 19:16:52 19:16:55

Q Can you go to Page 79 of your declaration? 19:17:02 19:17:06

A I'm there. 19:17:18

Q This is, here on this page you provide an illustration of the Froitzheim-Gan combination. 19:17:19 19:17:21

Correct? 19:17:24

A Yes. 19:17:26

Q And you draw an oxide layer in orange. 19:17:27

Correct? 19:17:34

A Correct. 19:17:34

Q This is referring to Gan's oxide layer. 19:17:34

Correct? 19:17:38

A That's correct. 19:17:50

Q Now, which of the 12 steps in Gan disclose the formation of that oxide layer? 19:17:50 19:17:53

A Gan describes in Step 3 how to form an oxide layer, thin thermal oxide growth at 800 degrees C, parentheses, ten minute oxygen flow. 19:18:14 19:18:17 19:18:21

And as I mentioned, many other -- many, many other reports of how to form tunnel oxide 19:18:25 19:18:31

layers have the same function as Gan's. 19:18:36

Q Going back to Page 79 of your 19:18:40

declaration, you also illustrate a P-type 19:18:43

polysilicon layer in dark blue. Right? 19:18:50

A Correct. 19:18:52

Q This would be Gan's polysilicon layer. 19:18:52

Is that right? 19:18:55

A That's what I describe, the 19:18:58

implementation of Gan's oxide layer and 19:18:59

polysilicon emitter into Froitzheim's back 19:19:02

junction solar cell is shown in the below figure, 19:19:05

which is the one you're referring to. 19:19:08

Q Now, which steps in Gan's 12 steps 19:19:09

disclose the formation of a polysilicon layer? 19:19:14

A Gan describes the deposition of a 19:19:26

polysilicon layer in Step 4 of his sequence, and 19:19:29

the subsequent doping of that to form an emitter 19:19:36

in Steps 9 and 10. In Paragraph 136 of my 19:19:39

declaration, forming such polysilicon emitters 19:19:48

were routine by 2008. And a POSITA would have 19:19:53

understood from the robust literature, and I cite 19:20:01

several instances like Tarr that says it's been 19:20:05

known for over a decade as of 1985 how to make a polysilicon emitter at -- that meets the specifications of Gan's polysilicon emitter. 19:20:09 19:20:18 19:20:20

Q Can we go to Page 171 of your '516 declaration. 19:20:24 19:20:31

A Page 171. Okay. 19:20:46

Q Here you illustrate a combination of Li and Gan. Right? 19:20:48 19:20:52

A That is correct. 19:21:04

Q You have in this illustration an oxide layer in orange. Right? 19:21:04 19:21:11

A Correct. 19:21:18

Q This is referring to Gan's oxide layer. Right? 19:21:18 19:21:21

A Yes. As I say in Paragraph 272, the implementation of Gan's tunnel oxide layer and polysilicon emitter to Li is shown in the figure below. In the below figure. 19:21:29 19:21:31 19:21:36 19:21:38

Q And in this figure you also show a polysilicon emitter in dark blue. Right? 19:21:41 19:21:45

A Correct. 19:21:48

Q And this is referring to Gan's 19:21:48

polysilicon emitter. Right? 19:21:53

A I can read the same sentence again. The implementation of Gan's tunnel oxide layer and polysilicon emitter to Li is shown in the below. 19:21:56 19:21:58 19:22:01

Q Well, is that a yes to my question? 19:22:11

A This is an oxide layer and polysilicon emitter as taught by Gan implemented in Li, yes. 19:22:15 19:22:18

Q Let's go to Paragraph 214 of the '516 declaration. 19:22:22 19:22:32

A 214. Okay, I'm looking at Paragraph 214. 19:22:42

Q In this paragraph you discuss Sheats isolation trench 516. Right? 19:22:45 19:22:50

A Yes, that is correct. 19:22:55

Q Is this the isolation trench you propose to incorporate with Froitzheim and Gan? 19:23:02 19:23:04

A Yes. In Ground 2, which is about Ground 5, I propose a combination of Froitzheim, Gan, and Sheats. And Sheats' contribution is the isolation trench shown in this figure on Page 139. 19:23:10 19:23:13 19:23:18 19:23:24

Q And you provide Sheats' Figure 5D in this paragraph. Right? 19:23:30 19:23:33

A Correct. 19:23:35

Q Figure 5D shows three rectangular blocks listed on top of Layers 508 and 510. Right? 19:23:35 19:23:42

A Yes. 19:23:52

Q And the isolation trench 516 is illustrated in two of those three rectangular blocks. Right? 19:23:52 19:23:54 19:23:58

A That is correct. 19:24:00

Q Is it accurate to say that those three rectangular blocks represent three solar cells? 19:24:01 19:24:05

A I am turning to Sheats. Just give me one moment. 19:24:32 19:24:34

(Exhibit 1012, previously marked, not attached.) 19:24:34 19:24:34

A Yes, it would be appropriate to call each of the blocks a solar cell, and more particularly the layer identified as 504 is the intended absorber layer of the solar cell, going back to our previous discussion. 19:25:28 19:25:32 19:25:39 19:25:45 19:25:48

Q Why does the rectangular block in the middle not have an isolation trench? 19:25:52 19:25:55

MR. SELWYN: What was the question? I didn't hear your question. 19:26:01 19:26:02

THE WITNESS: Why. Why does the block in the middle not have an isolation trench. 19:26:03 19:26:05

A So Sheats describes this process and the structure in -- I guess it begins Paragraph 56 of Sheats. And what Sheats is doing is connecting that middle block to what Sheats calls the back plane, which is labeled 510 on the drawing. 19:29:55 19:30:01 19:30:09 19:30:13 19:30:20

And Sheats describes that there can be electrical shorts between the top transparent conductive layer 502 and the bottom electrode 506, and identifies such shorts with the number 511 and 517 in the drawing. 19:30:29 19:30:51 19:31:00 19:31:16 19:31:22

And the left and right side blocks, which do not have this electrical connection 516 to the back plane, are meant to continue operating as functioning solar cells. And so this electrical short is bad and drains or reduces the power output. And so Sheats adds these isolation trenches 516 in order to remove that short. 19:31:28 19:31:32 19:31:39 19:31:42 19:31:44 19:31:48 19:31:52

However, the middle block 517 -- sorry, the middle block and the shorts on it 517 Sheats describes as not necessarily bad. Because the 19:32:00 19:32:05 19:32:11

purpose of that middle block is not to continue operating as a -- as a solar cell, but rather to act as a wire connecting to the back plane 510, which is why it has that weld or other electrical connection 512. 19:32:14 19:32:16 19:32:19 19:32:26 19:32:31

And so Sheats is not motivated to remove the shunts 517 of the middle block. 19:32:34 19:32:39

Q Go to Paragraph 224 of your declaration. 19:32:50

A Okay. 19:33:08

Q Here in the first sentence you state, "A person of ordinary skill in the art would have been motivated to modify Froitzheim to incorporate a polysilicon emitter and tunnel oxide layer as taught by Borden 575." 19:33:08 19:33:09 19:33:11 19:33:15 19:33:18

Do you see that? 19:33:21

A Yes. 19:33:22

Q I am going to call this structure the Borden -- I'm sorry, the Froitzheim-Borden 575 combination. 19:33:22 19:33:26 19:33:29

Is that okay? 19:33:30

A Yes. 19:33:31

Q On Page 146, above Paragraph 224, you 19:33:31

illustrate this Froitzheim-Borden 575 combination. 19:33:40

Right? 19:33:44

A Above Paragraph 226. 19:33:48

Q Yes. 19:33:50

A Yes. 19:33:51

Q And the orange line labeled as oxide layer is referring to the tunnel oxide layer as taught by Borden 575. Right? 19:33:51 19:33:56 19:34:00

A Borden teaches two oxide layers, and this oxide layer shown in the figure is purposefully labeled oxide layer. As I say in the text, we require Borden 575's tunnel oxide layer in order to make a functioning solar cell. But Borden teaches that its tunnel oxide layer doesn't necessarily have to cover the entire wafer surface, and that its other oxide layer may also occupy some of the wafer surface. 19:34:05 19:34:10 19:34:15 19:34:21 19:34:27 19:34:32 19:34:35 19:34:39 19:34:42

So this figure labeling the oxide layer as oxide layer recognizes that Borden's tunnel oxide layer is required, as described in the text, but doesn't limit Borden's teachings to his tunnel oxide layer. 19:34:45 19:34:49 19:34:53 19:34:56 19:35:00

Q So in the Froitzheim-Borden 575 combination, are you incorporating Borden 575's other oxide layer as well? 19:35:01 19:35:15 19:35:26

A I -- I leave that possibility, as Borden teaches both. I am incorporating at least Borden's tunnel oxide layer. 19:35:32 19:35:35 19:35:38

And you can see, for example, that in the footnote on Page 155 I indicate that Borden also teaches the other oxide layer, which he calls a buried oxide, between the polysilicon emitter and substrate. 19:35:40 19:35:45 19:35:50 19:35:54 19:35:57

Q Do you discuss a POSITA's motivation to incorporate Borden's 575 buried oxide layer anywhere? 19:35:58 19:36:10 19:36:17

A I discuss a POSITA's motivation to incorporate the tunnel oxide layer taught by Borden. Because as I just mentioned, one requires Borden's tunnel oxide layer to make a working combination because the tunnel oxide layer allows current to flow. That is to say, it has low contact resistivity, low C. But the combination doesn't have to necessarily be limited to Borden's 19:36:17 19:36:23 19:36:26 19:36:32 19:36:35 19:36:38 19:36:44 19:36:50

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tunnel oxide. Borden teaches a second oxide, a buried oxide, and it can -- Borden's full teachings also results in a combination that meets the limitation of -- limitations of the claims. 19:36:54 19:36:59 19:37:05 19:37:08

Q But my question was, do you discuss a POSITA's motivation to incorporate Borden's buried oxide layer anywhere? 19:37:12 19:37:19 19:37:22

A I do not. I discuss a POSITA's motivation to include Borden's tunnel oxide layer, as it is the tunnel oxide layer that is necessary to make a working solar cell. I'm explaining why I have labeled in the figure this oxide layer, as opposed to tunnel oxide layer, because it is possible for a POSITA to take more than just Borden's tunnel oxide layer because Borden teaches more than that, as I have acknowledged in the footnote on Page 155. 19:37:24 19:37:27 19:37:30 19:37:33 19:37:38 19:37:41 19:37:45 19:37:49 19:37:52 19:37:58

Q Let's go to Exhibit 1006, Borden 575. And I would like to direct you to Paragraph 22. 19:38:03 19:38:15

A Okay. 19:38:29

Q Paragraph 22 specifies a thin tunnel oxide would be included between the substrate 200 19:38:29 19:38:33

and the polysilicon 210 in the contact holes 212. 19:38:36

Right? 19:38:41

A Correct. 19:38:45

Q Are contact holes incorporated in the Froitzheim-Borden 575 combination? 19:38:45 19:38:48

A Contact holes are not included in my combination because contact holes are not recited in the claims. It's not one of the limitations of the claims, at least at the back side of the solar cell. 19:39:00 19:39:01 19:39:06 19:39:08 19:39:16

Borden teaches this tunnel oxide layer. Borden teaches another oxide layer that can have contact holes in it, with a tunnel oxide in those contact holes. Contact holes are not part of the recited claims. 19:39:16 19:39:20 19:39:26 19:39:29 19:39:33

Q Borden's tunnel oxide layer and -- I'm sorry, Borden 575's tunnel oxide layer and Borden 575's buried oxide layers are different components. Right? 19:39:34 19:39:42 19:39:47 19:39:52

MR. SELWYN: Objection. 19:39:55

A What do you mean by "different components"? 19:39:56 19:39:58

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Q For example, let's go to Paragraph 26 of Borden 575. 19:39:58 19:40:05

A Okay, I'm there. 19:40:15

Q This paragraph discloses a Step S402, where the buried oxide is formed. Right? 19:40:16 19:40:21

A Yes. 19:40:27

Q And later a Step S406, where a tunnel oxide is grown. Correct? 19:40:27 19:40:31

A Yes. 19:40:37

Q So when Borden talks about -- I'm sorry, when Borden 575 talks about a buried oxide and then a tunnel oxide, it is referring to two different things. Right? 19:40:37 19:40:39 19:40:43 19:40:46

A When you say "two different things," I need more clarity. In the sense that after both have been formed, if I were to cut the solar cell in half, I likely couldn't distinguish between the composition of one oxide and another oxide. There's not -- there's not a clear differentiation between them. 19:40:57 19:40:59 19:41:02 19:41:05 19:41:12 19:41:15 19:41:20

What I read Borden describing here is a fabrication sequence for these layers. 19:41:20 19:41:23

Q So would a POSITA understand the terms "buried oxide" and "tunnel oxide" to be interchangeable? 19:41:27 19:41:31 19:41:36

A No. Borden teaches that they have -- each has a function in Borden 575's structure. 19:41:38 19:41:45

Q What is the function of the tunnel oxide in Borden '75? 19:41:48 19:41:52

A It's what you read previously. This oxide provides passivation between the substrate and the polysilicon while allowing for tunnel current flow. 19:41:57 19:41:59 19:42:02 19:42:06

Q What is the function of the buried oxide in Borden 575? 19:42:07 19:42:10

A The buried oxide provides at least one of the things the tunnel oxide provides, in particular in Paragraph 16 Borden says, "The oxide provides an excellent passivation layer over most of the surface." 19:42:11 19:42:25 19:42:28 19:42:32 19:42:35

Q Does the buried oxide provide any other functions? 19:42:37 19:42:41

A Borden also describes a secondary function of the buried oxide. It's first 19:43:08 19:43:10

mentioned in Paragraph 16, the last sentence. 19:43:17
"The oxide isolates the contacts from the 19:43:26
substrate." And again in Paragraph 24. "It 19:43:29
should be noted that according to aspects of the 19:43:38
invention, the contact metal 202 is blocked from 19:43:40
reaching the substrate 200 by the buried oxide 19:43:44
214." 19:43:48
So I read that to mean that the buried 19:43:50
oxide has a secondary benefit of preventing the 19:43:53
metal contact, which is intended to touch the 19:43:57
polysilicon emitter, it does, from also touching 19:44:01
the wafer. 19:44:05
Q Okay. I understand that to mean that the 19:44:08
buried oxide cuts off current flow when it 19:44:18
isolates the metal contact from the substrate? 19:44:23
A No. What Borden is referring to is that 19:44:31
if, for example, the metal contact is made by 19:44:35
screen printing paste and firing, which is a 19:44:40
common way of forming metal contacts, that that -- 19:44:42
the paste that -- the filaments that go into the 19:44:46
polysilicon will not also be able to go through 19:44:51
the buried oxide. So it's actually a physical 19:44:55

prevention of metal from going to the wafer. That is what Borden is describing. 19:44:58 19:45:02

Q But in preventing the metal from going to the wafer, does it effectively also cut off current flow from the wafer to the metal? 19:45:04 19:45:14 19:45:17

MR. SELWYN: Objection to form. 19:45:22

A Whether there's current flow from the wafer to the metal will depend on the thickness of the buried oxide. Because if it becomes thin enough, it will also act as a tunnel oxide, that is to say, current would flow. 19:45:25 19:45:27 19:45:31 19:45:33 19:45:37

Q Do you understand Borden 575 to disclose a buried oxide that is thin enough to act as a tunnel oxide? 19:45:40 19:45:46 19:45:51

A I do. 19:45:54

Q Can you tell me where that is disclosed in Borden? 19:45:59 19:46:01

A Yes. I find it in Claims 3 and 10, for instance. 19:46:05 19:46:13

Q Can you elaborate on how Claim 3 teaches a buried oxide that is thin enough to act as a tunnel oxide? 19:46:13 19:46:41 19:46:45

A Claim 3 -- I'm sorry, I gave you the wrong numbers. I apologize. Claim 4 and Claim 10. 19:46:49 19:46:52 19:46:56

Q Okay. Claim 4 recites an insulating layer. Right? 19:46:58 19:47:03

A That's correct. 19:47:05

Q And you understand the insulating layer to mean the buried oxide layer? 19:47:06 19:47:09

A I do. Claim 4 depends from Claim 3, which discloses a thermally grown silicon oxide layer as the insulator. Sorry, a thermally grown silicon dioxide layer. Claim 2 -- I messed up my numbers. I apologize. Claim 3 depends from Claim 2, which describes that the insulating layer comprises silicon dioxide. 19:47:14 19:47:18 19:47:25 19:47:29 19:47:34 19:47:38 19:47:42

And Claim 2 depends from Claim 1, which describes that the -- an insulating layer between the emitter layer and a surface of the substrate. The insulating layer being patterned to include contact holes. That's how Borden describes the buried oxide layer. 19:47:45 19:47:48 19:47:54 19:47:58 19:48:02 19:48:06

Q So if the buried oxide layer is less than 19:48:08

about 20 -- is that angstroms? Is that how you say it? 19:48:12 19:48:15

A Angstroms, correct. 19:48:16

Q Less than about 20 angstroms thick, then you would understand it to act as a tunnel oxide. Is that right? 19:48:16 19:48:19 19:48:23

MR. SELWYN: Objection. Form. 19:48:26

A I understand and a POSITA would that, per my Paragraph 84 of my background section, that very thin oxide layers can also act as tunnel oxide layers and allow current to flow. And I recite from the literature instances of that. And you can see one, for example, that contains a 20- to 40-angstrom interfacial layer of silicon dioxide, which is so thin as to be permeable to electrons. 19:48:59 19:49:06 19:49:16 19:49:20 19:49:25 19:49:28 19:49:34 19:49:38 19:49:48

(Clarification by the court reporter.) 19:49:51

A So this is one instance. There are many more of that below 20 angstroms, and indeed in this reference even below 40 angstroms, oxides can begin to allow current to flow. 19:49:53 19:49:55 19:49:59 19:50:05

MR. SELWYN: And can we just pause for a 19:50:10

second and get a time check on how much we have left on the 7 hour record? 19:50:11 19:50:14

MS. ZHAO: That actually was my last question, unless you have anything. I may have some followup. But otherwise I'm done. 19:50:17 19:50:19 19:50:22

MR. SELWYN: Okay. I do have a few questions. 19:50:24 19:50:25

Let's just take three minutes so I can organize myself and then we can resume. 19:50:28 19:50:30

MS. ZHAO: Sounds good. 19:50:32

(A recess was taken.) 19:50:34

EXAMINATION BY COUNSEL FOR PETITIONER 19:53:49

BY MR. SELWYN: 19:53:49

Q Good afternoon, Dr. Holman. 19:53:50

A Good after moon. 19:53:51

Q Dr. Holman, can you put back in front of you your '516 declaration. 19:53:52 19:53:55

A Okay. 19:54:02

Q And let me direct you for context to Paragraph 121 of your '516 declaration. 19:54:02 19:54:06

A Okay, I'm there. 19:54:20

Q Dr. Holman, do you remember being asked 19:54:21

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questions earlier today about different types of emitters? 19:54:23 19:54:28

A Yes. 19:54:29

Q How, if at all, does Froitzheim's emitter differ from Gan's emitter? 19:54:29 19:54:34

A Froitzheim discloses a -- or teaches a diffused emitter in which dopants are diffused into the back side of the silicon wafer, whereas Gan teaches a deposited polycrystalline silicon emitter in which dopants are diffused into the polycrystalline layer. 19:54:36 19:54:42 19:54:45 19:54:52 19:54:58 19:55:01

Q Now, would a POSITA have been motivated to combine Froitzheim and Gan despite those differences? 19:55:02 19:55:05 19:55:09

A Yes. Both pieces of art are seeking to improve solar cell efficiency. And Gan teaches that his polysilicon emitter and oxide structure results in low contact resistivity and low J naught. These are desirable things for a emitter. 19:55:09 19:55:18 19:55:24 19:55:30 19:55:37

Gan's emitter can be implemented successfully at the back of Froitzheim's solar cell, and in fact can be done so without changing 19:55:45 19:55:48 19:55:53

equipment or other -- making other large changes, because the two pieces of art teach similar methods. And Gan teaches that his emitter can be used at the back of a solar cell, such as a back-contact solar cell. 19:55:58 19:56:03 19:56:06 19:56:12 19:56:15

And, indeed, Gan gives explicit motivation within his paper, when he talks about that his deposited polysilicon emitter can replace and -- can replace a diffused emitter and improve the solar cell, and he says, for example, that more than one absolute percent of cell efficiency could be expected if it was -- if his polysilicon emitter was implemented. 19:56:17 19:56:22 19:56:33 19:56:45 19:56:49 19:56:52 19:56:56 19:57:00

Q How, if at all, does Froitzheim's emitter differ from Borden's 575 emitter? 19:57:01 19:57:06

A The answer is the same. Froitzheim's emitter is a diffused emitter into the back side of Froitzheim's wafer, whereas Borden 575's emitter is like Gan's, deposited polysilicon. 19:57:11 19:57:14 19:57:19 19:57:24

Q Now, despite those differences, would a POSITA have been motivated to combine Froitzheim and Borden 575? 19:57:28 19:57:31 19:57:34

A Yes. And for similar reasons. Borden teaches that his oxide layer and polysilicon structure result in good surface passivation. And while current is still allowed to flow, which are ways of expressing and, as Gan did, that there's low contact resistivity and low J naught, and these are the characteristics of a good emitter. 19:57:38 19:57:44 19:57:50 19:57:57 19:58:00 19:58:05 19:58:08

Similarly, Borden, or also, Borden teaches that his emitter can be used at the back side of a solar cell, and Froitzheim has his emitter at the back side of a solar cell, and gives a reason for having it there. 19:58:14 19:58:18 19:58:21 19:58:27 19:58:30

And the processing steps of Borden and Froitzheim are compatible. So a POSITA would have been motivated to implement a better emitter into the back side of Froitzheim. And Borden's emitter fits the bill. 19:58:32 19:58:36 19:58:42 19:58:46 19:58:51

Q How, if at all, does Li's emitter differ from Gan's emitter? 19:58:52 19:58:56

A Li's emitter is a deposited emitter like Gan's emitter. But Li -- Li's emitter is a silicon thin film, I believe he calls it. And he 19:58:59 19:59:04 19:59:19

describes that that thin film can be amorphous silicon, microcrystalline silicon, or nanocrystalline silicon. And Gan's emitter includes an oxide layer and a polycrystalline silicon emitter. 19:59:23 19:59:27 19:59:30 19:59:37 19:59:42

So they're both deposited, but they have different -- different structures and potentially different materials. Li gives some choice there. 19:59:43 19:59:48 19:59:51

Q And despite those different structures and possibly different materials, would a POSITA have been motivated to combine Li and Gan? 19:59:55 19:59:57 19:59:59

A Yes, as I describe in my declaration starting on Paragraph 270. Gan's deposited emitter is quite similar to Li's deposited emitter. So a substitution of one for the other is -- is an easy change to make, and a POSITA would have understood how to do it. 20:00:03 20:00:09 20:00:18 20:00:22 20:00:26 20:00:32

Both Li and Gan are looking to increase solar cell efficiency. Li doesn't provide specifics about the performance of his emitter, but Gan shows that his oxide polycrystalline silicon structure provides low contact resistivity 20:00:34 20:00:40 20:00:45 20:00:49 20:00:56

and low J naught, which are the hallmarks of a good emitter. And Gan teaches that it can be used at the back side of silicon solar cells, which is where Li has his emitter. 20:00:59 20:01:04 20:01:08 20:01:12

So a POSITA would have been motivated to implement Gan's oxide polysilicon emitter structure into Li's solar cell to realize efficiency improvements because of Gan's excellent emitter performance. 20:01:15 20:01:20 20:01:25 20:01:29 20:01:37

Q Now, please, sir, would you turn to your '053 declaration. 20:01:39 20:01:43

A Okay. 20:01:49

Q And may I ask you to direct your attention to Paragraph 163, which discusses Element 9D. 20:01:49 20:01:51 20:02:10

A Okay, I am looking at it. 20:02:10

Q Does Froitzheim teach about diffusing dopants into the front surface of the silicon substrate? 20:02:11 20:02:14 20:02:17

A Yes. Froitzheim teaches how to make a solar cell and teaches how to make his solar cell which has N plus regions at the front of the 20:02:17 20:02:25 20:02:30

wafer. And he teaches how to make those -- that N plus region. In particular he talks about diffusing phosphorous from the gas phase into the front side of the wafer to form the N plus. 20:02:32 20:02:39 20:02:41 20:02:45

Q In Paragraph 165 of your '053 declaration you discuss Froitzheim's teaching of, quote, "diffusing phosphorous from the gas phase to form a front side N plus layer." 20:02:51 20:02:56 20:03:00 20:03:04

Do you see that? 20:03:07

A Yes. That was where I was just reading from. 20:03:08 20:03:09

Q Is this a front surface field? 20:03:09

A It is. So the N plus region that is created has the same doping polarity of the wafer. If it was at the back of the solar cell, we would call it a back surface field. If it's at the front of the solar cell instead, we call it a front surface field. 20:03:14 20:03:17 20:03:22 20:03:25 20:03:31 20:03:34

Q Now, please, Dr. Holman, turn to Paragraph 191 in your '053 declaration. 20:03:34 20:03:35

A Okay. 20:03:43

Q You see that Paragraph 191 discusses 20:03:43

Claim Element 16C through E? 20:03:46

A Yes, I do. 20:03:52

Q Does Froitzheim disclose, quote, "diffusing dopants into a front surface of the silicon substrate" for the purpose of Claim 16 for the same reasons as for Claim 9? 20:03:53 20:03:56 20:04:00 20:04:03

A Yes. As I describe here, and I described previously, Froitzheim discloses or teaches diffusing dopants into the front side of the wafer, phosphorous dopants in particular, to make an N plus. 20:04:06 20:04:10 20:04:14 20:04:19 20:04:21

Q Now would you please turn back to Paragraph 176 of your '053 declaration. 20:04:25 20:04:27

A Okay. 20:04:35

Q And do you see that that's discussing Claim 12? 20:04:35 20:04:38

A I do. 20:04:40

Q Does Froitzheim teach, quote, "forming a second dopant source layer over the silicon substrate, diffusing dopants from the second dopant source layer into the silicon substrate"? 20:04:41 20:04:46 20:04:48 20:04:52

A Yes. In particular this second dopant 20:05:00

source layer of Claim 12 is taught by Froitzheim in the diffusion of the phosphorous that forms the N plus layer at the front of Froitzheim as we were just discussing, the first dopant source layer, which is not mentioned in this part of the claim, would then have been the P-type diffusion at the back that forms the emitter. 20:05:05 20:05:13 20:05:16 20:05:20 20:05:24 20:05:26 20:05:29

Q In Paragraph 177 of the '053 declaration you discuss Froitzheim's teaching of, quote, "forming N plus regions by diffusing phosphorous into the front side of the silicon substrate, the N-type silicon layer." 20:05:31 20:05:35 20:05:38 20:05:41 20:05:45

Did I read that right? 20:05:47

A Yes, that's what it says. 20:05:48

Q Is this a front surface field? 20:05:49

A Yes, it is. 20:05:52

Q Can you explain why? 20:05:52

A Yes. Because the resulting diffused region has the same doping polarity as the wafer. It's not the opposite doping polarity like an emitter would have. And within solar cells we use the word "emitter" to describe the layer of the 20:05:54 20:05:59 20:06:03 20:06:08 20:06:12

solar cell that has the opposite doping of the wafer, and we use the word "front surface field" or "back surface field," depending on its location, to describe the layer that has the same doping polarity as the solar cell wafer. 20:06:14 20:06:16 20:06:20 20:06:23 20:06:25

Q Do you believe that Claim 12 is obvious in view of Froitzheim's teachings -- let me try that again. 20:06:27 20:06:30 20:06:37

Is Claim 12 obvious in view of Froitzheim's teachings of a front surface field? 20:06:38 20:06:41

A Yes, as I've described here beginning on Paragraph 176. 20:06:43 20:06:47

Q Now would you please turn to Paragraph 194 of your '053 declaration. 20:06:50 20:06:53

A Okay, I'm looking at Paragraph 194. 20:07:00

Q And do you see that that includes a discussion of Claim 18? 20:07:03 20:07:05

A Yes. 20:07:07

Q Does Froitzheim disclose and render obvious, quote, "forming a second dopant source layer over the silicon substrate and diffusing dopants in the second dopant source layer into the 20:07:07 20:07:11 20:07:14 20:07:18

silicon substrate" for the purpose of Claim 18 for the same reasons as for Claim 12? 20:07:21 20:07:24

A Yes, just as we discussed. 20:07:26

Q Now, earlier, in response to a question that Ms. Zhao asked you, you said, "Froitzheim is describing a more heavily doped N plus layer that is located only in certain areas at the front of the solar cell. That is to say, not across the entire front of the solar cell. And in particular under the metal contacts. He describes, for example, that that can reduce the contact resistance. That is the selective front surface field that he speaks of." 20:07:34 20:07:37 20:07:42 20:07:45 20:07:49 20:07:52 20:07:56 20:07:59 20:08:02 20:08:06

Do you recall testimony to that effect? 20:08:06

A Yes, that sounds right. 20:08:08

Q And when asked would the Froitzheim-Gan combination have a selective front surface field, you stated, "It could but it doesn't need to." 20:08:10 20:08:16 20:08:18

Do you remember that? 20:08:21

A Yes. 20:08:21

Q In view of our discussion just now about Claims 9, 12, 16, and 18, can you explain what you 20:08:22 20:08:24

meant that the Froitzheim-Gan combination did not have to have a selective front surface field? 20:08:29 20:08:31

A Yes. Froitzheim teaches a front surface field formed by diffusing dopants into the front surface. And the selective front surface field is a bonus, if you will, that Froitzheim offers as a possibility, where in addition to the front surface field there is select regions under the contacts that get extra doping. 20:08:35 20:08:40 20:08:45 20:08:51 20:08:55 20:08:59 20:09:03

And so Froitzheim teaches that. It is a possibility. A POSITA could use it. But it's not necessary to meet any of the limitations of the claim, because Froitzheim already teaches a front surface field, as we just discussed. 20:09:06 20:09:10 20:09:13 20:09:16 20:09:20

MR. SELWYN: Thank you, Dr. Holman. I have no further questions at this time. 20:09:24 20:09:26

MS. ZHAO: I have no further questions either. Thank you so much, Dr. Holman. 20:09:28 20:09:30

(Off the record at 8:09 p.m. EDT.)

IPR2024-01199
Maxeon Exhibit 2029

ACKNOWLEDGMENT OF DEPONENT

I, ZACHARY C. HOLMAN, 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)

IPR2024-01199
Maxeon Exhibit 2029

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 ZACHARY C. HOLMAN, 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, HANWHA SOLUTIONS CORPORATION, was represented by counsel at the deposition.

I further certify that the deposition of ZACHARY C. HOLMAN, Ph.D., occurred virtually, on Thursday, May 8th, 2025, from 11:57 a.m. to 8:09 p.m. EDT.

IPR2024-01199
Maxeon Exhibit 2029

I further certify that I am not related to any of the parties to this action by blood or marriage, I am not employed by or an attorney to any of the parties to this action, and that I am in no way interested, financially or otherwise, in the outcome of this matter.

IN WITNESS WHEREOF, I have hereunto set my hand this 15th day of May, 2025.

My commission expires:
October 31, 2027



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