UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

CANADIAN SOLAR INC.,
Petitioner,

v.

MAXEON SOLAR PTE. LTD.
Patent Owner.

Case No. IPR2024-01038

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

Issued: February 15, 2022

Filed: May 18, 2020

Inventors: David D. Smith, Tim Dennis, Russelle De Jesus Tabajonda

Title: Solar Cells with Improved Lifetime, Passivation and/or Efficiency

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PETITION FOR INTER PARTES REVIEW OF
U.S. PATENT NO. 11,251,315

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I. INTRODUCTION

Petitioner Canadian Solar Inc. ("CSI") respectfully requests that claims 10-15 of U.S. Patent No. 11,251,315 ("315 Patent") be cancelled as unpatentable.

As demonstrated herein, the claims are directed to well-known and obvious features of **back-contact** solar cells that were disclosed publicly long before the alleged invention, for example, by a patent application by Li published in 2011, in conjunction with decades-old teachings regarding the optimal front dopant concentration for back-contact solar cells, as shown in multiple prior art references (e.g., a Swanson patent in 1980, and publications by King in 1990, Marvin in 1990, and Muller in 2014).

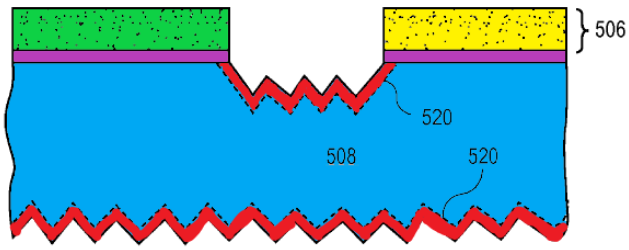

FIG. 5E

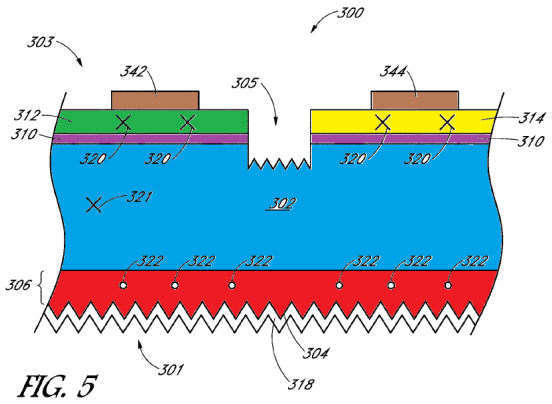

FIG. 5

Li **315 Patent**

As seen above, the solar cells in Li and the 315 Patent are very similar. They both disclose a silicon substrate (blue), having a front portion (red) that is doped at a particular concentration. On the back side (shown as the top of each figure), a dielectric region (purple) is deposited over the silicon substrate. Over the

dielectric region, doped polysilicon regions (green and yellow) are deposited to form "emitter regions." To transmit electricity out of the solar cell, metal contacts (brown)—a basic component of all "back-contact" solar cells—are deposited over the doped polysilicon regions.

The challenged claims add only two well-known requirements to this basic structure.

First, the claims specify that the substrate's front portion (red) should be doped at a concentration of "approximately less than or equal to $2x10^{18}$ cm^{-3}." The advantages of doping at this concentration had been published in at least four prior art references, the first of which dates back to 1980 (a Swanson patent) and the fourth (Muller) being a few months before the earliest possible effective filing date of the 315 Patent.

Second, the claims require the emitter region to have "metal impurities." Several pre- and post-effective filing-date references confirm that Li's process of heating the solar cell to 950°C to diffuse dopants into the polysilicon regions will necessarily result in metal impurities being present in Li's polysilicon emitter regions. This is because of a well-known process called "gettering," in which metal impurities naturally present in the silicon substrate are moved into the polysilicon regions when heated at high temperatures. The gettering phenomenon has been extensively studied and was well understood as a desirable and standard

step in the production of silicon solar cells long before the 315 Patent's effective filing date.

None of these prior art references were before the Examiner during prosecution of the 315 Patent. Accordingly, Claims 10-15 should never have issued and should be cancelled as unpatentable.

II. COMPLIANCE WITH IPR REQUIREMENTS

A. CSI Can Contest The 315 Patent

CSI certifies that it is not barred or estopped from requesting *inter partes* review of the 315 Patent and that this patent is available for *inter partes* review. Neither CSI, nor any party in privity with CSI, has filed a civil action challenging the validity of any claim of the 315 Patent. The 315 Patent has not been the subject of any prior *inter partes* review. CSI also certifies this petition for *inter partes* review is filed within one year of the filing date of a complaint alleging infringement of the patent, March 25, 2024. Further, the 315 Patent was issued on February 15, 2022, which is more than nine months prior to the date of this Petition.

B. IPR Fee (§ 42.15(a))

The Director is authorized to charge the fee specified by 37 CFR §42.15(a) to Deposit Account No. 50-1597.

C. Mandatory Notices (§ 42.8(b))

CSI and Canadian Solar (USA) Inc. are the real parties in interest. The 315 Patent is asserted in the following proceedings:

- *Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.,* Case No. 2:24-cv-210 (E.D. Tex., filed March 25, 2024).
- *Maxeon Solar Pte. Ltd. v. Hanwha Solutions Corp., et al.,* Case No. 2:24-cv-262 (E.D. Tex., filed April 19, 2024)
- *Maxeon Solar Pte. Ltd. v. REC Solar Holdings AS*, Case No. 2:24-cv-00260 (E.D. Tex., filed April 19, 2024)

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Proof of service of this petition is provided in **Attachment A**.

III. IDENTIFICATION OF CHALLENGED CLAIMS

Claims 10-15 of the 315 Patent are unpatentable as follows:

Ground	Claims Challenged	35 U.S.C. §	References/Basis
1	10-12, 15	103	Li combined with King or Swanson-352 or Marvin
2	10, 13-15	103	Li combined with Muller
3	10-12, 15	103	Li combined with King or Swanson-352 or Marvin, in further view of Hu, Ramappa
4	10, 13-15	103	Li combined with Muller, in further view of Hu, Ramappa

Attachment B lists the evidence relied upon in this petition.

IV. CONTESTED PATENT OVERVIEW

A. The 315 Patent's Effective Filing Date

The 315 Patent was filed on May 18, 2020 and claims priority to a series of earlier patents, the earliest of which was filed on December 22, 2014. EX1001,1:5-17. Without conceding entitlement to the earliest filing date, all references relied on in the unpatentability grounds of this Petition were published before December 22, 2014. Therefore, they are prior art under the America Invents Act (which governs the 315 Patent). 35 U.S.C. § 102(a)(1).

B. Person of Ordinary Skill in the Art

The person of ordinary skill in the art in the 315 Patent's field of solar cell design or manufacture in the December 2014 timeframe ("Skilled Artisan") would

have been someone with an advanced degree involving the discipline of electrical engineering, applied physics, chemistry, or materials science, and at least two years of experience designing, developing, or researching in the field. Alternatively, that person would have had a bachelor's degree in electrical engineering, applied physics, or materials science, and at least three years of experience designing, developing, or researching in the field. EX1003,¶47.

C. Overview of the 315 Patent

The 315 Patent's Figure 5 describes a "solar cell 300" that has "a front side 301 which faces the sun during normal operation and a back side 303 opposite the front side 301." EX1001,6:40-44. The solar cell includes a "silicon substrate 302" which "can be single-crystalline or multicrystalline," and, further, "can be a N-type silicon substrate" in an embodiment. EX1001,3:35-38, 6:44-47, FIG. 5 (shown in blue below).

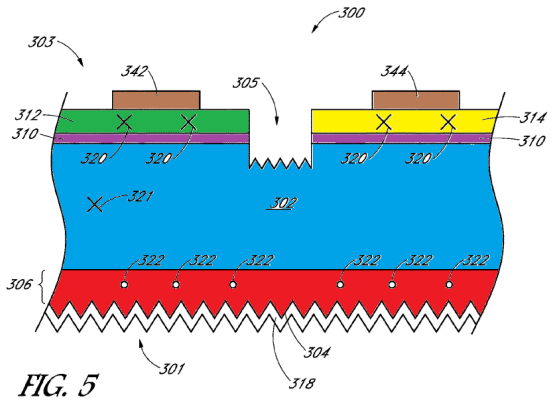


FIG. 5

On the front side (which is the figure's bottom side), dopants are diffused into the substrate to form a dopant-diffused front "portion 306 of the silicon

substrate 302 [that] can have a doping concentration 322 of approximately less than or equal to $2x10^{18}$ cm^{-3}." EX1001,4:15-24, 6:47-49; EX1003, ¶52. This front dopant-diffused portion is layer 306 in FIG. 5 (reproduced and shown in red). EX1003, ¶52. An antireflection layer 318 (no color) is further deposited on the front portion of the solar cell. EX1001,7:9-12.

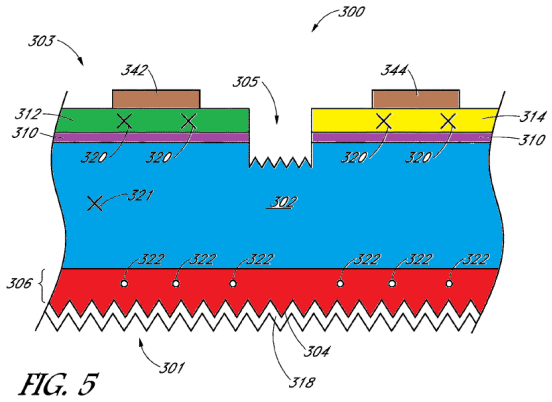


FIG. 5

At the back side (which is the topside in FIG. 5), the solar cell "can have a dielectric region 310 formed over the silicon substrate 302," which "can be a tunnel oxide" such as "silicon dioxide." EX1001,6:50-53 (shown in purple). The solar cell's rear is described as having "first and second emitter regions 312, 314" which "can be P-type and N-type doped polysilicon regions, respectively." EX1001,6:53-57 (shown in green and yellow). The patent further describes that "impurities and/or contaminants 320, e.g., metal impurities 320 and/or metal contaminants, can be located in the first and second emitter regions 312, 314 as shown" by "X" in FIG. 5, while "some impurities 321" can "remain[]" in the substrate itself. EX1001,6:57-62. Finally, "the solar cell 300 can have first and

second metal contacts 342, 344 formed on the first and second emitter regions 312, 314, respectively." EX1001,6:63-65 (shown in brown above). In FIG. 5, when all metal contacts are arranged at the backside away from the sun, the solar cell is called "a back contact solar cell." EX1001,7:13-14; EX1003, ¶54.

Figures 1-4 of the specification describe the method of making the solar cell of FIG. 5. EX1001, 6:40-42. As Dr. Banerjee explains, "Example Process C of FIG. 11" exemplifies the fabrication method of Figures 1-4, and compares it with other methods (Examples A, B, and D) for forming different solar cells. EX1003, ¶¶55-57; EX1001,8:40-9:9; FIG. 11. In Example Process C, the front "surface, or a portion near the surface, of a silicon substrate was doped at approximately less than or equal to $2x10^{18}$ cm^{-3}." EX1001,8:40-45; FIG. 11 ("Surface Dopant Conc."). In contrast, Example Processes B and D have surface dopant concentrations of $4x10^{18}$ cm^{-3}, significantly higher than the $2x10^{18}$ cm^{-3} used in Example C. EX1001,8:40-9:9; FIG. 11. Example C is also described as heating the solar cell at a temperature above 900°C to getter metal impurities to the polysilicon region. EX1001,8:44-46.[1] "Gettering" traps the metal impurities 220 in the emitter regions 212 by moving them from the substrate into the polysilicon

[1] FIG. 11 appears to have typographical errors for the "Temp" column for Examples C and D. The temperature should have been above 900°C per the description in the text. EX1003, ¶57; EX1001,8:44-46, 9:3-5.

regions upon heating above 900°C. EX1003, ¶58; EX1001,5:10-15, 5:21-25. In contrast, the patent states that heating at or below 900°C "can be insufficient to diffuse metal impurities through a tunnel oxide and into a polysilicon region." EX1001,5:18-20.

The process of Example C exemplifies both the doping of the front portion of the substrate at approximately equal or less than $2x10^{18}$ cm^{-3} and heating the solar cell above 900°C to getter the metal impurities to the polysilicon region. EX1003, ¶60. Claims 10-15 claim the solar cell resulting from Example Process C. *Id*.

D. Prosecution History

The 315 Patent was allowed without any rejections. EX1002, 206-207. In the Examiner's reasons for allowance, she stated: "Claims 1-20 are allowable over the prior art of record because none of the prior art … teach: … portion of the silicon substrate is formed at the front side of the solar cell; a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of the solar; a first emitter region having metal impurities formed over the dielectric region as recited in the independent claim 10." *Id*., 207.

The prior art relied upon in this Petition taught these limitations, but none were considered during prosecution.

E. Discretionary Denial is Inapplicable

The PTAB should **not** deny institution based on Section 325(d) because none of the obviousness references relied on here were presented or considered by the Examiner during the 315 Patent's prosecution.

The factors set forth in *Apple Inc. v. Fintiv, Inc.*, IPR2020-00019, Paper 11, 5-6 (PTAB Mar. 20, 2020) also weigh against discretionary denial:

Factor 6: The merits here are compelling and require institution. The 315 Patent did not face any rejections during prosecution, and the Examiner did not articulate any substantive analysis of any reference. None of the prior art references relied in this Petition were considered by the Examiner, and these references demonstrate that claims 10-15 of the 315 Patent were nothing more than a product of ordinary skill yielding predictable results.

Factors 1&2: Maxeon filed suit on March 25, 2024 against CSI in the Eastern District of Texas. The Texas court has not held a scheduling conference nor set a trial date as of this IPR's filing. The presiding Judge Gilstrap has frequently granted stays based on instituted IPRs, with at least 48 stays granted and only 41 denied with prejudice. EX1030.

Furthermore, a recent study confirmed that in over 94% of cases, future trial dates considered by the PTAB in its *Fintiv* analysis do not hold. EX1031. As Senator Tillis has written to Acting Director Hirshfeld, "the PTAB's historical

practice of crediting unrealistic trial schedules … has not only produced outcomes that are untethered from the policy underpinnings of the *Fintiv* rule, but [] has also created harmful incentives for forum shopping and inappropriate judicial behavior." EX1032, 1.

Factor 3: CSI filed this Petition expeditiously, within three months after Maxeon's complaint, which favors institution. *SK Hynix Inc. v. Netlist, Inc.*, IPR2020-01042, Paper 14, 14 (PTAB Dec. 17, 2020). By the time an institution decision will be made, little or no substantive proceedings will have occurred in the parallel litigation. It is likely that initial contentions will be exchanged and possibly some *Markman* briefing will take place. But it is unlikely that substantial investment in the court proceeding will have occurred on invalidity.

Factor 4: CSI stipulates that, if this IPR is instituted, it will not assert in any district court or ITC litigation that any claim at issue in this IPR is invalid on the basis of any ground raised or that reasonably could have been raised during this IPR.

Factor 5: CSI is one of the defendants in the district court cases, a fact that should weigh against denial because it permits CSI to provide the §315 stipulation above, thereby avoiding any possibility of duplication.

F. Claim Construction

Claim terms are generally given their ordinary meaning in the context of the patent as understood by the Skilled Artisan. 37 C.F.R. §42.100(b). CSI does not presently believe claim construction is necessary to resolve the issues presented in this Petition, but CSI reserves the right to respond to any constructions proposed by Maxeon or the Board. *See* Trial Practice Guide, §II.B.6.

V. OVERVIEW OF THE PRIOR ART

A. Known Background Technologies

1. Back-Contact Solar Cells

The basic concept and structure of a "back-contact solar cell" had been known in the art for decades before December 22, 2014. EX1003, ¶¶70-73. The key feature of the back-contact solar cell is that all the metal contacts of the solar cell are on the back side opposite incident sunlight, such that incoming light is not blocked by having metal contacts on the front side. *Id*. "Interdigitated back contact (IBC) solar cells were investigated by Lammert and Schwartz" as far back as 1977. EX1011, 11; EX1003, ¶72.

Luque, a 2002 Handbook of Photovoltaic Science and Engineering published in 2003 (EX1023, ¶¶132-139), disclosed a basic "[s]chematic of a back-contact solar cell," showing that the front side facing the sun has no metal contacts and the opposite/back side contains P-type and N-type doped regions, with both the

positive and negative metal contacts formed at the backside and contacting the doped regions, respectively:

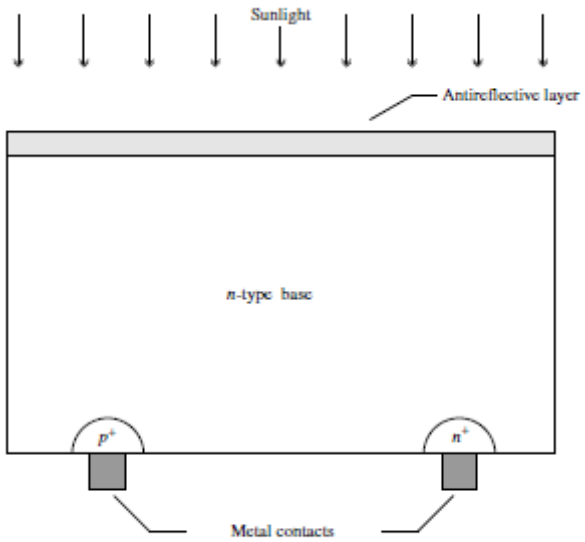


Figure 3.26 Schematic of a back-contact solar cell

EX1010, 108; EX1003, ¶71. Similarly, a 2007 review by Neuhaus recognized "[k]ey design features that contribute to high efficiency" of back-contact solar cells include "localized back contacts" and "a gridless front surface which permits optimization of light trapping and passivation," as shown in the "IBC solar cell structure" of Neuhaus Figure 8. EX1011, 11. As shown below, the front side also included a "front surface field" having the same dopant type (N-type) as the substrate and further passivated by silicon oxide and silicon nitride layers on top.

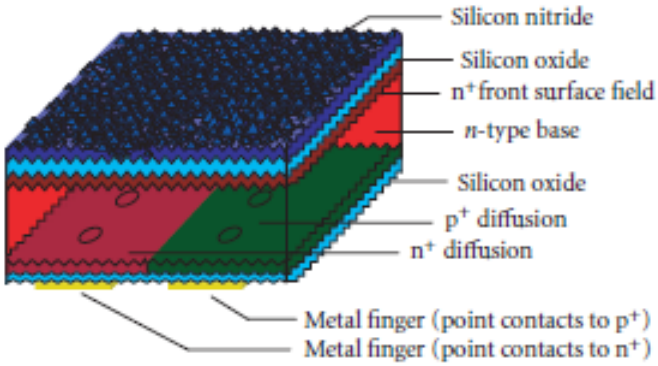
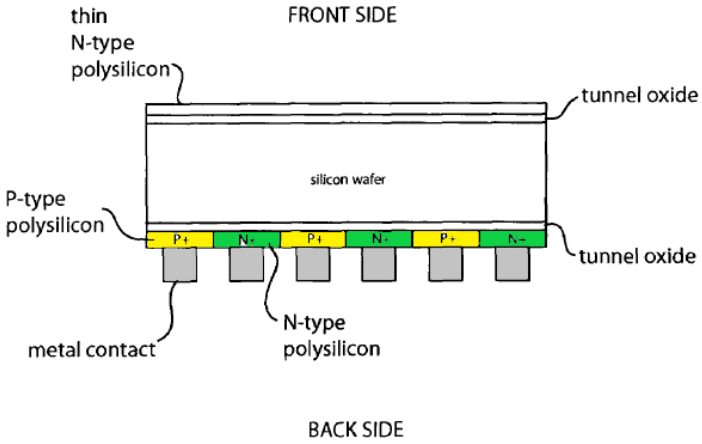


FIGURE 8: Schematic drawing of an IBC solar cell of SunPower.

Id.; EX1003, ¶72.

U.S. Patent 7,468,485 ("Swanson-485") issued in 2008 and showed a back-contact solar cell having metal contacts (shown in gray) over doped polysilicon regions (shown in yellow and green) formed over a tunnel oxide layer on the back side:



EX1012, Fig. 1. Swanson-485's "Description of the Background Art" recognized that "[i]n a back side contact solar cell, the p-type and n-type regions are coupled to metal contacts on the back side of the solar cell to allow an external electrical circuit or device to be coupled to and be powered by the solar cell." EX1012,1:20-

23. Forming metal contacts over doped polysilicon was well known and within the level of ordinary skill in the art. EX1003, ¶¶70-73. Indeed, according to Swanson-485, forming them can use "[c]onventional solar cell back-end processes." EX1012,6:38-46; EX1003, ¶73.

2. Front Surface Doping in Back-Contact Solar Cells

By December 22, 2014, it had been known for decades that the front portion formed in the silicon substrate of a back-contact solar cell should be optimally doped at a concentration of approximately $2x10^{18}$ cm^{-3} or less. EX1003, ¶¶74-80. For example, a 1990 publication by King and Swanson ("King") reported that "[i]n the case of a back-contacted cell in which the sunside diffusion is used mainly to reduce surface recombination, not to collect current, the **optimum** emitter is the one with the **lowest** J_0," and that for both textured and untextured surfaces this corresponds to a surface dopant concentration of approximately "**1×10^{18} cm^{-3} that is as thin as possible**." EX1006, 369 (emphasis added); EX1003, ¶¶75-77. As Dr. Banerjee explains, this lower front dopant concentration is preferred for back contact cells because it reduces surface recombination leading to higher cell efficiency. EX1003, ¶¶75-76.

Notably, one of the authors of King, Richard Swanson—referred to by Maxeon as "[t]he father of solar in the U.S." (EX1013, ¶2)—received a patent in 1980 that also described, consistent with King, that for a "photovoltaic cell" with

contacts on the back surface, the "**maximum** surface dopant concentration" of the front diffused region "is **10^{18} atoms per cubic centimeter**." EX1015,4:38-51, 5:9-41, Figs. 3-10 (emphasis added). *See* §VI.B below.

Other studies have confirmed these findings. For example, Marvin, a 1989 study, concluded that optimal performance and efficiency of back-contact solar cells for space use should include a silicon substrate with a front portion having "**peak doping concentration of 1E18 [1 x 10^{18}] cm^{-3}**." EX1035, 826-827 (emphasis added); *see also* EX1007, 5, 21, 25; EX1003, ¶79. And, more recently, in September 2014, Muller published the results of a comparative study of back-contact solar cells with either a boron or phosphorus ion-implanted front region, in both cases at dopant concentration less than or equal to approximately 2×10^{18} cm^{-3}. EX1008, 269; EX1003, ¶80.

King, Swanson's patent, Marvin, and Muller are discussed in greater detail below. §§VI.B-VI.D, VII.A.

3. Gettering of Metal Impurities in Silicon Substrates

Recombination is one of the primary factors controlling solar cell efficiency. EX1003, ¶82. In solar cell manufacturing, the presence of other types of metallic impurities **in the substrate** such as iron, nickel, or gold have long been known to lead to recombination, in which energized electrons recombine with "holes," thus

reducing the ability of the cell to generate electricity from those electrons. *Id*. (emphasis added).

To address this problem, it was well-known before December 2014 to remove these metal impurities from the substrate by "gettering" them into another location of the device where they do not affect the device's performance. EX1003, ¶83. It was well known that "[g]ettering techniques eliminate or reduce contaminant impurities in a [silicon] wafer." *Id*. (citing EX1010, 262). Before 2014, it was long recognized that "the incorporation of gettering steps into the processing scheme is a **prerequisite** for the production of efficient solar cells." EX1016, 696 (emphasis added); EX1003, ¶83.

As Dr. Banerjee explains, known gettering methods before 2014 included moving the metal impurities from the substrate and into a back side polysilicon layer. EX1003, ¶84. For example, a 1977 IBM issued patent by Hu disclosed that during heating in the range of 1000°C or less, "getterable impurities such as copper, lithium, sodium, potassium, iron, cobalt, nickel, chromium, and gold will diffuse to, and become trapped in, the polycrystalline silicon film impurity sink" formed on the back surface of the silicon substrate. *Id*. (citing EX1017,5:61-6:6).

In solar cell manufacturing, it was also standard industry practice before 2014 to use the dopant diffusion step to getter metal impurities. EX1003, ¶¶85-87. Numerous publications before 2014 described the simultaneous diffusion of

dopants and gettering in solar cell fabrication. EX1003, ¶¶85-86 (citing EX1018, 1; EX1010, 262; EX1016, 707).

At and around 2014, it was well known that multicrystalline silicon wafers were most commonly used for the production of wafer-based solar cells. EX1003, ¶90; EX1018, 1. For example, the National Renewable Energy Laboratory reported that as of 2013, multicrystalline silicon wafers accounted for the vast majority (at least 65%) of silicon substrates used for solar panels worldwide. EX1022, 66 The Skilled Artisan knew that because of their lower quality, multicrystalline silicon substrates were known to contain substantial concentrations of metal impurities. EX1003, ¶¶88-89 (citing EX1021, 402; EX1010, 283; EX1020, ¶0006; EX1016, 696). For example, iron impurities in multicrystalline silicon substrates were known to be as high as 10^{14}-10^{16} cm^{-3} in concentration. EX1016, 696. Thus, gettering "[was] even more important to improve material quality" in multicrystalline silicon substrates before 2014. EX1010, 283.

VI. LI COMBINED WITH KING OR SWANSON-352 OR MARVIN WOULD HAVE RENDERED CLAIMS 10-12 AND 15 OBVIOUS

A. Li (EX1005)

Li is US Patent Publication 2011/0214719, entitled "Method of Fabricating a Back-Contact Solar Cell and Device Thereof." EX1005, Face. Li published on

September 8, 2011. *Id*. Thus, it is prior art under 35 U.S.C. §102(a)(1).[2] Although Li names a common inventor with the 315 Patent, the less-than-one-year exception of 35 U.S.C. §102(b)(1) does not apply because Li was published over 3 years before the earliest possible effective filing date of the 315 Patent.

Like the claims of the 315 Patent, Li disclosed a back-contact solar cell with a front side that faces the sun (bottom/textured side in the figures below) and a back side (top side in the figures below) that is opposite the front side. *See*, EX1005, FIGS. 3 and 5E (which disclosed an identical device).

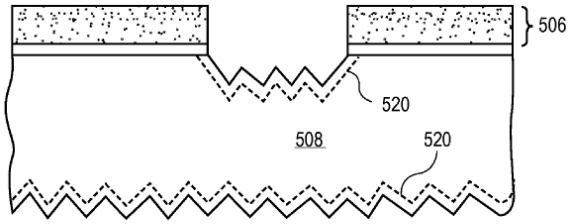


FIG. 5E

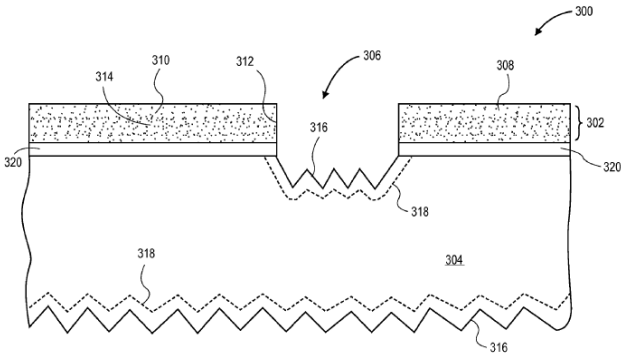


FIG. 3

[2] All references to 35 U.S.C. §102 in this Petition refer to the AIA version of the statute.

Stepping through each feature of both FIGS. 3 and 5E of Li, Dr. Banerjee explains that the Skilled Artisan reviewing Li would understand that FIG. 5E and FIG. 3 of Li disclosed the identical structure and device even though the numerical labels are different. EX1003, ¶¶95-99. The Skilled Artisan would understand that FIGS. 5A-5E disclosed the different stages within the fabrication of the solar cell of FIG. 3, and the process steps in FIGS. 5A-5E result in the same structure shown in FIG. 5E and FIG. 3. *Id.*; EX1005, ¶¶0029, 0036-0049. Thus, later discussions in this Petition may refer to numerical elements in either FIG. 3 or FIG. 5E for the same elements.

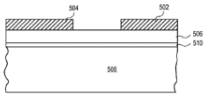


FIG. 5A

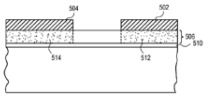


FIG. 5B

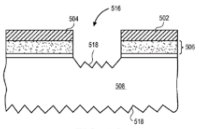


FIG. 5C

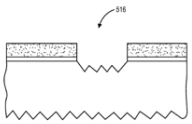


FIG. 5D

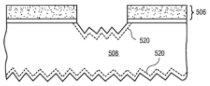


FIG. 5E

Dr. Banerjee further explains that the Skilled Artisan would understand that Li's back-contact solar cell (left below) also disclosed a substantially identical structure to FIG. 5 of the 315 Patent (right below), as shown in the annotated versions of the figures below. EX1003, ¶¶100-108.

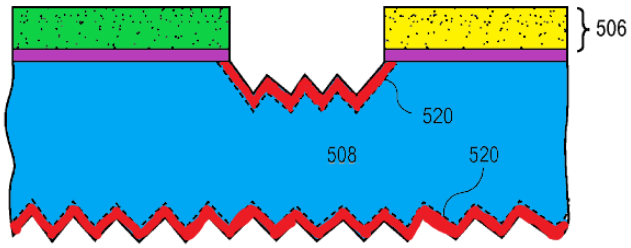


FIG. 5E

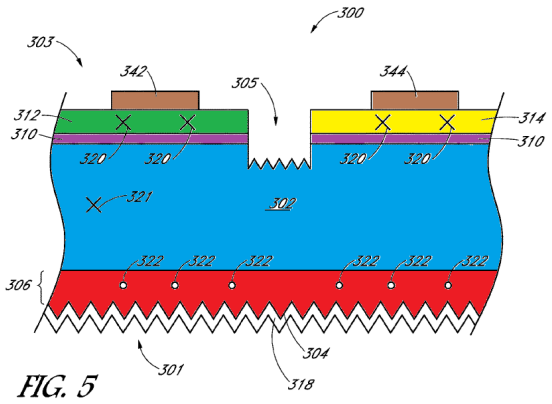


FIG. 5

Li **315 Patent**

Specifically, the solar cell of Li comprises a silicon substrate 508 (blue). The substrate is described as a "single-crystalline silicon substrate" or, alternatively, "a multi-crystalline substrate is used in its place." EX1005, ¶0042; *id.* ¶0037 (same).

Next, just like the 315 Patent, Li describes diffusing dopants at the front surface to form the front portion 520 (shown in red above) with a "gaseous N-type dopant source." EX1005, ¶0049. As can be seen in FIG. 5E, the presence of N-type dopants specifically "at or near surfaces of the substrate" includes the front surface facing the sun, as indicated by the numeral 520 on the textured (jagged) surface. EX1003, ¶¶102-103. Li did not specify the concentration of the dopant in this portion of the substrate. EX1003, ¶103.

On the back-side, just like the 315 Patent's FIG. 5, Li disclosed a "dielectric film 510" formed over the substrate's backside surface. EX1003, ¶104. This "dielectric film 510" may be "composed of silicon dioxide and has a thickness approximately in the range of 1-2 nanometers" and may be "a tunnel oxide barrier

layer film." EX1005, ¶0043. Although the layer 510 is not labeled in Fig. 5E, it corresponds to the purple layer noted above, as confirmed by FIG. 5B, which shows an earlier step in Li's fabrication process. EX1003, ¶104.

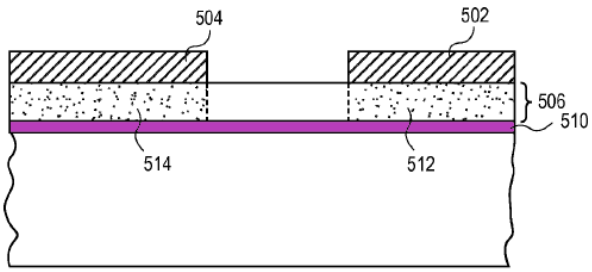


FIG. 5B

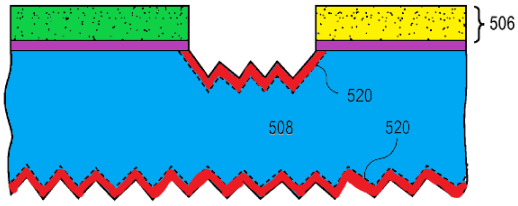


FIG. 5E

This same dielectric film is labeled 320 in FIG. 3. EX1005, ¶0039; EX1003, ¶104. On the "dielectric film" is formed a "material layer 506" which may be "poly-crystalline silicon." EX1005, ¶0042; EX1005, ¶0037. "Poly-crystalline silicon" is another name in the art for "polysilicon." EX1003, ¶105.

During the fabrication process, two dopant source layers are applied on the polysilicon layer 506: an "N-type dopant source layer 502" and a "P-type dopant source layer 504," as seen in FIG. 5B. EX1005, FIG. 5B; EX1003, ¶106. To diffuse dopants into the polysilicon layer 506, Li describes heating "at a temperature of approximately 950 degrees Celsius." EX1005, ¶0045; EX1005, claim 9. By so doing, "N-type dopants and P-type dopants" are "transferred" "into portions 512 and 514, respectively, of material [polysilicon] layer 506, as depicted in Fig. 5B." EX1005, ¶0045. As shown in FIG. 3 (same as FIG. 5B), the "transferring" (i.e., diffusing) of the dopants into the polysilicon material layer

forms an "N-type region 308 and a P-type region 310." EX1005, ¶0036; EX1003, ¶¶106-107. These are the same green and yellow regions shown in FIG. 5E above.

Finally, Li describes that in solar cells, it was well-known that "[t]he doped regions are connected to metal contacts on the solar cell to direct an electrical current from the cell to an external circuit coupled thereto." EX1005, ¶0004; EX1003, ¶108.

B. King (EX1006)

King is titled "Studies of Diffused Phosphorous Emitters: Saturation Current, Surface Recombination Velocity, and Quantum Efficiency." EX1006, 365. King is a journal article published by at least in January 1990, no later than February 1990, and in any event before December 22, 2014. EX1023, ¶¶6, 57-64. Exhibit 1006 is an authentic copy of King that was published and publicly available on January 25, 1990 in print from the Linda Hall Library of Science, Engineering & Technology and was also publicly disseminated by IEEE in February 1990. EX1023, ¶¶60, 63; EX1049. It was widely distributed and has been known and cited by others in the field by at least February 2003, including in a US patent issued on February 28, 2012, further confirming its public dissemination before December 22, 2014. EX1023, ¶63; EX1050; EX1051. Thus, King is prior art under at least 35 U.S.C. §102(a)(1).

King "report[ed] experimental measurements of the emitter saturation current density for a variety of emitters, with differing surface concentration and junction depth." EX1006, 365. King observed that in solar cells, "[o]ne of the most important parameters for predicting J_0 [saturation current density] and the quantum efficiency of a passivated emitter is the surface recombination velocity s as a function of surface dopant concentration $N_{, surf}$." EX1006, 365. In its "Discussion" section, King concluded the optimum front surface dopant concentration for untextured and textured front surfaces would be 1 x 10^{18} cm^{-3}:

> In the case of a back-contacted cell in which the sunside diffusion is used mainly to reduce surface recombination, not to collect current, the **optimum emitter** is the one with the **lowest J_0**. For untextured surfaces, this corresponds an **emitter with $N_{D, surf} \approx 1 \times 10^{18}$ cm^{-3} that is as thin as possible**. Fig. 3 shows an emitter with these specification is probably near optimum in J_0 when it has a **textured front surface, as well**.

EX1006, 369 (emphases added). *See also* EX1003, ¶¶75-77, 110 (explaining King's disclosure that decreasing the front dopant concentration lowers unwanted recombination for textured and untextured front surfaces in back-contact solar cells). King contrasted this conclusion with the concentration "of the emitter on

the sunward surface of a conventional [i.e., front-contact] solar cell,"[3] in which front surface dopant concentrations at or above 2 x 10^{19} cm^{-3} were preferred. *Id.*, 369. Therefore, King taught that the optimal front dopant concentration for a front-facing doped region of a back-contact solar cell was approximately 1 x 10^{18} cm^{-3}. EX1003, ¶110.

C. Swanson-352 (EX1015)

Swanson-352 is U.S. Patent No. 4,234,352, entitled "Thermophotovoltaic Converter and Cell for Use Therein." EX1015, Face. It issued on November 18, 1980. *Id.* The inventor, Richard M. Swanson, was also an author of the King publication discussed above. *Id.* Swanson-352 is prior art under 35 U.S.C. §102(a)(1).

[3] Conventional non-back contact solar cells would have metal contacts on the front, which would require a higher dopant concentration on the front to reduce the contact resistivity and increase conductivity for the collection of electric current. EX1003, ¶110.

Swanson-352 pertains to "improved photovoltaic cell[s]," which is another name for solar cells. EX1015,1:5-17, 2:5-6; EX1003, ¶112. Swanson-352 describes a back-contact solar cell with electrical contacts 72 formed on the back surface over and contacting the P-type and N-type doped regions 53 and 55. *See* EX1015, FIGS. 6 and 10, 5:5-41. Figures 5 through 10 are fabrication steps of the solar cell and are "bottom side up for illustration purposes." EX1003, ¶112; EX1015, 4:38-51.

FIG_5

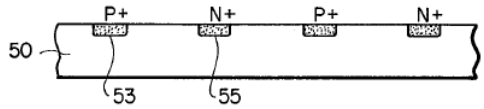


FIG_6

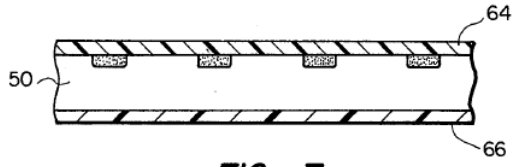


FIG_7

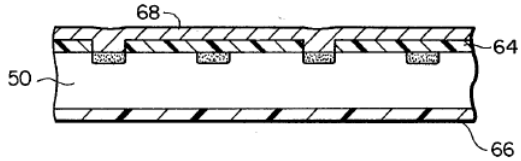


FIG_8

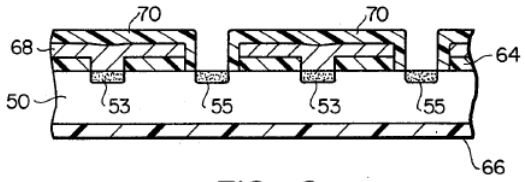


FIG_9

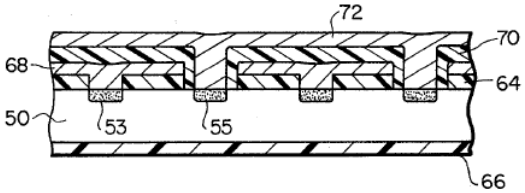


FIG_10

The fabrication process in Swanson-352 starts with FIG. 5, which depicts "an intrinsic or lightly doped N-type silicon substrate 50." EX1003, ¶113; EX1015,4:42-43. This lightly doped N-type substrate "[p]referably" is doped at "10^{14} dopant atoms per cubic centimeter or less." EX1015,4:43-51. Swanson-352 further described that a "shallow diffused region" 62 in the front portion of the substrate is formed by "diffusion of an N type dopant such as phosphorous into the surfaces to a depth of 0.1 micron," *i.e.*, 100 nanometers. EX1015, 4:45-49.

Swanson-352 disclosed that "[t]he **maximum surface dopant concentration** of the diffused regions 60 and **62 is 10^{18} atoms per cubic centimeter**." EX1015,4:43-51 (emphasis added). Diffused region 62 is on the solar cell's front side, as shown in FIG. 5 above. EX1015, 4:38-51. A silicon oxide layer 66 is also formed on the front side. *Id*. 4:60; EX1003, ¶113.

Diffused region 60 is on the backside and is further doped in later steps to become p+ and n+ regions having dopant concentration of 10^{21} atoms/cubic centimeter, as shown in FIG. 6. EX1015, 4:52-57. Connected to these backside p+ and n+ regions are metal contacts 72 (made of silver or titanium) to electrically contact the doped regions. EX1015, 5:36-41; EX1003, ¶114.

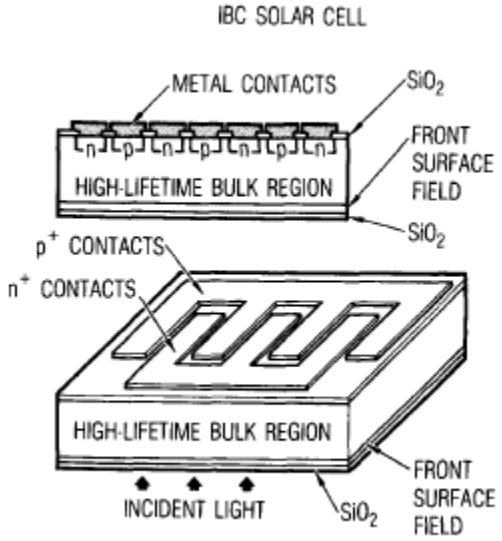
Finally, Swanson-352 explains that the "photovoltaic cell substrate processed in accordance with the present invention provides a high minority carrier lifetime," which the Skilled Artisan would understand leads to a higher efficiency solar cell. EX1015,5:42-44; EX1003, ¶115.

D. Marvin (EX1035)

Marvin is a paper entitled "Analysis of Interdigitated Back Contact Solar Cells for Space Use" presented in 1989. EX1035, 821; EX1023, ¶75. Exhibit 1006 is an authentic copy of Marvin published and publicly available by August 1989, and it was also made available for electronic download from *IEEE Xplore* by August 6, 2002, and in any event was publicly available before December 22,

2014. EX1023, ¶¶6, 29-30, 75-83; EX1048; EX1054. It was registered with the US Copyright Office in September 1989 and even cited in a July 12, 2006 International Search Report for a PCT Application, published March 1, 2007, further confirming its public accessibility and dissemination before December 22, 2014. EX1023, ¶¶81-82; EX1055, 15. Accordingly, Marvin is prior art under 35 U.S.C. §102(a)(1).

Like Li, Marvin disclosed a back contact solar cell (IBC) with a silicon substrate having a doped portion on the front side ("FSF") and P-type and N-type doped regions on the back side with metal contacts formed over both of the back-side doped regions, as shown in the figures reproduced below:



EX1035, 822, Fig. 1; *see also* EX1007, 3-4.

Marvin is a study whose purpose was "to evaluate the IBC cell design for use in space missions." EX1035, 822. Reasoning that the "primary incentive" for

use of back-contact solar cells is "increased efficiency," Marvin studied "optimum design[s]" for "concentrated light." EX1035, 822, 826. Among other characteristics, Marvin simulated different cell thicknesses and FSF doping concentrations, and calculated "End of Life" (EOL) efficiencies. EX1035, 822-823; EX1003, ¶119.

Specific "consideration was given to optimization of the front surface field region" of the back-contact solar cell. EX1035, 826. With respect to this issue, "[i]t was found that by replacing [front surface field uniformly doped at 5E18] with a Gaussian doping profile with a characteristic width of 15 [micrometers] and a peak concentration of 1E17, the EOL efficiency was 12.3%." EX1035, 826. This EOL efficiency was higher than FSF doped at higher concentrations. EX1007, Table 7.[4] "EOL" refers to end of life efficiency of the solar cell. EX1003, ¶120. With thinner silicon wafers, the efficiency increased more. *Id*.

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[4] The authors of Marvin also submitted a report to the government that contained substantially the same study and conclusions. The government report is entitled "Interdigitated Back Contact Silicon Solar Cell Analysis and Design Recommendations for Space Use." EX1007, Cover. This 1989 report was approved for public release with a date of April 11, 1990 and made available through the Defense Technical Information Center ("DTIC"). *Id.* (DTIC accession number "AD-A220 414"); EX1023, ¶¶65-66. The National Technical Information Service ("NTIS") confirmed that the report was indexed and

Based on its findings, Marvin concluded that, especially for high radiation space environments, the FSF should be "graded over 15 [micrometers] with a peak doping concentration of 1E18 [i.e., $1x10^{18}$] cm^{-3}," which, at high radiation, yields "EOL efficiency [that] approaches 16%." EX1035, 827.

E. Motivation to Combine Li with King or Swanson-352 or Marvin

Li disclosed a back-contact solar cell in which the front portion of the silicon substrate should include a doped region on the front side of the solar cell. EX1005, ¶49, FIG. 3 (318) and 5E (520). Although Li does not specify the precise concentration of dopants to be used for this front doped portion of the substrate, the optimal concentration for this front doped region was well known and would have been obvious in view of the teachings of King, Swanson-352, or Marvin. EX1003, ¶123.

Li, King, Swanson-352, and Marvin are analogous art, and they all relate to solar cell design and in particular, **back contact** solar cells. The Skilled Artisan would have been motivated to combine Li's back contact solar cell with the front

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catalogued in the NTIS Bibliographic Database on or about July 1990 making it available to anyone interested to find and retrieve it. EX1023, ¶66; EX1040. Given its publication date, it is also prior art under 35 U.S.C. 102(a)(1). *See, e.g.*, *Boileau v. Diamond*, 659 F.2d 247, 248-50 (D.C. Cir. 1981) (holding government report was a printed publication when declassified and made available to the DTIC).

portion doping concentration of $1x10^{18}$ cm^{-3} or less as disclosed in King, Swanson-352, or Marvin. All three disclosed this front dopant concentration. King taught that this concentration was the "optimum" for back-contact solar cells, and Swanson-352 taught to use it as the maximum concentration for this portion of a back contact solar cell. EX1003, ¶124.

Marvin likewise taught that for space applications, a "peak doping concentration of 1E18 [1×10^{18}] cm^{-3}" or lower with a "Gaussian doping profile with a characteristic width of 15 [micrometers]" resulted in better efficiency metrics than higher doping concentrations. EX1035, 826-827. The government report version of Marvin's study also confirmed this, thus bolstering the motivation to rely on Marvin's FSF doping concentration. EX1003, ¶125. For example, for cells of the same thickness, Marvin reported that end-of-life efficiency as a function of cell thickness was consistently worse at higher FSF doping concentrations, including when comparing cells with thickness of 65 and 80 microns at concentrations of 1×10^{18} cm^{-3} and 5×10^{18} cm^{-3} (*see* Table 8 of Marvin EX1007, annotated below):

Table 8. EOL Efficiency as a Function of cell Thickness and FSF at 100 Suns

Cell Thickness (μm)	Graded FSF (μm)	Step FSF (μm)	FSF Doping cm^{-3}	*Spacing a/b/c	Cell Efficiency (%)
50	15	—	1E18	10/20/10	14.64
50	15	—	1E18	5/10/5	15.44
65	15	—	1E18	5/10/5	11.57
80	15	—	1E18	5/10/5	8.97
200	15	—	5E18	5/10/5	1.18
65	—	0.5	5E18	5/10/5	8.17
80	—	0.5	5E18	5/10/5	6.83

*a,c = spaces between right and left edges of collectors and unit cell boundaries, resp.; b = space between collectors. All dimensions are in micrometers.

Based on this data, the report concluded that "to maximize the EOL performance," the "FSF is graded over 15 [microns] with a peak doping concentration of 1E17 to 1E18 cm^{-3}." EX1007, 25.

Given Li's acknowledgement that "[e]fficiency is an important characteristic of a solar cell as it is directly related to the solar cell's capability to generate power" and that "[a]ccordingly, techniques for increasing the efficiency of solar cells are generally desirable" (EX1005, ¶0005), the Skilled Artisan reviewing Li would further have been motivated to select the efficient front doping concentration disclosed by any of King, Swanson-352 or Marvin. EX1003, ¶126.

Notably, Maxeon has alleged that Dr. Richard Swanson, one of the authors of King and the inventor of Swanson-352, is often referred to as "[t]he father of solar in the U.S." EX1013, ¶2. It would thus be natural for the Skilled Artisan to

look to Dr. Swanson's patents and publications (including King and Swanson-352) regarding the "optimum"/"maximum" doping concentrations for the front portion of back-contact solar cells to determine the dopant concentration to be used at the textured front portion of the back-contact solar cell disclosed in Li (EX1005, ¶0049, FIG. 5E). EX1003, ¶127; EX1006, 369; EX1015,5:42-44.

Marvin's focus on high radiation environments, such as space, would not have deterred the Skilled Artisan from combining with Li because Li does not limit its back-contact solar cell to low radiation or terrestrial environments. EX1003, ¶128. Li stressed the importance of increased efficiency in solar cell design (EX1005, ¶0005), and increased solar cell efficiency is no less important in space environments than in terrestrial environments. EX1003, ¶128. And Marvin described the higher efficiency that can be achieved with its disclosed FSF doping concentration. EX1035, 826-827.

F. Reasonable Expectation of Success

As Dr. Banerjee explains, combining the back-contact solar cell of Li with the front dopant concentration taught by King or Swanson-352 or Marvin for back-contact solar cells would have been straightforward and done with a reasonable expectation of success by the Skilled Artisan. EX1003, ¶¶129-130. It is nothing more than using the same technique disclosed by Li to diffuse the front dopants to a certain concentration as taught by King, Swanson-352, or Marvin. *Id*.

Specifically, Li described using an N-type dopant for the front portion of the substrate. EX1005, ¶0049. The Skilled Artisan would have recognized that King and Swanson-352's teaching to dope the front portion with phosphorus (the same N-type dopant disclosed in Li) to a surface concentration of 1 x 10^{18} cm^{-3} (EX1006, 369, Fig. 3; EX1015,4:43-51) could be readily implemented using Li's disclosed process of heating the substrate in the presence of a gaseous N-type dopant (phosphorous). EX1003, ¶130 (citing EX1041). Doping a silicon surface to a particular surface doping concentration would have been within the ordinary skill of the Skilled Artisan. *Id*.

Although Marvin appears to have used a "p+" FSF on a P-type substrate[5] (EX1035, 823; EX1007, 15, 26), it would have been obvious to the Skilled Artisan that the **concentration** taught by Marvin is equally applicable to an N-type front doped region on an N-type substrate, as seen from the teachings of King and Swanson-352 and explained by Dr. Banerjee. EX1003, ¶131 (citing EX1043, 2946-47).

Finally, combining Li with the front portion's dopant concentration of King or Swanson-352 or Marvin would not have changed Li's inherent disclosure of

[5] "FSF" refers to front surface field, which reduces surface recombination. EX1003, ¶150. A FSF has the same dopant type as the substrate. *Id*.

gettering metal impurities from the silicon substrate to the backside emitter region. EX1003, ¶132. As discussed in §VI.G.1.v below, the natural result of Li's process of doping the backside emitter region at 950°C would be to getter metal impurities from the silicon substrate, through the 1-2 nm thick silicon oxide dielectric layer, and into the N-doped and P-doped regions of the polysilicon layer. *Hospira, Inc. v. Fresenius Kabi USA, LLC*, 946 F.3d 1322, 1332 (Fed. Cir. 2020) ("If a property of a composition is in fact inherent, there is no question of a reasonable expectation of success in achieving it.").

G. The Combination of Li and King or Swanson-352 or Marvin Disclosed All Elements of Claims 10-12, 15

1. Claim 10

i. *Preamble*

Claim 10 recites: "*A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising*."

To the extent the preamble is limiting, Li disclosed the preamble. Specifically, Li disclosed a "back-contact solar cell." EX1005, Title, Abstract, ¶0041. As discussed in §V.A.1, the Skilled Artisan would recognize that a "back-contact solar cell," as depicted in Li Figure 5E, has a front side facing the sun during normal operation (shown at the bottom) and a back side opposite the front

side that contains the N-doped and P-doped regions of the polysilicon layer (506), as shown below. EX1003, ¶134.

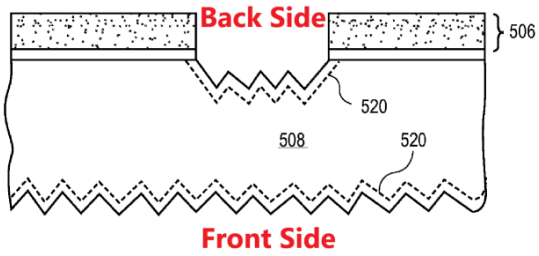


FIG. 5E

The Skilled Artisan would further recognized that the jagged/textured bottom side in FIG. 5E is the front side (as annotated above) because solar cells are often textured on the front side to reduce the reflection of incident light. *Id.*; EX1010, 269. Li described its solar cell as a "back-contact solar cell," and thus the p-type and n-type regions in layer 506 (above) would be on the back side in FIG. 5E, as understood by the Skilled Artisan for a back-contact solar cell. *E.g.,* EX1010, 108; EX1003, ¶71.

ii. *Front portion of substrate and its doping concentration*

Claim 10 requires "*a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to* 2×10^{18} cm^{-3} *and wherein the portion of the silicon substrate is formed at the front side of the solar cell*."

Li disclosed "*a silicon substrate*," (EX1005, ¶¶0037, 0041) identified with numeral 508 (blue) in FIG. 5E shown below.

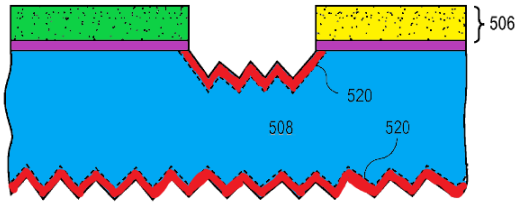


FIG. 5E

Li also disclosed that a front "*portion of the silicon substrate*" is formed by diffusing with phosphorus, as identified in red with numeral 520 on the bottom side of FIG. 5E. EX1003, ¶137; EX1005, ¶¶0049, 0038. This dopant-diffused front "portion of the silicon substrate" would naturally have a certain "*dopant concentration*" when doped. EX1003, ¶137. Further, because the phosphorus dopant in Li is diffused into the substrate, rather than deposited, the doped front portion would be "*formed*" as part of, *i.e.*, "*a portion*" of, the substrate. EX1003, ¶137.

While Li did not specify the dopant concentration of this front portion of the substrate, it would have been obvious to the Skilled Artisan to use a concentration "*approximately less than or equal to* 2×10^{18} *cm*$^{-3}$," as claimed. EX1003, ¶¶138-139. As discussed above (§VI.B), decades before the 315 Patent, King studied this very question, and taught that, particularly for back-contact solar cells (such as Li), the optimum front surface dopant concentration is 1×10^{18} cm^{-3}, consistent with the claim limitation. EX1006, 369. Likewise, Swanson-352 (from the same author as King) taught that the "*maximum* surface dopant concentration" of the silicon

substrate for a back-contact solar cell should be 1×10^{18} cm^{-3} for a depth of 0.1 micron (i.e., 100 nm), and that the remainder of the substrate is "[p]referably" doped at 1×10^{14} cm^{-3} or less. EX1015,4:43-51.

The Skilled Artisan would have understood that when the front surface dopant concentration is at 1×10^{18} cm^{-3}, as taught by King and Swanson-352, the concentration in the rest of the doped front portion in Li would be below 1×10^{18} cm^{-3}. EX1003, ¶139. As Dr. Banerjee explains, when gaseous phosphorus dopant used by Li is diffused into silicon, the concentration is highest at the surface of the silicon and decreases as a function of the depth of diffusion, as seen for example in the figure below. *Id*. (citing EX1041, Fig. 1).

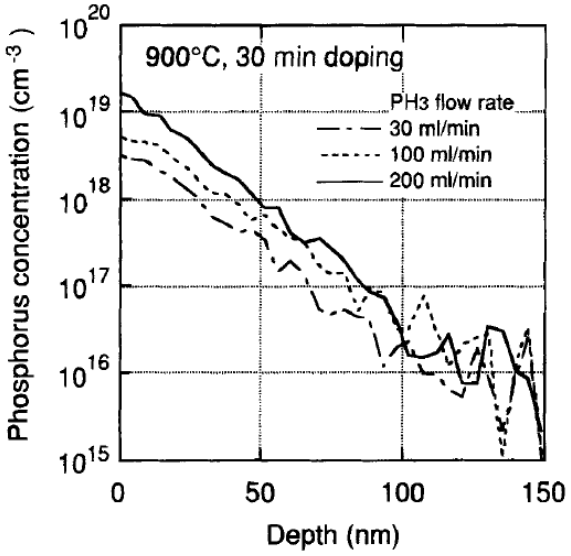


Fig. 1. SIMS profiles of phosphorus. Doping was carried out at 900°C for 30 min. PH_3 flow rate was varied from 30 to 200 ml/min.

Specifically, the above figure is reproduced from Kiyota, a 1994 publication, showing the diffusion profiles for PH_3, a gaseous phosphorus dopant, at 900°C for

30 minutes at various flow rates. EX1041, Figure 1. The surface phosphorus concentration is highest at the surface (0 nm depth) and decreases as the depth of diffusion increases into the solid substrate. EX1003, ¶139. The slower the flow rate, the lower the surface phosphorus concentration. *Id*. Notably, Swanson-352 taught a depth of 0.1 micron or 100 nm for the doped front portion, which is about the depth of the gaseous phosphorus diffusion shown in Kiyota for a gaseous phosphorus dopant. *Id*.; EX1041, 2242 (based on doping time of 30 minutes, "[s]hallow phosphorus-doped layers were formed about 100 nm deep").[6]

Likewise, Marvin expressly disclosed that, for a back contact solar cell to be used in space applications, the front portion of the substrate should be doped at a "**peak** doping concentration" of approximately 1×10^{17} to 1×10^{18} cm^{-3}. EX1035, 826 (emphasis added); *see also* EX1007, 25-26. Because 1×10^{18} cm^{-3} is the "peak," the dopant concentration within the front doped portion of the substrate, as taught by Marvin, would not exceed 1×10^{18} cm^{-3} as well, consistent with the claimed concentration "*approximately less than or equal to* 2×10^{18} cm^{-3}. EX1003, ¶140.

[6] If a deeper diffusion depth is desired as taught by Marvin, Kiyota also disclosed that the diffusion depth can be increased with longer processing times. EX1003, ¶139; EX1041, Fig. 4.

Thus, the combination of Li with King, Swanson-352, or Marvin disclosed and would have rendered obvious the claimed front portion dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3}. EX1003, ¶141.

iii. *Backside dielectric region*

Claim 10 requires "*a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of the solar cell*."

Li disclosed this element. EX1003, ¶¶142-143. The back-contact solar cell described in Li's FIG. 3 or 5E includes, on the back-side, a "dielectric film 510" formed above the silicon substrate (508), which film may be "composed of silicon dioxide and has a thickness approximately in the range of 1-2 nanometers." EX1005, ¶0043. Although the layer 510 is not labeled in FIG. 5E, it corresponds to the purple layer noted above, as confirmed by FIG. 5B, which shows an earlier step in Li's fabrication process. EX1003, ¶142. This same "dielectric film" is depicted as 320 in FIG. 3. EX1005, ¶0039.

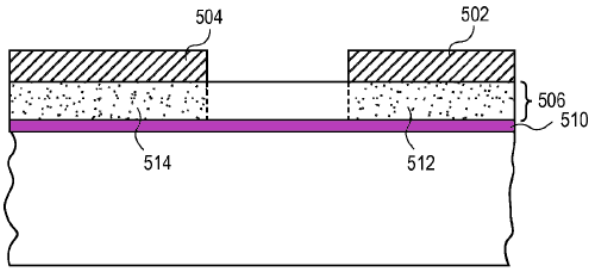


FIG. 5B

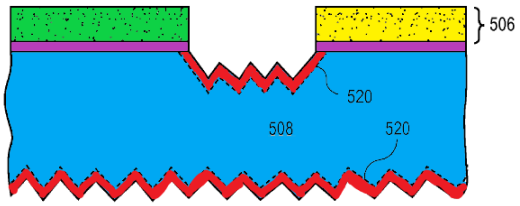


FIG. 5E

"Silicon dioxide" is a dielectric material, and Li's silicon dioxide dielectric film 510 (FIG. 5B) or 320 (FIG 3) is the same material used by the 315 Patent for its dielectric region. EX1003, ¶143; EX1001, 4:47-48.

iv. *Emitter region*

Claim 10 requires "*a first emitter region … formed over the dielectric region*." Li disclosed this element. EX1003, ¶¶144-151.

The 315 Patent refers to the "P-type and N-type doped polysilicon regions" formed over the dielectric region 310 (purple) in FIG. 5 as the "first and second emitter regions 312, 314" (green and yellow). EX1001,6:55-57.

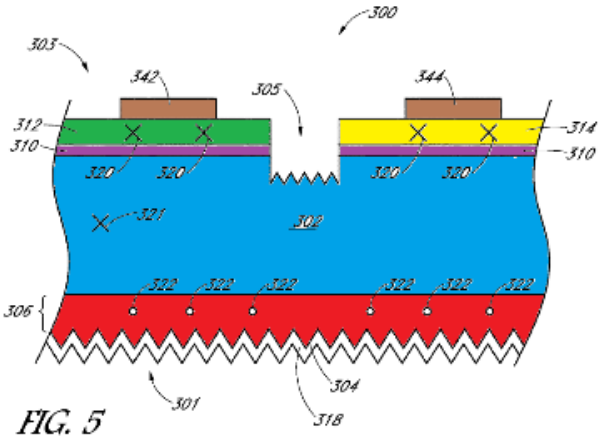


FIG. 5

Just like FIG. 5 of the 315 Patent, Li described the same structures of a polysilicon "material layer" (506 in FIG. 5E or 302 in FIG. 3) made up of an "N-type region 308 [yellow] and a P-type region 310 [green]" formed over the dielectric film 320 (purple circle below). EX1005, ¶¶36-37; EX1003, ¶147. Because Li's polysilicon "P-type region 310" and "N-type region 308" (in FIG. 3

and corresponding green and yellow regions in FIG. 5E of Li) are the same structure, arrangement, and doping as the "P-type and N-type doped polysilicon regions" in FIG. 5 of the 315 Patent, they satisfy "*the first and second emitter regions*" of the 315 Patent claims. EX1003, ¶¶147-149.

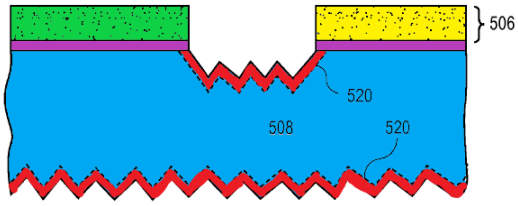


FIG. 5E

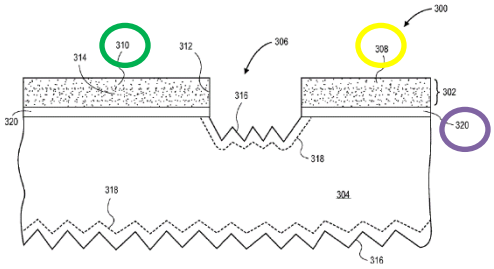


FIG. 3

Li

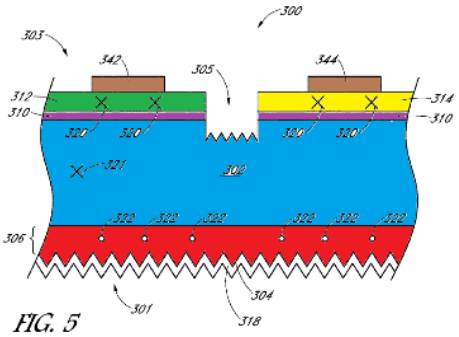


FIG. 5

315 Patent

Specifically, the "P-type and N-type doped polysilicon regions" in FIG. 5 of the 315 Patent are formed on a silicon dioxide dielectric layer 310, which is formed on a silicon substrate 302. EX1001, 6:50-62. The P-type and N-type polysilicon regions are described as the "first and second emitter regions, 312, 314." EX1001, 6:55-57.

FIG. 5 of the 315 Patent is the same arrangement as disclosed in Li. Li's polysilicon "P-type region 310" and "N-type region 308" are likewise formed on a silicon dioxide dielectric layer 320 which is formed on the silicon substrate 304 in

FIG. 3. EX1003, ¶149. These doped polysilicon regions are the same as the "emitter" regions described and claimed by the 315 Patent. *Id*. Thus, Li disclosed *a first emitter region formed over the dielectric region,* as claimed. EX1003, ¶¶147-151.

At one point, the 315 Patent also states that "[i]n an embodiment, the silicon substrate can be an N-type silicon substrate." EX1001, 5:45-46. To the extent Maxeon argues that an N-type substrate is required (despite not appearing in the claims), the Skilled Artisan would have understood that Li's silicon substrate is N-type. EX1003, ¶150. Dr. Banerjee explains that this is because Li disclosed diffusing the front portion of the substrate with an N-type dopant (EX1005, ¶49) just as Swanson-352 taught to diffuse the front portion with N-type dopant (EX1015; 4:45-49). The purpose of diffusing the front portion of a back contact solar cell in Li and Swanson-352 with the N-type dopant would be to create a front surface field to reduce surface recombination on the front side. EX1003, ¶150. Front surface fields have the same dopant types as the substrate but with higher dopant concentration than the substrate. *Id*.; EX1011 (Figure 8).

To the extent that Maxeon argues that Li's substrate is not N-type and the claim somehow requires an N-type substrate, it would have been obvious to the Skilled Artisan to use an N-type substrate for Li, as taught by Swanson-352, Neuhaus, and Swanson-485. EX1003, ¶152; EX1015, 4:42-43 (Swanson-352:

"lightly doped N-type silicon substrate 50"). It was common before 2014 for back-contact solar cells to have an N-type substrate, as disclosed, for example, in Swanson-352, Luque, Neuhaus, and Swanson-485. EX1003, ¶71-73, 110-113, 152; EX1015, 4:42-43; EX1010, 108 (Figure 3.26), EX1011, 11 (Figure 8); EX1012, 3:23. And given Li's teaching to dope the front portion of the substrate with an N-type dopant, and Swanson-352, Neuhaus, and Swanson-485's teaching that the front n-type dopant is diffused into an N-type substrate, the Skilled Artisan would have been motivated to use an N-type substrate for Li's solar cell to create a front surface field and thereby reduce surface recombination on the front side. EX1003, ¶152; EX1015, 4:43-52; EX1011, 11 (Figure 8); EX1012, 5:38-47.

v. *Metal impurities*

Claim 10 requires the "*first emitter region*" to have "*metal impurities*." Li disclosed this element. EX1003, ¶¶153-170.

The 315 Patent specification describes that heating the solar cell above 900°C can getter metal impurities into the emitter region and at the same time perform diffusion of the dopant. EX1001, 5:21-31. The 315 Patent notes that heating at or below 900°C "can be insufficient to diffuse metal impurities through a tunnel oxide and into a polysilicon region." EX1001, 5:15-20.

In Li, dopant diffusion is conducted above 900°C, just like in the 315 Patent, and more specifically it is heated at 950°C. EX1005, ¶0045. While Li did not

explicitly state that its polysilicon "emitter region" "*ha[s] metal impurities*," the Skilled Artisan would have understood that this limitation is inherently disclosed because the doping method disclosed in Li (of heating above 900°C) would necessarily and inevitably result in metal impurities being present due to gettering of metal impurities from the silicon substrate and into the polysilicon doped regions of the material layer 506, in the same way as described in the 315 Patent. EX1003, ¶¶155-170.

"When the prior art does not expressly disclose a claim limitation, 'inherency may supply a missing claim limitation in an obviousness analysis.'" *Hospira*, 946 F.3d at 1329. That Li's backside polysilicon doped regions would inherently include metal impurities is demonstrated by evidence both before and after the effective date of the 315 Patent. *Id.* at 1329 ("Extrinsic evidence can be used to demonstrate what is 'necessarily present' in a prior art embodiment even if the extrinsic evidence is not itself prior art.").

First, Li disclosed that either a single crystalline or multicrystalline silicon substrate may be used. EX1005, ¶¶0037, 0042. Particularly in the case of multi-crystalline silicon substrates (which are contemplated by both Li and the 315 Patent (EX1001, 3:35-36), and which accounted for the majority of substrates used in the solar cell industry in 2013 (EX1022, 66)), the Skilled Artisan would have

immediately recognized that substantial metal impurities were known to exist in all such substrates. *See* §V.A.3; EX1003, ¶¶88-90, 157.

Second, as discussed in §V.A.3, combining gettering and dopant diffusion into a single step of heating was the standard practice in the solar cell industry. EX1003, ¶¶85-87.

Third, publications both before and after the effective date have shown that metallic impurities are transferred from silicon substrates into polysilicon layers, including through thin silicon oxide layers. EX1003, ¶¶159-170. This is achieved by a process called gettering that necessarily occurs when the solar cell of Li is heated at the 950°C processing temperature contemplated by Li. *Id*.

For example, in 1977, an IBM patent by Hu, titled "Method of Gettering Using Backside Polycrystalline Silicon," disclosed that heating a "semiconductor body" with a deposited backside "polycrystalline layer" at 1000°C or less results in "getterable impurities such as copper, lithium, sodium, potassium, iron, cobalt, nickel, chromium, and gold [diffusing] to, and becom[ing] trapped in, the polycrystalline silicon film." EX1017, 5:61-6:6. The Hu patent described "gettering with a **backside layer of polycrystalline silicon**" to remove "unwanted impurities" from the semiconductor. *Id.*, Abstract (emphasis added). Hu explained that "[d]uring these high temperature processing steps, unwanted impurities such as copper, iron, nickel, sodium and potassium ions move toward and into the

polycrystalline silicon layer and thereby away from the semiconductor devices." *Id.* Thus, Hu confirmed that during the heating steps of Li, metal impurities in the silicon substrate would have naturally and inevitably gettered to the backside polysilicon "material layer" of Li that comprises the N-doped and P-doped regions. EX1003, ¶160.

Ramappa, a 1999 publication, confirmed that the natural gettering effect would have occurred despite the presence of Li's 1-2 nm thick silicon dioxide dielectric layer. EX1025; EX1003, ¶161. Ramappa observed that metal impurities such as iron "exhibit[] very high diffusivity (10^{-6} cm^2/s at 900°C) and solubility (2 x 10^{13} cm^{-3} at 900°C) in silicon." EX1025, 3773. Ramappa then "present[ed] results on diffusion of iron in SiO_2 films grown on Si," showing that at the temperature used by Li, iron diffuses readily across silicon dioxide layers even much thicker (50-100nm) than the 1-2 nm layer used by Li. EX1025, 3773-3774, Fig. 1; EX1003, ¶161. A red line is added to the Figure 1 of Ramappa reproduced below to show approximately where 1-2 nm thickness would be in this figure.[7] EX1003, ¶161.

[7] Iron impurity levels in multicrystalline silicon were reported to be as high as 10^{14}-10^{16} cm^{-3} in concentration. *Supra* §V.A.3.

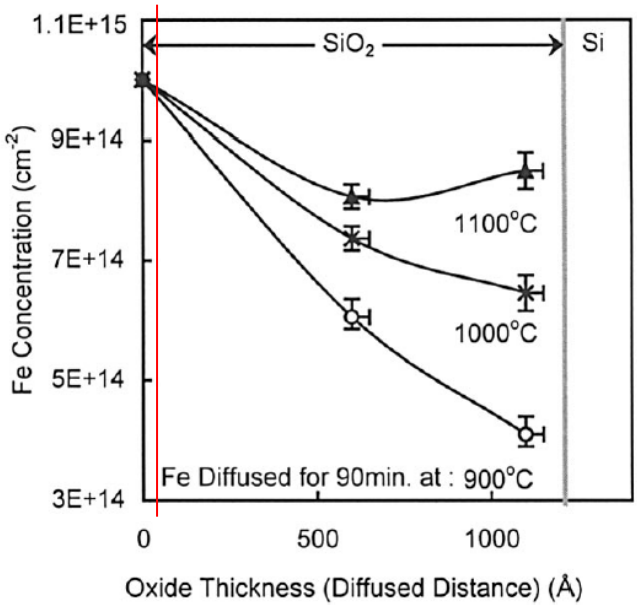


Figure 1. Iron concentration profile in SiO_2 following in-diffusion at temperatures of 900, 1000, and 1100°C for 90 min. Iron concentrations were measured by TXRF.

Based on this data, the Skilled Artisan would conclude that the metal impurities in Li's substrate would necessarily have diffused across the thin silicon oxide layer of Li at the temperature disclosed in Li. EX1003, ¶162. Yoshimura, published in 2006, further confirms that during gettering processes, a "silicon oxide film" having "thickness of 0.5 to 1 nm thereabouts" necessarily allowed "impurity metal Md" to "readily pass through." EX1026, ¶0056; EX1003, ¶163.

Moreover, Federal Circuit precedent allows inherency to be demonstrated by non-prior art references. *Hospira*, 946 F.3d at 1329. Here, after 2014, the scientific literature confirms that metal impurities are gettered into polysilicon layers even through a thin silicon dioxide layer when heated to the temperature of Li. For example, Liu-1 reported in a 2018 publication direct observations of iron

impurities being gettered and present in both phosphorous-doped polysilicon and boron-doped polysilicon layers despite the presence of silicon oxide layers grown on the silicon wafer surface at "thickness of around 1.3-1.4 nm." EX1003, ¶164; EX1028, 2276-2277. For example, as shown by the red line in Figure 4 of Liu-1 reproduced below, iron atoms are gettered and present in the phosphorus-diffused polysilicon ("Poly-Si") layer as they move from the substrate to the PSG (phosphosilicate glass) layer. EX1003, ¶164; EX1028, Figure 4. The phosphorus diffusion was performed at 890ºC. EX1028, 2276.

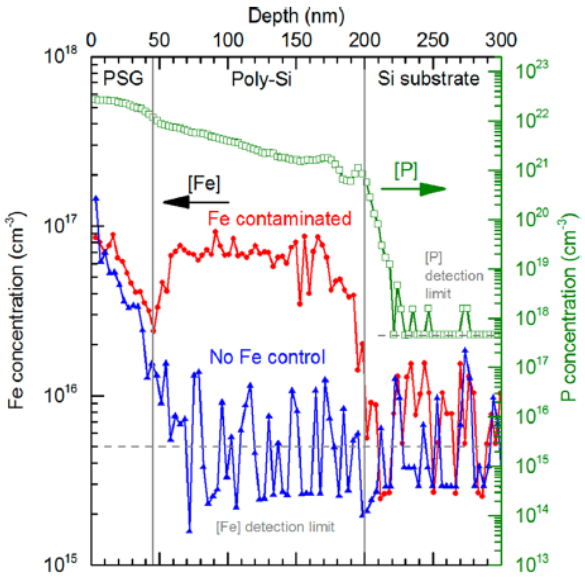


Figure 4. SIMS Fe and P concentrations (top) and uncalibrated O signal (bottom) in $POCl_3$-diffused polysilicon passivating contact layers and the near-surface silicon substrate, for samples with and without an initial bulk Fe contamination of 10^{14} cm^{-3} prior to the contact formation.

Liu-1 also reported that iron impurities are gettered and present in boron-diffused polysilicon layers, as seen from the red line in Figure 7 reproduced below.

EX1003, ¶165; EX1028, Figure 7. The boron diffusion was performed at 900ºC. EX1028, 2276.

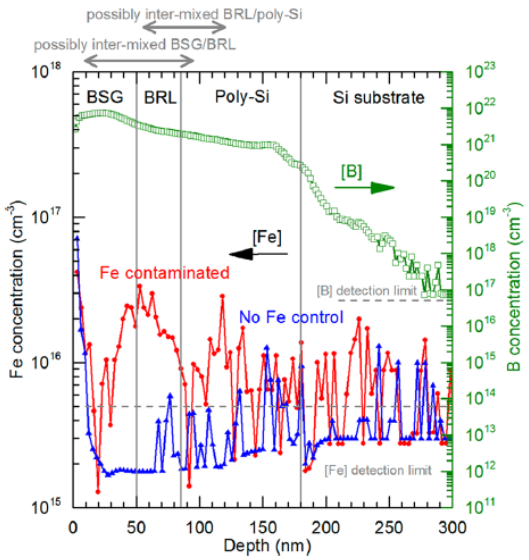


Figure 7. SIMS Fe and B concentrations in BBr_3-diffused polysilicon passivating contact layers and the near-surface silicon substrate, for samples with and without an initial bulk Fe contamination of 10^{14} cm^{-3} prior to the contact formation. Note that the positions of the BSG/BRL and BRL/poly-Si interfaces are indicative only, as the boundaries are intermixed (particularly at the BSG/BRL interface).

Another 2018 paper by the same author, Liu-2, reported that while a "thin oxide interlayer hinders the gettering effectiveness at low diffusion temperatures… its blocking effect becomes small at the moderate temperatures used to fabricate optimum polysilicon contacts," and "[t]he gettering effectiveness increases with increasing diffusion temperature." EX1029, 136. In particular, Liu-2 studied gettering with phosphorus diffusion carried out between 780-890°C and boron diffusion at 930°C and observed gettering through the "chemical oxide interlayers" in the range of ~1.3 nm (in the same thickness range contemplated by Li). EX1029, 137-139; EX1003, ¶167.

Thus, the art amply demonstrates that Li's heating and diffusing of the dopants into the polysilicon layer at 950°C (which is higher than the temperature used in Liu-1 and Liu-2) would necessarily have resulted in impurities being gettered and present in Li's doped polysilicon regions, even despite an intervening thin 1-2 nm interfacial silicon oxide layer.[8] EX1003, ¶168; EX1029, 136 ("The gettering effectiveness increases with increasing diffusion temperature.").

Furthermore, the disclosure of the 315 Patent itself can also be used as evidence of inherency. *Hospira*, 946 F.3d at 1329-1330. Here, Li's heating process is nearly identical to the heating process described in the 315 Patent. EX1003, ¶170. The 315 Patent describes that "the silicon substrate 202 can have contaminants and/or impurities 220, for example metal contaminants and/or metal impurities." EX1001, 4:65-67. As discussed above, this was a well-known characteristic of all silicon substrates, and particularly multi-crystalline silicon substrates. *See* §V.A.3. In one example, the 315 Patent discloses using a

[8] The metal impurities would be present in the polysilicon emitter regions using Li's two-step heating approach for the back and front of the solar cell. EX1003, ¶169. Alternatively, it would also have been obvious to the Skilled Artisan to combine the two heating steps of Li into a single heating step for the doping of the front and back sides of the solar cell. This would have saved energy and cost of manufacturing, and would not have had any negative impacts on the resulting solar cell. EX1003, ¶169.

temperature of 975ºC (EX1001, 5:40-44), while Li used a temperature of 950ºC. The 315 Patent describes that temperatures above 900ºC would nonetheless be sufficient: "heating at temperatures above 900 degrees Celsius can include gettering metal impurities 220 through the dielectric region 210, e.g., tunnel oxide, to into the emitter region 212, e.g., polysilicon regions." EX1001, 5:21-25; EX1003, ¶170. In contrast, the 315 Patent discloses temperatures at or below 900ºC would be ***in***sufficient. EX1001, 5:10-39 (emphasis added). Given the identical structures and processing temperatures—greater than 900°C (315 Patent) and 950°C (Li)—of the solar cells disclosed in the 315 Patent and Li, the gettering effect observed in the 315 Patent would also have necessarily and inevitably been observed in Li for precisely the same reasons. EX1003, ¶170.

vi. *Metal contact*

Claim 10 requires "*a first metal contact formed over the first emitter region.*" Li disclosed this element. EX1003, ¶¶171-175.

Li described that in solar cells, it was well known that "[t]he doped regions are connected to metal contacts on the solar cell to direct an electrical current from the cell to an external circuit coupled thereto." EX1005, ¶0004. From this description, the Skilled Artisan would have understood that Li's "**back-contact** solar cell" would, by definition, be fabricated with a metal contact over the doped

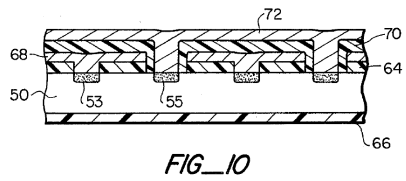
emitter region on the back surface of the solar cell such that it can direct an electrical current from the cell to an external circuit. EX1003, ¶172.

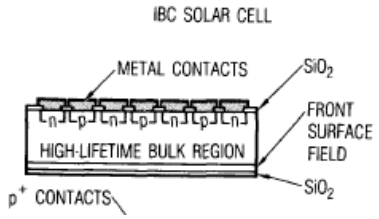
Although Li did not depict metal contacts in its figures,[9] the Skilled Artisan would have understood from Li's description that "doped regions are connected to metal contacts on solar cells" and from Li's repeated reference to "**back-contact** solar cell" that Li's solar cell would necessarily have included metal contacts on the back surface over the N-doped and P-doped regions 502 and 504. EX1003, ¶173. The name "back contact solar cell" itself denotes that the metal contacts are on the backside of the solar cell contacting the doped regions. EX1003, ¶70. As Dr. Banerjee explains, metal conducts electricity, and without the addition of metal contacts on the back surface, a "back-contact solar cell" cannot transmit electricity to an external circuit. EX1003, ¶173.

Alternatively, to the extent Maxeon argues that Li does not disclose metal contacts, it would have been obvious to the Skilled Artisan to add metal contacts on backside doped N and P regions, as taught by Swanson-352 and Marvin in the combination with Li, because that was the standard practice for back contact solar cells. EX1003, ¶¶70-73, 174. Forming metal contacts on the doped regions of the

[9] Li stated that "well-known fabrication techniques … are not described in detail in order to not unnecessarily obscure embodiments of the present invention." EX1005, ¶0021

back-contact solar cell was well known in the art. *Id.*; §V.A.1. Both Swanson-352 (FIG. 10, element 72) and Marvin, as reproduced below, showed decades ago metal contacts formed over the doped regions and contacting them.





EX1015, Fig. 10; EX1035, Fig. 1; *see also* EX1007, Fig. 1.

Thus, to the extent Maxeon argues that Li does not disclose metal contacts, the combination of Li and Swanson-352 or Marvin disclosed this element. EX1003, ¶¶174-175. And it would have been obvious to the Skilled Artisan to add metal contacts over the doped emitter regions based on Li in combination with the general knowledge of the Skilled Artisan, or, alternatively, by the combination of Li with either of Swanson-352 or Marvin, at least because the Skilled Artisan would have recognized that metallic contacts are necessary for a back-contact solar cell to perform its intended function. EX1003, ¶175.

2. Claim 11

Claim 11 depends from claim 10 and further recites: *"wherein the portion of the silicon substrate comprises N-type dopants."*

As discussed above (§VI.G.1.ii), Li described "*the portion of the silicon substrate,*" which refers back to the front doped portion of claim 10. Further, Li

described doping the front portion 520 (shown in red) "with the gaseous **N-type dopant** source." EX1005, ¶0049 (emphasis added); *see also* EX1005, ¶0038 ("[S]ubstrate 304 of back-contact solar cell 300 includes **N-type dopants** 318 at or near surfaces of substrate 304 not covered by material layer 302, as further depicted in Fig. 3.") (emphasis added).

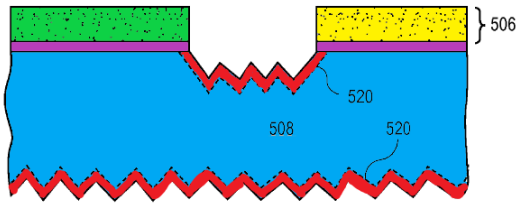


FIG. 5E

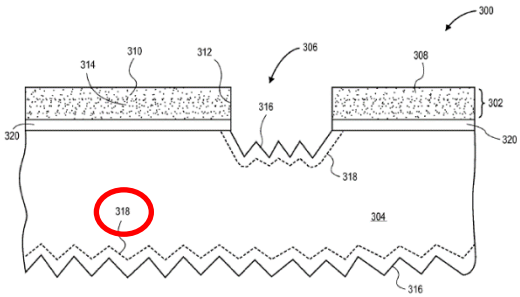


FIG. 3

Thus, the combination of Li with Swanson-352, or King, or Marvin disclosed this element.[10]

3. Claim 12

Claim 13 depends from claim 10 and further recites: *"wherein the portion of the silicon substrate comprises phosphorous."*

[10] Swanson-352 also taught to dope the front portion of the silicon substrate with "an N-type dopant such as phosphorous." EX1015, 4:38-51. Figures 1-6 of King all disclosed an N-type dopant (again phosphorus) for the dopant concentration. EX1006, 367.

As discussed above for Claim 11, Li described "*the portion of the silicon substrate comprises N-type dopants.*" Li further disclosed that N-type dopants "include[] phosphorous dopant impurity atoms." EX1005, ¶0037. Swanson-352 and King also disclosed to use phosphorous. EX1015,4:38-51; EX1006, 367.

4. Claim 15

Claim 15 depends from claim 10 and further recites: *"wherein the first emitter region comprises polysilicon."*

Li disclosed that "*the first emitter region comprises polysilicon*." As discussed above (§VI.G.1.iv), either one of the P-typed doped or N-type doped regions (310, 314) in the "material layer 506" or 302 of Li would have been an "emitter region" corresponding to the "first and second emitter regions 312 and 314" referred to by the 315 Patent. EX1003, ¶¶105-106, 182.

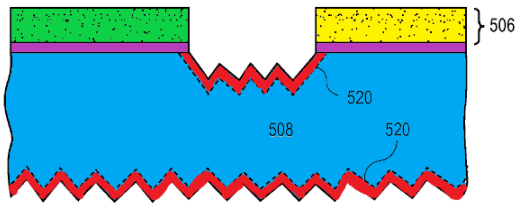


FIG. 5E

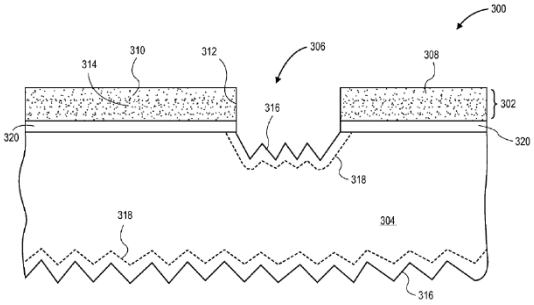


FIG. 3

Li described material layer 506/302 to be "a poly-crystalline silicon layer," *i.e.*, polysilicon layer. EX1003, ¶¶105, 183; EX1005, ¶¶0037, 0042. Thus, Li's "first emitter region comprises polysilicon."

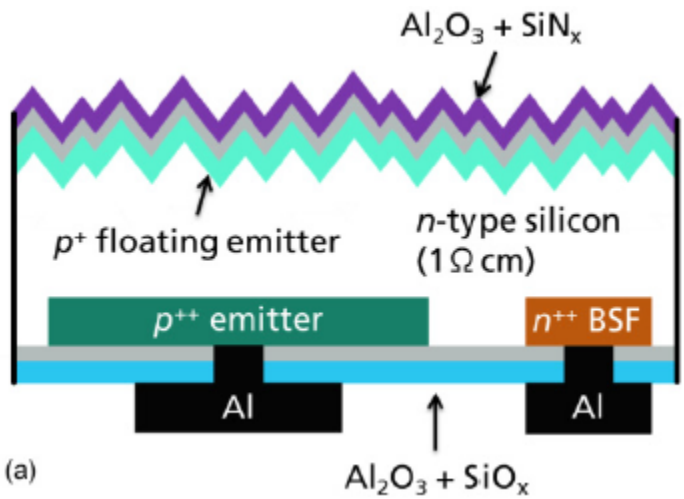
VII. LI COMBINED WITH MULLER WOULD HAVE RENDERED CLAIMS 10 AND 13-15 OBVIOUS

As discussed above, Li disclosed all elements of claim 10 except for the front dopant concentration, which as discussed above, was disclosed by King, Swanson-352, or Marvin. In the following combination of Li and Muller, Muller (instead of King, Swanson-352, or Marvin) is used for its disclosure of the front dopant concentration. Additionally, Muller disclosed that the front portion of the substrate is beneficially doped with boron, a P-type dopant, as required by claims 12 and 13.

A. Muller (EX1008)

Muller is a journal article entitled "Ion implantation for all-alumina IBC solar cells with floating emitter" that was published electronically online on September 19, 2014 and in any event was publicly available before December 22, 2014. EX1008, 265; EX1047; EX1023, ¶¶67-74. Exhibit 1008 is an authentic copy of Muller published before December 22, 2014, and it was publicly available from the publisher's website and also widely available from over 700 libraries. EX1023, ¶¶67, 73; EX1047. It has been widely distributed and has been also known and cited by others by at least October 15, 2014, further confirming its public dissemination before December 22, 2014. EX1023, ¶73; EX1048. Accordingly, Muller is prior art under 35 U.S.C. §102(a)(1).

Like Li, Muller disclosed a back contact solar cell, referred to therein as "interdigitated back contact (IBC) solar cells." EX1008, 265. Muller described that such solar cells "have a high efficiency potential as there are no metal contacts on the front side resulting in a maximum absorption of incident light," and both[] *n*- and *p*-contacts [are] on the back side." *Id*. The back-contact solar cells of Muller included an N-type substrate having a doped portion on the front side (identified as the "p+floating emitter") and a "p++ [doped] emitter" and an "n++ [doped] BSF" on the back side with a metal contact (aluminum) formed over and contacting the back side doped regions, as shown below in Muller Fig. 3a:



EX1008, 269; EX1003, ¶188.[11]

[11] The backside "p++ emitter" and "n++ BSF" regions of Muller corresponds to the P-type doped regions and N-type doped regions of Li, except that Li's emitter regions are made of polysilicon, while in Muller these regions are ion-implanted into the substrate. EX1003, ¶188.

Muller investigated "*n*-type IBC solar cells with a low-dose ion-implanted [boron-doped] front floating emitter (FFE) which [Muller] compare[d] to a low-dose ion implanted [phosphorus-doped] front surface field (FSF) passivated by SIO_2." EX1008, 265. "Ion implantation" is a process in which dopant atoms are ionized and then accelerated at the silicon substrate to implant the ions/dopant atoms into the substrate. EX1003, ¶189. Ion-implantation had been shown before 2014 to increase solar cell efficiency while reducing the process sequence in production. EX1003, ¶194.

In both cases, the back contact solar cells constructed by Muller had a front doped region with a concentration of approximately equal to or less than 2×10^{18} cm^{-3}. EX1003, ¶190. The orange dotted lines in FIG. 1 of Muller (below) showed the dopant profile of the two back-contact solar cells constructed and compared by Muller: one fabricated with a boron-doped front region (as a "front floating emitter" "FFE") having front portion peak dopant concentration equal to approximately 2×10^{18} cm^{-3} and another fabricated with a phosphorus-doped front region (as a "front surface field" / "FSF") having a front portion peak dopant concentration less than 2×10^{18} cm^{-3}. *Id.*; EX1008, 269 (FIG. 1).

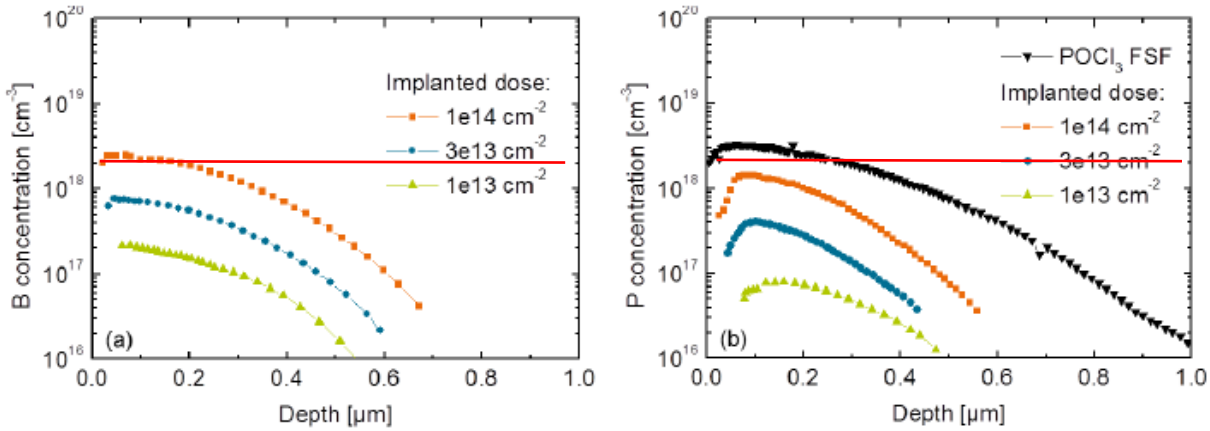


Fig. 1. ECV profiles measured on planar samples after ion implantation and annealing for 80 min at 1050 °C. (a) Low dose boron implantations for a floating emitter; (b) low dose phosphorus implantations for a front surface field. A conventional $POCl_3$-diffused FSF used in Ref [8] is shown for comparison.

In both cases, the concentration of dopant at or near the front surface of the cell is highest and the concentration decreases with depth into the substrate, as shown in Muller Fig. 1 (red lines added at 2×10^{18} cm^{-3}).[12] EX1008, 267. In both cases, the front portion of the substrate was doped by "ion implantation." EX1008, 265.

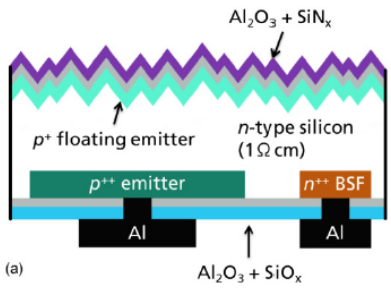
Muller reported that in comparative testing, "[t]he best solar cell with a boron doped FFE has a conversion efficiency of 21.8% (see Fig. 3b)." EX1008, 269. This boron ion-implated FFE solar cell was also passivated on the front by aluminum oxide, instead of the silicon oxide that was used with the phosphorus ion-implanted FSF solar cell. *Id.* The boron FFE having peak dopant concentration of about 2×10^{18} cm^{-3} lowered recombination, and when implemented

[12] The vertical axis of this figure is on a logarithmic scale and thus the first tick above 10^{18} marks the concentration of $2x10^{18}$ cm^{-3}. EX1003, ¶190.

together with aluminum oxide and silicon nitride passivation on the front side, resulted in greater resistance to UV degradation of solar cell efficiency, compared to the phosphorus ion-implated FSF that was front passivated with silicon oxide. EX1003, ¶191; EX1008, 271 ("For textured FFE samples, J_0 values down to 5 fA/cm^2 were measured with an Al_2O_3 passivation. This configuration turned out to be quite stable against UV-irradiation."); *id.* (reporting that under UV-illumination, "[t]he efficiency of [ion-implanted] FSF cells dropped dramatically by more than 50% while the [ion-implanted] FFE cells lost only about 1 % absolute"). *See also*, *id.at* 269-270 (Table 2); *id.* 265, Abstract.

B. Motivation to Combine Li and Muller

The Skilled Artisan would have been motivated to combine the ion-implanted front floating emitter and aluminum oxide and silicon nitride passivation of Muller with Li because of its better solar cell efficiency and resistance to UV degradation, as disclosed by Muller. EX1003, ¶¶192-197. In the combination of Muller and Li, the ion-implanted boron-doped FFE of Muller (along with its frontside aluminum oxide and silicon nitride passivation) would replace the phosphorus (N-type) doped front portion 520 of Li's back-contact solar cell. *Id.*



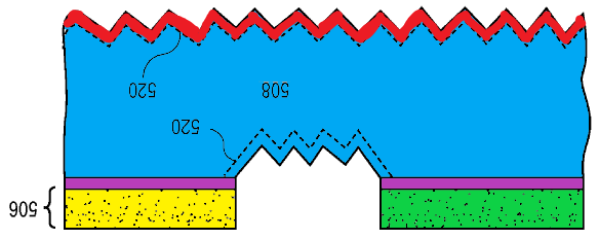


FIG. 5E

Li and Muller are both directed to back-contact solar cells and their fabrication. EX1003, ¶188. Li disclosed a back-contact solar cell in which the front portion 520 of the silicon substrate should be doped (EX1005, ¶0049), but Li did not specify the concentration of dopants that should be utilized at the front surface. Muller supplies that information by showing that, for a back-contact solar cell utilizing an N-type substrate (as in Li) using a boron-doped ion-implanted front floating emitter ("FFE") at a front dopant concentration of $2x10^{18}$ cm^{-3} or less and then passivating the front side with a Al_2O_3/SiN_x stack resulted in better resistance to surface recombination (J_o) and UV degradation, and overall efficiency of the solar cell, than a N-type back contact solar cell having a phosphorus-doped ion-implanted front surface field (FSF), passivated by SiO_x and/or SiN_x. EX1003, ¶193; EX1008, Tables 1 and 2.

Moreover, as recognized in the art, using ion implantation for doping solar cells "provides a unique opportunity to obtain grid-parity because it simplifies the fabrication of advanced cell structures." EX1036, 10. Ion-implantation had also

been shown before 2014 to increase solar cell efficiency while reducing the process sequence in production. *Id*., 11; EX1003, ¶194.

And, as seen in Muller Table 1 (below), the solar cell with the ion-implanted boron-doped FFE and Al_2O_3 passivation had a lower *Jo* (leakage current, where a lower value indicates better passivation) than the ion-implanted phosphorus-doped FSF solar cell:

Table 1. Characteristics of the investigated profiles (best values achieved so far). Sheet resistance was measured by 4 point probe on planar reference samples. J_0 was extracted from QSSPC measurements (textured samples for FSF & FFE and planar samples for emitter and BSF) using the high injection method [11].

Sample type	Species	Implanted dose [cm^{-2}]	R_{Sheet} [Ω/sq]	J_0 [fA/cm^2]	Passivation
Floating emitter (FFE)	Boron	1e13	3900	5	Al_2O_3
		3e13	1500	6	
		1e14	650	7	
Front surface field (FSF)	Phosphorus	1e13	2200	12	SiO_2/SiN_x
		3e13	880	15	
		1e14	440	10	
Emitter	Boron	7e14	147	9	Al_2O_3
		1e15	108	22	
		1.5e15	73	24	
Back surface field (BSF)	Phosphorus	3e15	39	370	Al_2O_3

Further, as seen in Muller Table 2 (below), when the ion-implanted FFE and FSF were tested with 1.5X UV-illumination to assess degradation, the FSF solar cell conversion efficiency (η) dropped 2 fold from 20.9% to 9.6% after UV exposure, while the FFE η only dropped 1.1%:

Table 2. Degradation of IBC solar cells under UV-illumination in a sun tester for 36 h at 500 W/m^2.

Front side	State	V_{OC} [mV]	J_{SC} [mA/cm^2]	*FF* [%]	*η* [%]
Front surface field (FSF)	before UV exposure	672	39.2	79.6	20.9
	after UV exposure	612	19.8	79.3	9.6
Floating emitter (FE)	before UV exposure	673	39.9	77.3	20.7
	after UV exposure	668	38.2	76.7	19.6

EX1003, ¶195-196.

Given Li's acknowledgement that "[e]fficiency is an important characteristic of a solar cell as it is directly related to the solar cell's capability to generate power" and that "techniques for increasing the efficiency of solar cells are generally desirable" (EX1005, ¶0005), the Skilled Artisan reviewing Li would have been motivated to modify Li's solar cells to replace the diffusion doped front portion 520 with the more efficient ion-implanted boron-doped FFE and passivation layers as disclosed by Muller. EX1003, ¶197. And, as between Muller's ion-implanted FSF and FFE, the Skilled Artisan would have been highly motivated to select the ion-implanted boron FFE with concentration of approximately $2x10^{18}$ cm^{-3} because of its higher efficiency and stability. EX1008, 267, Fig. 1; EX1003, ¶197.

C. Reasonable Expectation of Success

Combining the back-contact solar cell of Li with the front side ion-implanted floating emitter of Muller would have been straightforward and done with a reasonable expectation of success by the Skilled Artisan, particularly given that Li does not disclose any other layers on the front surface of the solar cell (Li at Fig. 5E). EX1003, ¶¶198-199. The Skilled Artisan would have recognized that Muller's teaching to dope the front surface with an ion-implanted boron floating emitter to a peak dopant concentration of approximately 2×10^{18} cm^{-3} could be

readily implemented. *Id*. As Dr. Banerjee explains, it would have been well within the level of the Skilled Artisan before 2014 to insert Muller's ion-implanted boron FFE process steps for the front side before Li's process of fabricating the back side of the solar cell. *Id*. The fabrication of the front portion of the solar cell could have been done (and was often done) independently of the application and treatment of layers on the back surface of the solar cell, and without impacting the layers applied to the back surface of the solar cell. EX1003, ¶¶199-200.

Muller's FFE and passivation layers would also be entirely consistent with the solar cell fabrication process described in Li, even for the diffusion of the back side trench region 520 using a gaseous N-type dopant source. EX1005, ¶0049; EX1003, ¶199-200. No substantial changes would have been necessary in this combination. Dr. Banerjee explains that diffusion masks (i.e., barriers) were well-known, and would allow diffusion of Li's trench between the backside doped "emitter regions" 310, 314 without cross-doping the substrate's front portion. *Id*. (citing EX1046). Indeed, it was well known in the art that a silicon nitride layer would act as a diffusion barrier during phosphorus diffusion of other portions of the solar cell, in addition to its functions as an antireflection coating and surface passivation for the front surface. EX1003, ¶199 citing EX1010, 291. Here, Muller taught to cap the front side of the solar cell with a silicon nitride layer over the the boron ion-implanted FFE and aluminum oxide layer. EX1008, 266 and Fig. 3.

Thus, when Li's front portion of the substrate is replaced with an FFE with aluminum oxide layer and capped with a silicon nitride layer, as taught by Muller, the silicon nitride layer would prevent cross-doping of the boron implanted front portion of the substrate with phosphorus during doping of Li's trench region, while still maintaining its function as an anti-reflection and passivation layer. EX1003, ¶199.

Finally, combining Li with the front-side boron FFE of Muller would not have changed Li's inherent disclosure of gettering metal impurities from the silicon substrate to the emitter region, as discussed above in §VI.G.1.v, because the Skilled Artisan would have recognized that fabrication of the front side of the solar cells would have been independent of the fabrication of the back side of the solar cells. EX1003, ¶201.

D. The Combination of Li and Muller Disclosed All Elements of Claims 10, 13-15

As discussed above (§VI.G.1.i- VI.G.1.vi), Li disclosed all elements of Claim 10, except for the dopant concentration of the front portion of the substrate. Li also disclosed the additional "polysilicon" element of claim 15, as discussed in §VI.G.4. The following discussions will focus on the front dopant concentration of Claim 10 and the additional elements recited in Claims 13-14.

1. Claim 10 – front dopant concentation

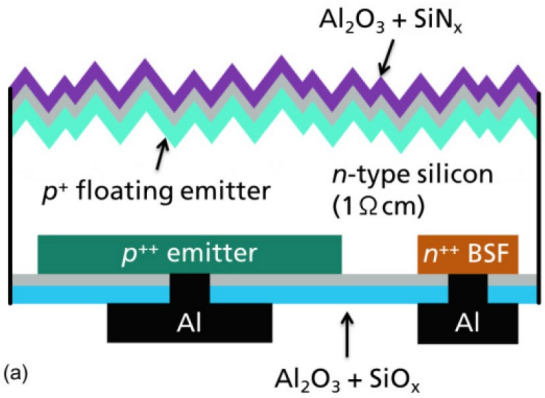
As discussed above (§VI.G.1.ii), Li disclosed to dope the front portion of its substrate but does not disclose the specific dopant concentration to use. Using an "n-type" silicon substrate similar to Li, Muller taught the benefits and advantages to a back contact solar cell of having the substrate's front portion be ion-implanted with a "boron doped front floating emitter" at a peak doping concentration of approximately 2×10^{18} cm^{-3}. EX1008, 267, 269. It would have been obvious to the Skilled Artisan to combine Li and Muller, as discussed above (§VII.B), to replace the phosphorus diffused front portion of Li with the ion-implanted boron-doped FFE at the dopant concentration taught by Muller because such combination would result in increased solar cell efficiency and better stability under UV illumination, as taught by Muller. EX1003, ¶¶192-203. Further, the Skilled Artisan would have recognized that the ion-implanted FFE on the front is "*a portion of the silicon substrate*" itself, as claimed. EX1003, ¶203.

Therefore, Muller's ion-implanted boron-doped FFE at doping concentration of approximately 2×10^{18} cm^{-3} would disclose this limitation.

2. Claim 10 - metal contact

As discussed above (§VI.G.1.vi), Li disclosed that metal contacts are formed over the doped regions of solar cells. Muller confirms that back-contact solar cells

were known to include metal contacts formed over and connected to the N-doped and P-doped region of a back contact solar cell, as shown in Muller Fig. 3(a):



Muller specifically shows a aluminum contact positioned over and contacting the "p^{++} emitter" and the "n++ BSF" doped regions. Therefore, Muller would have confirmed to the Skilled Artisan that the "back-contact solar cell" of Li would have a "metal contact formed over the first emitter region." EX1003, ¶208.

To the extent that Maxeon argues that Li alone does not disclose the metal contacts over the emitter region, it would have been obvious to the Skilled Artisan to incorporate the metal contacts of Muller over the doped emitter region of Li because they are both in the same particular field of **back contact** solar cells and the incorporation of such metal contacts was well known and also expressly recognized by Li as being part of any solar cell. EX1003, ¶209; §VII.B. Further, the Skilled Artisan would have been motivated to incorporate metallic contacts to contact the emitter doped region because metal contacts were known to be

necessary for a back-contact solar cell to perform its intended function. EX1003, ¶209.

3. Claims 13 and 14

Claim 13 depends from claim 10 and further recites: "*wherein the portion of the silicon substrate comprises P-type dopants.*" Claim 14 depends from claim 10 and further recites: "*wherein the portion of the silicon substrate comprises boron.*"

In the combination of Li and Muller, the front portion of the silicon substrate would comprise ion-implanted **boron, a P-type dopant** (EX1005, ¶0037), because the boron-doped FFE, as taught by Muller would have replaced the diffused phosphorus doped front portion originally disclosed by Li, as discussed above with respect to claim 10. EX1003, ¶¶211-212. Thus, the combination of Li and Muller disclosed claims 13 and 14.

VIII. CLAIMS 10-15 WOULD HAVE BEEN OBVIOUS IN VIEW OF THE PREVIOUS COMBINATIONS, FURTHER IN VIEW OF HU AND RAMAPPA

The obviousness grounds presented above disclose all limitations of the Claims 10-15. To the extent Maxeon disputes that claim 10's requirement that the "emitter region having metal impurities" is inherently disclosed by Li alone, it would have been obvious to the Skilled Artisan that such metal impurities would be present in the emitter region due to gettering that occurs during Li's dopant diffusion step, as taught by Hu and Ramappa.

A. Hu (EX1017)

Hu is US Patent 4,053,335, entitled "Method of Gettering Using Backside Polycrystalline Silicon." EX1017, Face. Hu issued on October 11, 1977. EX1017, Face. Accordingly, Hu is prior art under 35 U.S.C. §102(a)(1).

Hu disclosed gettering of metal impurities from a silicon "semiconductor body" into a "polycrystalline layer" on the backside of the silicon at temperatures of 1000°C or less. EX1017, 5:61-6:6 and Abstract; EX1003, ¶217. In particular, Hu described "deposition of a polycrystalline silicon film on a semiconductor wafer prior to any or some high temperature processing steps." EX1017, Abstract. Hu explained that "[d]uring these high temperature processing steps, unwanted impurities such as copper, iron, nickel, sodium and potassium ions move toward and into the polycrystalline silicon layer and thereby away from the semiconductor devices." *Id.*

B. Ramappa (EX1025)

Ramappa is a journal article entitled "Diffusion of Iron in Silicon Dioxide" that was published on October 21, 1999, and in any event was publicly available before December 22, 2014. EX1023, ¶¶84-91. Exhibit 1025 is an authentic copy of Ramappa that was published before December 22, 2014, and it was widely available from over 800 libraries and has been known and cited by others, for example, by a 2002 conference paper available electronically at IEEE Xplore by

April 2003, further confirming its public dissemination before December 2014. EX1023, ¶84, 90-91; EX1056. Thus, it is therefore prior art under 35 U.S.C. §102(a)(1).

Ramappa "present[ed] results on diffusion of iron in SiO_2 films grown on Si," showing that at the temperature used by Li, iron diffuses readily across silicon dioxide layers that were even much thicker (50-100nm) than the 1-2 nm layer used by Li. EX1025, 3773-3774, Fig. 1. Figure 1 of Ramappa reproduced below to shows this diffusion and a red line is added approximately where 1-2 nm thickness would be:

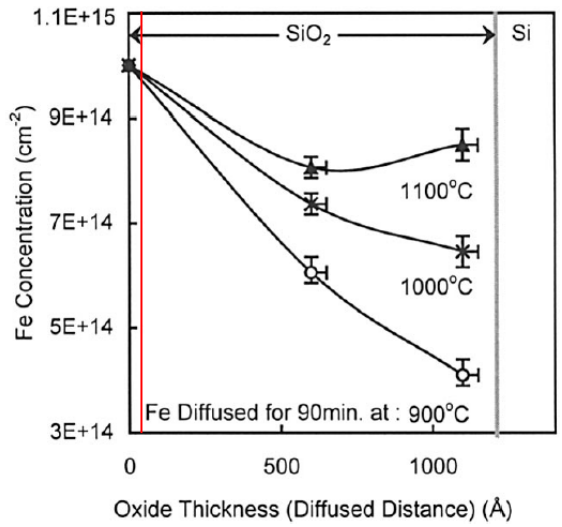


Figure 1. Iron concentration profile in SiO_2 following in-diffusion at temperatures of 900, 1000, and 1100°C for 90 min. Iron concentrations were measured by TXRF.

C. Motivation to Combine Li With Hu and Ramappa

The Skilled Artisan would have had a strong motivation to remove metal impurities from the multicrystalline silicon substrate disclosed in Li by gettering, as discussed in §V.A.3. EX1003, ¶220. In 2013, over 65% of the silicon solar

cells utilized multicrystalline silicon substrates, which were known to have substantial metal impurity concentrations (such as iron) in the substrate. EX1022, 66; EX1016, 696; EX1003, ¶220. Li disclosed using multicrystalline substrates for its solar cells. EX1005, ¶0037, 0042.

As discussed above (§V.A.3), integrating a gettering step into solar cell fabrication processes simultaneously with the diffusion step was well known and used routinely to getter metal impurities from the silicon substrate in order to improve cell efficiency, especially with respect to multicrystalline silicon solar cells. EX1016, 696; EX1003, ¶¶82-90.

Incorporating the teachings of Hu and Ramappa using high temperatures, *e.g.*, 900°C to 1,000°C, to expressly getter metal impurities would have been obvious in view of the similarities to Li's teaching to heat at 950°C and Li's disclosure of polysilicon and thin silicon dioxide layers on the back side of the silicon substrate. EX1003, ¶221. Specifically, Hu discloses gettering to a backside layer of polysilicon, just as Li also disclosed a polysilicon layer on the backside. *Id*. It would likewise be obvious to the Skilled Artisan that at the high temperature processing step disclosed by Hu and Li (*i.e.* above 900°C), the silicon dioxide layer would not hinder gettering, as shown by Ramappa, and thus would not deter the Skilled Artisan from gettering the metal impurities. *Id*. Based on Ramappa, it would be apparent to

the Skilled Artisan that iron would readily diffuse across the thin 1-2 nm silicon dioxide layer of Li into the polysilicon layer. *Id*.

D. Reasonable Expectation of Success

The Skilled Artisan would have recognized that the combination of any of the above Li combinations with Hu and Ramappa is merely an arrangement of old elements (i.e., known gettering steps and temperatures) with each performing the same function it had been known to perform (the gettering of iron metal impurities into backside polysilicon layer) and yielding no more than what one would expect from such an arrangement (a solar cell with metal impurities being present in the backside polysilicon emitter region). EX1003, ¶222.

The Skilled Artisan would have recognized from Hu and Ramappa that Li's description of heating the polysilicon layers to 950°C during the doping process (EX1005, ¶0045), would result in the gettering of metal impurities, such as iron, from silicon substrate, through the 1-2 nm dielectric layer, and into the doped polysilicon emitter region. EX1003, ¶223. This would not have required substantial changes to the process of Li, and heating steps could be combined into a single heating step as needed to simultaneously getter and diffuse dopants, as would have been known in the art, and would also have conserved energy and costs. *Id*. Any adjustments, if needed at all, would have been routine and well within the level of skill of the Skilled Artisan. *Id*.

E. Combining Hu and Ramappa With Any of the Previous Combinations Would Have Disclosed All Elements of the Challenged Claims

As described above (§§VI-VII), the above combinations of King, Swanson-352, Marvin, or Muller with Li would have disclosed all limitations of Claims 10-15. However, to the extent Maxeon disputes Li's inherent disclosure of Claim 10's requirement of "*a first emitter region having metal impurities formed over the dielectric region*," combining any of these combinations with the gettering teachings of Hu and Ramappa would have rendered a solar cell with this limitation obvious.

As discussed above, Hu and Ramappa confirm that Li's heating of the polysilicon material layers at 950°C during formation of the emitter region would result in metallic impurities such as iron being gettered from Li's multicrystalline silicon substrate, through the 1-2 nm silicon dioxide layer, and into the doped emitter region. EX1003, ¶225. Therefore, Hu and Ramappa in combination with Li would disclose this limitation.

IX. SECONDARY CONSIDERATIONS SUPPORT OBVIOUSNESS

There is no objective evidence of non-obviousness that might support patentability of Claims 10-15. And there is no evidence of commercial success or any nexus of any alleged commercial success to the alleged invention. There is no long and unfulfilled need for the claimed invention, as seen from the readily

available teaching in the prior art of all aspects of solar cells according to the 315 Patent's claims. These teachings such as the optimal front dopant concentration for a back contact solar cell (King, Swanson-352, Marvin, Muller) or the gettering of metal impurities through silicon dioxide and to the backside polysilicon of a silicon substrate (Ramappa, Hu), go back decades before 2014. The concept of a back-contact solar cell with backside polysilicon emitter region formed over a dielectric region was also well known and publicly disclosed even before 2014 (e.g., by Li (EX1005), Swanson-485 (EX1012)). These teachings demonstrate that the claimed invention simply followed conventional wisdom to reach results already predicted by the prior art. There was no industry praise or unexpected results, nor any evidence of copying.

Furthermore, even if Maxeon were able to establish any secondary considerations and a proper nexus to the claims, any such secondary considerations would be insufficient to overcome the strong case of obviousness presented here. *Leapfrog Enters., Inc. v. Fisher-Price, Inc.*, 485 F.3d 1157, 1162 (Fed. Cir. 2007).

X. CONCLUSION

CSI respectfully requests that Claims 10-15 of the 315 Patent be canceled as unpatentable.

Dated: June 25, 2024

Respectfully Submitted,

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CERTIFICATE OF COMPLIANCE

I hereby certify that this brief complies with the type-volume limitations of 37 C.F.R. § 42.24, because it contains 13,958 words (as determined by the Microsoft Word word-processing system used to prepare the brief), excluding the parts of the brief exempted by 37 C.F.R. § 42.24.

Dated: June 25, 2024

Respectfully Submitted,

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PETITION FOR INTER PARTES REVIEW

OF U.S. PATENT NO. 11,251,315

Attachment A:

Proof of Service of the Petition

CERTIFICATE OF SERVICE

I hereby certify that on this 25th day of June, a copy of this Petition, including all attachments, appendices and exhibits, has been served in its entirety by overnight mail on the following counsel of record for patent owner:

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Attachment B:

List of Evidence and Exhibits Relied Upon in Petition

Exhibit #	Reference Name
1001	U.S. Patent No. 11,251,315 to Smith et al. ("315 Patent")
1002	File History of U.S. Patent Application No. 16/877,255
1003	Declaration of Sanjay Banerjee, Ph.D. Regarding U.S. Patent No. 11,251,315
1004	Curriculum Vitae of Sanjay Banerjee, Ph.D.
1005	U.S. Patent Pub. No. 2011/0214719, "Method of Fabricating a Back-Contact Solar Cell and Device Thereof." ("Li")
1006	King, Sinton and Swanson, "Studies of Diffused Phosphorous Emitters: Saturation Current, Surface Recombination Velocity, and Quantum Efficiency," IEEE Transactions On Electron Devices, Vol 37, No. 2 (Feb. 1990) ("King")
1007	Marvin and Froedge, "Interdigitated Back Contact Silicon Solar Cell Analysis and Design Recommendations for Space Use," AD-A220-414 (Sept. 30, 1989) ("Marvin-DTIC")
1008	Muller et al., "Ion Implantation for All-Alumina IBC Solar Cells with Floating Emitter," Energy Procedia 55 (2014), 265-271 ("Muller")
1009	Reserved
1010	Luque and Hegedus, Handbook of Photovoltaic Science and Engineering (2002) ("Luque")
1011	Neuhaus and Munzer, *Industrial Silicon Wafer Solar Cells*, Advances in OptoElectronics, 1-15, at 11 (2007) ("Neuhaus")
1012	U.S. Patent No. 7,468,485 to Swanson ("Swanson-485")
1013	Complaint, *Maxeon Solar Pte. Ltd. v. Canadian Solar, Inc.,* Case No. 2:24-cv-210 (E.D. Tex., filed March 25, 2024)
1014	U.S. Patent Pub. No. 2007/0256728

Exhibit #	Reference Name
1015	U.S. Patent No. 4,234,352 ("Swanson-352")
1016	Seibt et al., "Gettering in silicon photovoltaics: current state and future perspectives," phys. stat. sol. (a) 203, No. 4, 696–713 (2006) ("Seibt")
1017	U.S. Patent No. 4,053,335 to Hu ("Hu")
1018	Ferre, et al., "Simultaneous gettering and emitter formation in multicrystalline-Si wafers by annealing phosphorus doped amorphous silicon compounds," Applied Physics Letters 98, 022102 (2011) ("Ferre")
1019	Vahanissi et al., "Gettering of Iron in Silicon Solar Cells with Implanted Emitters," IEEE Journal of Photovoltaics (Volume: 4, Issue: 1, January 2014) ("Vahanissi")
1020	U.S. Patent Pub. No. 2010/0105190 A1 ("Tomas")
1021	Buonassisi, et al. "Transition metals in photovoltaic-grade ingot-cast multicrystalline silicon: Assessing the role of impurities in silicon nitride crucible lining material," Journal of Crystal Growth 287 (2006) 402–407 ("Buonassisi")
1022	2013 Renewable Energy Data Book, U.S. Department of Energy (2013) ("REDB-2013")
1023	Declaration of Sylvia Hall-Ellis
1024	Curriculum Vitae of Sylvia Hall-Ellis
1025	Ramappa and Benley, "Diffusion of Iron in Silicon Dioxide," Journal of the Electrochemical Society 146(1) 3773-3777 (1999) ("Ramappa")
1026	U.S. Patent Pub. No. 2006/0118868 A1 ("Yoshimura")
1027	Reserved

Exhibit #	Reference Name
1028	Liu et al., "Direct Observation of the Impurity Gettering Layers in Polysilicon-Based Passivating Contacts for Silicon Solar Cells," ACS Appl. Energy Mater. 2018, 1, 2275−2282 ("Liu-1")
1029	Liu et al., "Effective impurity gettering by phosphorus- and boron-diffused polysilicon passivating contacts for silicon solar cells," Solar Energy Materials and Solar Cells 179 (2018) 136–141 ("Liu-2")
1030	DocketNavigator Report
1031	Fintiv Study https://www.law360.com/articles/1436071/print?section=ip
1032	Senator Tillis Letter
1033	Reserved
1034	Reserved
1035	Marvin and Froedge, "Analysis of Interdigitated Back Contact Silicon Solar Cells for Space Use," IEEE (1989) ("Marvin-IEEE")
1036	Rohatgi et al, "High-Throughput Ion-Implantation for Low-Cost High Efficiency Silicon Solar Cells," Energy Procedia 15 (2012), 10-19 ("Rohatgi")
1037	Reserved
1038	Reserved
1039	Reserved
1040	NTIS Signed Attestation re: "Interdigitated Back Contact Silicon Solar Cell Analysis and Design Recommendations for Space Use" ("ADA220414")

Exhibit #	Reference Name
1041	Kiyota et al., "Phosphorus Direct Doping from Vapor Phase into Silicon for Shallow Junctions," J. Electrochem. Soc. 141(8) 2241-2244 (August 1994) ("Kiyota")
1042	French, "Polysilicon: a versatile material for microsystems," Sensors and Actuators A 99 (2002) 3-12.
1043	Green, "Intrinsic concentration, effective densities of states, and effective mass in silicon," J. Appl. Phys. 67, 2944 (1990) ("Green")
1044	Henry, "Limiting efficiencies of ideal single and multiple energy gap terrestrial solar cells," J. Appl. Phys. 51, 4494 (1980) ("Henry")
1045	Birkmire et al., "Harnessing the Sun with Thin-Film Photovoltaics," NREL (April 1999) ("Birkmire")
1046	Ghoshtagore, "Silicon Dioxide Masking of Phosphorus Diffusion in Silicon," Solid-State Elements Vol. 18 (1975) ("Ghoshtagore")
1047	Muller et al., "Ion Implantation for All-Alumina IBC Solar Cells with Floating Emitter," Energy Procedia 55 (2014), 265-271, https://www.sciencedirect.com/science/article/pii/S1876610214013022 ("Muller Science Direct Webpage")
1048	IEEE Xplore, "IEEE Xplore Resources and Help: Publication Dates," https://ieeexplore.ieee.org/Xplorehelp/ieee-xplore-training/working-with-documents#publication-dates
1049	IEEE Xplore King Entry, https://ieeexplore.ieee.org/document/46368
1050	U.S. Patent No. 8,124,502
1051	Science Direct Liou Entry, https://www.sciencedirect.com/science/article/abs/pii/092702489290104W
1052	IEEE Xplore Yang Entry, https://ieeexplore.ieee.org/document/6924717

Exhibit #	Reference Name
1053	Reserved
1054	IEEE Xplore Marvin Entry, https://ieeexplore.ieee.org/document/74564
1055	WO 2007/022955 A1
1056	IEEE Xplore Slaoui Entry, https://ieeexplore.ieee.org/document/1190463
1057	Science Direct Kalkofen Entry, https://www.sciencedirect.com/science/article/abs/pii/S0921510704003654
1058	Wiley Online Library Seibt Entry, https://onlinelibrary.wiley.com/doi/abs/10.1002/pssa.200664516
1059	Science Direct Haarahiltunen Entry, https://www.sciencedirect.com/science/article/abs/pii/S0921510708005163
1060	IEEE Xplore Holt Entry, https://ieeexplore.ieee.org/abstract/document/4922483
1061	Semantic Scholar Ferre Entry, https://www.semanticscholar.org/paper/Simultaneous-gettering-and-emitter-formation-in-by-Ferre%CC%81-Mart%C3%ADn/1d060d97443c0ccad7bc812e7cc12b2c0afedbe1
1062	Science Direct Paviet-Salomon Entry, https://www.sciencedirect.com/science/article/abs/pii/S0921510712005661
1063	IEEE Xplore Cho Entry, https://ieeexplore.ieee.org/document/6925554
1064	Science Direct Reimann Entry, https://www.sciencedirect.com/science/article/abs/pii/S0022024810000758

Exhibit #	Reference Name
1065	Science Direct Bentzen Entry, https://www.sciencedirect.com/science/article/abs/pii/S0921510708005060
1066	IEEE Xplore Mutoh Entry, https://ieeexplore.ieee.org/document/1348791
1067	IEEE Xplore Bello Entry, https://ieeexplore.ieee.org/document/1529625
1068	IEEE Xplore Stavrides Entry, https://ieeexplore.ieee.org/document/1488115

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OF U.S. PATENT NO. 11,251,315

Attachment C:

Listing of the Claims of 11,251,315

Claim	Element
10[pre]	A solar cell, the solar cell having a front side which faces the sun during normal operation and a back side opposite the front side, the solar cell comprising:
10[a]	a silicon substrate, wherein a portion of the silicon substrate has a dopant concentration of approximately less than or equal to 2×10^{18} cm^{-3} and wherein the portion of the silicon substrate is formed at the front side of the solar cell;
10[b]	a dielectric region formed over the silicon substrate, wherein the dielectric region is formed over the back side of solar;
10[c]	a first emitter region having metal impurities formed over the dielectric region; and
10[d]	a first metal contact formed over the first emitter region.
11	The solar cell of claim 10, wherein the portion of the silicon substrate comprises N-type dopants.
12	The solar cell of claim 10, wherein the portion of the silicon substrate comprises phosphorous.
13	The solar cell of claim 10, wherein the portion of the silicon substrate comprises P-type dopants.
14	The solar cell of claim 10, wherein the portion of the silicon substrate comprises boron.
15	The solar cell of claim 10, wherein the first emitter region comprises polysilicon.