

Supplemental Declaration of Sanjay Banerjee
Regarding U.S. Patent No. 11,251,315

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. IPR2024-01194
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

**SUPPLEMENTAL DECLARATION OF SANJAY BANERJEE, Ph.D.
REGARDING U.S. PATENT NO. 11,251,315**

Petitioner Canadian Solar Inc., Ex. 1087, p. 1
Canadian Solar Inc. v. Maxeon Solar PTE. Ltd., IPR2024-01194

Petitioner Canadian Solar Inc., Ex. 1103, p. 1
Canadian Solar Inc. v. Maxeon Solar PTE. Ltd., IPR2024-01038

Supplemental Declaration of Sanjay Banerjee, Ph.D. Regarding U.S. Patent No.
11,251,315

I, Sanjay Banerjee, do hereby declare and state, that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, under Section 1001 of Title 18 of the United States Code.

Executed on: February 19, 2025



Sanjay Banerjee

Declaration of Sanjay Banerjee Regarding U.S. Patent No. 11,251,315

1. I am the Sanjay Banerjee, Ph.D. who has previously submitted a declaration in this proceeding. *See* EX1003. I have set forth the details of my engagement, background and qualifications, compensation and prior testimony, information considered, and understanding of relevant legal standards in my previously submitted Declaration Of Sanjay Banerjee, Ph.D. Regarding U.S. Patent No. 11,251,315, EX1003, which I hereby incorporate by reference.

2. I have been asked to offer additional opinions concerning some of the evidence I cited in my previous declaration.

3. In particular, in that previous declaration I cite to a number of articles that have been published in various technical journals, which for convenience I have set forth in the attached Appendix C.

4. I am and have been throughout my career personally familiar with each of the journals cited in Appendix C. I have read many papers published in these journals during the course of my career, and have myself published papers in many of them. Each cited journal is a well-known, reputable, reliable, and authoritative periodical which publishes compilations of scientific and technical publications and would be generally known to those in the field of solar cell design or manufacture.

5. Moreover, I have inspected each of the exhibits listed in Appendix C. In my opinion, and based on my experience with the journals cited in Appendix C

and on the appearance, contents, substance, and distinctive characteristics of such exhibits, each listed exhibit is what it appears to be, *i.e.*, an article published in the journal with which it is associated in the exhibit. Indeed, I see nothing in any of those exhibits to suggest that the exhibit is not what it appears to be, or which raises any doubt as to the exhibits authenticity or accuracy.

6. Also, in my opinion, and based on my experience, the dates on the exhibits of Appendix C are reliable and trustworthy because journals of the type listed in the Appendix have a reputational incentive to accurately publish the submissions each such journal receives, including by attaching an accurate publication date on such documents. Any such journal that was known to publish inaccurate information, including publication dates, would likely soon not be read by those in the field. Indeed, if such journal were not reliable, they would quickly cease to operate because those working in the field would not contribute articles to them.

7. Moreover, it would be very difficult for such dates to be mistakenly or intentionally altered because the underlying document remains available to those working in the field, including the authors and the general public, from the journals themselves. Any question as to the date of a paper published in any of the journals listed in Appendix C could therefore easily be verified and resolved.

Supplemental Declaration of Sanjay Banerjee Regarding U.S. Patent No.
11,251,315

8. It is also my opinion that the exhibits listed in Appendix C are the most probative and best source for both the content of the exhibit and the date of that content's publication because other ways of obtaining that information such as personally contacting the author(s) and publishers of the exhibits listed in Appendix C, would require an unreasonable amount of effort given the publicly available nature of the exhibits.

9. Finally, so that the record in this proceeding accurately reflects the specific statements of each exhibit in Appendix C that I have previously cited, I have included in Appendix C the statements I have previously cited in my earlier declaration.

APPENDIX C: List of Certain Exhibits Considered and Cited Statements

Exhibit Number	Exhibit Reference	Exhibit Citation
Ex. 1011	Neuhaus and Munzer, <i>Industrial Silicon Wafer Solar Cells</i> , Advances in OptoElectronics, 1-15, at 11 (2007) (“Neuhaus”)	(1) “First designs of interdigitated back contact (IBC) solar cells were investigated by Lammert and Schwartz.” EX1011, 11. 315 IPR Pet., 15. (2) Figure (8). EX1011 Fig. 8. 315 IPR Pet., 16, 45, 46. FIGURE 8: Schematic drawing of an IBC solar cell of SunPower.

Ex. 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”)

(1) EX1028, 2276-2277. 315 IPR Pet., 51, 52.

ACS Applied Energy Materials

which further augments its potential for the mass production of high-efficiency solar cells.

The work aims to gain a better understanding of the impurity gettering effects of polysilicon passivating contacts. The impurity gettering to be developed, and the means behind the different gettering mechanisms, are discussed. The impurity gettering could be explained and resolved. We use two (Fe) as a marker impurity to elucidate the qualitative and quantitative effects of rehydrogenation during contact formation and subsequent processes, which allows a direct identification of the gettering sites in polysilicon passivating contacts. The Fe concentration in the bulk of the silicon wafer is measured by a carrier lifetime-based technique,^{10,11} and the Fe distributions and concentration in the surface polysilicon passivating contact layers and the near-surface region of the silicon wafer bulk are measured by secondary ion mass spectrometry (SIMS). High-resolution transmission electron microscopy (HR-TEM) and scanning TEM (STEM) are applied to understand the surface layer structures and compositions, and to reveal microscopic features of the polysilicon passivating contacts. The polysilicon layers are cross-sectioned by a conventional thermal diffusion using POCl₃ or RBE, whereas a process that is directly compatible with the existing cell fabrication route is under study.

2. EXPERIMENTAL DETAILS

A flowchart of the experimental procedures is shown in Figure 1.

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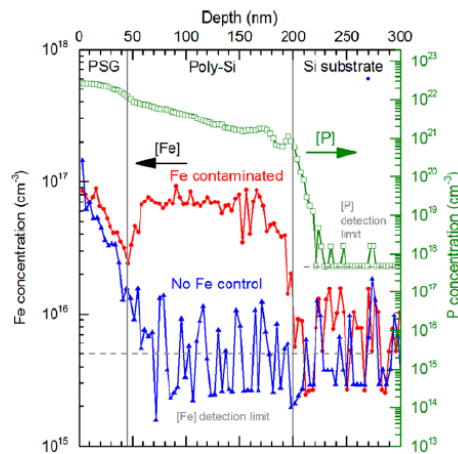
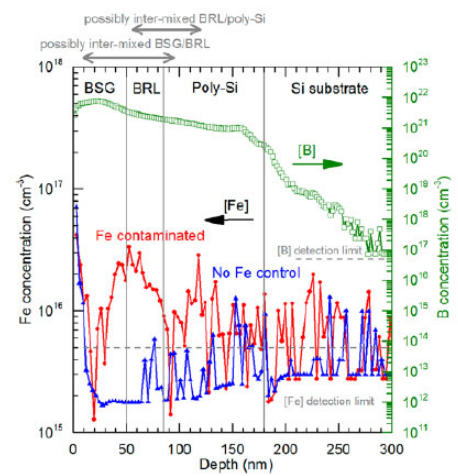
graph TD
    A[Fe-doped polysilicon P-doped] --> B[Fe-doped polysilicon P-doped]
    A --> C[Fe-doped polysilicon P-doped]
    B --> D[Fe-doped polysilicon P-doped]
    C --> E[Fe-doped polysilicon P-doped]
    D --> F[Fe-doped polysilicon P-doped]
    E --> G[Fe-doped polysilicon P-doped]
    F --> H[Fe-doped polysilicon P-doped]
    G --> I[Fe-doped polysilicon P-doped]
    H --> J[Fe-doped polysilicon P-doped]
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    X --> Z[Fe-doped polysilicon P-doped]
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    AD --> AF[Fe-doped polysilicon P-doped]
    AE --> AG[Fe-doped polysilicon P-doped]
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    AL --> AN[Fe-doped polysilicon P-doped]
    AM --> AO[Fe-doped polysilicon P-doped]
    AN --> AP[Fe-doped polysilicon P-doped]
    AO --> AQ[Fe-doped polysilicon P-doped]
    AP --> AR[Fe-doped polysilicon P-doped]
    AQ --> AS[Fe-doped polysilicon P-doped]
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    AS --> AU[Fe-doped polysilicon P-doped]
    AT --> AV[Fe-doped polysilicon P-doped]
    AU --> AW[Fe-doped polysilicon P-doped]
    AV --> AX[Fe-doped polysilicon P-doped]
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    AY --> BA[Fe-doped polysilicon P-doped]
    AZ --> BB[Fe-doped polysilicon P-doped]
    BA --> BC[Fe-doped polysilicon P-doped]
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    BC --> BE[Fe-doped polysilicon P-doped]
    BD --> BF[Fe-doped polysilicon P-doped]
    BE --> BG[Fe-doped polysilicon P-doped]
    BF --> BH[Fe-doped polysilicon P-doped]
    BG --> BI[Fe-doped polysilicon P-doped]
    BH --> BJ[Fe-doped polysilicon P-doped]
    BI --> BK[Fe-doped polysilicon P-doped]
    BJ --> BL[Fe-doped polysilicon P-doped]
    BK --> BM[Fe-doped polysilicon P-doped]
    BL --> BN[Fe-doped polysilicon P-doped]
    BM --> BO[Fe-doped polysilicon P-doped]
    BN --> BP[Fe-doped polysilicon P-doped]
    BO --> BQ[Fe-doped polysilicon P-doped]
    BP --> BR[Fe-doped polysilicon P-doped]
    BQ --> BS[Fe-doped polysilicon P-doped]
    BR --> BT[Fe-doped polysilicon P-doped]
    BS --> BU[Fe-doped polysilicon P-doped]
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    BX --> BY[Fe-doped polysilicon P-doped]
    BY --> BZ[Fe-doped polysilicon P-doped]
    BZ --> CA[Fe-doped polysilicon P-doped]
    CA --> CB[Fe-doped polysilicon P-doped]
    CB --> CC[Fe-doped polysilicon P-doped]
    CC --> CD[Fe-doped polysilicon P-doped]
    CD --> CE[Fe-doped polysilicon P-doped]
    CE --> CF[Fe-doped polysilicon P-doped]
    CF --> CG[Fe-doped polysilicon P-doped]
    CG --> CH[Fe-doped polysilicon P-doped]
    CH --> CI[Fe-doped polysilicon P-doped]
    CI --> CJ[Fe-doped polysilicon P-doped]
    CJ --> CK[Fe-doped polysilicon P-doped]
    CK --> CL[Fe-doped polysilicon P-doped]
    CL --> CM[Fe-doped polysilicon P-doped]
    CM --> CN[Fe-doped polysilicon P-doped]
    CN --> CO[Fe-doped polysilicon P-doped]
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    CP --> CQ[Fe-doped polysilicon P-doped]
    CQ --> CR[Fe-doped polysilicon P-doped]
    CR --> CS[Fe-doped polysilicon P-doped]
    CR --> CS[Fe-doped polysilicon P-doped]
    CS --> CT[Fe-doped polysilicon P-doped]
    CT --> CU[Fe-doped polysilicon P-doped]
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    CV --> CW[Fe-doped polysilicon P-doped]
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    CX --> CY[Fe-doped polysilicon P-doped]
    CY --> CZ[Fe-doped polysilicon P-doped]
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    DG --> DH[Fe-doped polysilicon P-doped]
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    DI --> DJ[Fe-doped polysilicon P-doped]
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    DL --> DM[Fe-doped polysilicon P-doped]
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    DN --> DO[Fe-doped polysilicon P-doped]
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    DR --> DS[Fe-doped polysilicon P-doped]
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    DT --> DU[Fe-doped polysilicon P-doped]
    DU --> DV[Fe-doped polysilicon P-doped]
    DV --> DW[Fe-doped polysilicon P-doped]
    DW --> DX[Fe-doped polysilicon P-doped]
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    DY --> DZ[Fe-doped polysilicon P-doped]
    DZ --> EA[Fe-doped polysilicon P-doped]
    EA --> EB[Fe-doped polysilicon P-doped]
    EB --> EC[Fe-doped polysilicon P-doped]
    EC --> ED[Fe-doped polysilicon P-doped]
    ED --> EE[Fe-doped polysilicon P-doped]
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    EF --> EG[Fe-doped polysilicon P-doped]
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    EK --> EL[Fe-doped polysilicon P-doped]
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    EM --> EN[Fe-doped polysilicon P-doped]
    EN --> EO[Fe-doped polysilicon P-doped]
    EO --> EP[Fe-doped polysilicon P-doped]
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    FG --> FH[Fe-doped polysilicon P-doped]
    FH --> FI[Fe-doped polysilicon P-doped]
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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”)

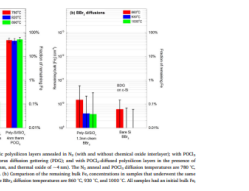
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Petitioner Canadian Solar Inc., Ex. 1103, p. 7
c. v. Maxeon Solar PTE. Ltd., IPR2024-01038

Supplemental Declaration of Sanjay Banerjee Regarding U.S. Patent No. 11,251,315

Exhibit Number	Exhibit Reference	Exhibit Citation
		 Figure 4. SIMS Fe and P concentrations (top) and uncalibrated O signal (bottom) in POCl₃-diffused polysilicon passivating contact layers and the near-surface silicon substrate, for samples with and without an initial bulk Fe contamination of 10¹⁴ cm⁻³ prior to the contact formation.
		(3) EX1028, Fig. 7. 315 IPR Pet., 52.  Figure 7. SIMS Fe and B concentrations in BBr₃-diffused polysilicon passivating contact layers and the near-surface silicon substrate, for samples with and without an initial bulk Fe contamination of 10¹⁴ 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).

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Exhibit Number	Exhibit Reference	Exhibit Citation
		A.7. 10.4.1. 3.2.1. <i>Effect of silicon wafer and on implanted boron-doped polysilicon contacts.</i> 3.2.2. <i>Understanding the gettering effect: Impact of dopant diffusion, segregation, and oxide interlayer</i>  Fig. 4. (a) Comparison of the remaining bulk P_0 concentrations in samples with intrinsic polysilicon layers annealed at 800 °C with and without thermal oxide interlayer with POC₀ diffusion profiles in the remaining bulk P_0 wafer. (b) Comparison of the remaining bulk P_0 concentrations in samples with intrinsic polysilicon layers annealed at 800 °C with and without thermal oxide interlayer with POC₀ diffusion profiles in the remaining bulk P_0 wafer. (c) Comparison of the remaining bulk P_0 concentrations in samples with intrinsic polysilicon layers annealed at 800 °C with and without thermal oxide interlayer with POC₀ diffusion profiles in the remaining bulk P_0 wafer. 3.2.3. <i>Separating the gettering effect of intrinsic and doped polysilicon</i> The observed strong gettering effects of doped polysilicon/wafer layers [12] could arise from the polycrystallinity of the films [12–14], the heavy doping present in them [5,6], or a combination of both. To investigate this, we compare the gettering effects of intrinsic polysilicon films in those of doped-diffused ones. The results are presented in Fig. 5. Fig. 5(a) shows that the intrinsic polysilicon films used in this work do not have a significant gettering action, removing only half of the initial bulk P_0 concentration. The gettering inefficiency is similar for samples with and without the oxide interlayer, and it is also similar to intrinsic polysilicon films annealed at different temperatures in 700–800 °C. The inability of these intrinsic polysilicon films to getter bulk impurities may be related to their oriented configurations and/or bulk ones. The polysilicon films used in this work come from partially recrystallized α-Si films deposited by PECVD at a low temperature of ~200 °C, while those used as monocrystalline for backside gettering purpose consist of polysilicon deposited by CVD at much higher temperatures of 600–800 °C [12]. In addition, the recrystallized film thickness for backside polysilicon gettering is 500 nm to 1 μm [12], which is much thicker than our 30–40 nm deposited α-Si films, offering more grain boundaries and/or more impurity segregation and retention. Moreover, the segregation coefficient of boron in polysilicon and crystalline silicon (k_B) is only 2–4 at 1175–1020 °C [17]. Therefore, the presence of a sufficient amount of grain boundaries is imperative for the gettering action of intrinsic polysilicon layers, that is, the thickness ratio of the remaining bulk P_0 to the crystalline silicon substrate, when impurity are given, should be considered. It is interesting to note that the 120 nm thick LPCVD polysilicon films used in Kröger et al.'s work also have poor gettering effects, even after having been heated in nitrogen [18]. The same may be related to the different film compositions, thickness (especially thickness ratios), and perhaps the higher thermal budget used in fabricating devices, which are estimated based on assuming a constant 100% uncertainty in the measured lifetimes before and after first passivation. 3.2.2. <i>Comparison to gettering from direct dopant diffusion</i> Compared to the POC₀-diffused polysilicon without the oxide interlayer, POC₀-diffused crystalline silicon demonstrates better gettering effects, as shown in Fig. 5(b) for the bare Si samples. The residual bulk P_0 concentrations of the bare α-Si wafers are all below the $P_{0,0}$ detection limit. This probably relates to the different gettering phosphorus doping in crystalline silicon and polysilicon layers, as the points tend to segregate into grain boundaries [10–14] in polysilicon. These concentrations of the diffused layer P_0 values are found to be consistently lower than those with the polysilicon contacts, for both POC₀ and BPO₀-diffused samples, indicating a higher concentration of intrinsically active dopants in the bare α-Si samples. Similar to the results in Fig. 5(a), bare α-Si diffuses better gettering effects than those of doped polysilicon/wafer layers under the same diffusion conditions, as shown in Fig. 5(b). Results in Fig. 5 therefore clearly indicate that, the dominant gettering mechanism of these P and B diffused-doped polysilicon/wafer layers is related to the POC₀ and BPO₀ diffusion. Polysilicon shows other poor gettering effects. The lacking effect of the oxide interlayer on the gettering for the different temperatures, will be discussed later in Section 3.3. The gettering effectiveness of both polysilicon contacts and diffused α-Si wafers is tested by comparing diffusion profiles, respectively, for both POC₀ and BPO₀ diffusion (see Fig. 1). As the gettering action of polysilicon layers is dominated by the dopant diffusion processes, the dependence of the gettering effectiveness on the diffusion time parameter can be explained by the well-understood gettering effect of the dopant diffusion. Higher diffusion temperatures lead to more heavily doped silicon layers, which are known to achieve better gettering effects [10]. However, the segregation coefficient of metals in heavily doped silicon

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Exhibit Number	Exhibit Reference	Exhibit Citation
Ex. 1043	Green, "Intrinsic concentration, effective densities of states, and effective mass in silicon," J. Appl. Phys. 67, 2944 (1990) ("Green")	(1) EX1043, 2946-47. 315 IPR Pet., 36.

Petitioner Canadian Solar Inc., Ex. 1046, p. 406