

**UNITED STATES PATENT AND TRADEMARK OFFICE**

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**BEFORE THE PATENT TRIAL AND APPEAL BOARD**

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LONGI SOLAR TECHNOLOGY (HEFEI) CO., LTD.,  
AND LONGI SOLAR TECHNOLOGY (US), INC.,  
Petitioners,

v.

HANWHA Q CELLS & ADVANCED MATERIALS CORP.,  
Patent Owner.

Patent No. 9,893,215

Issued: Feb. 13, 2018

Filed: July 2, 2010

Inventors: Jan Schmidt  
Bram Hoex

Title: METHOD FOR MANUFACTURING A SOLAR CELL WITH A  
SURFACE-PASSIVATING DIELECTRIC DOUBLE LAYER, AND  
CORRESPONDING SOLAR CELL

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*Inter Partes* Review No. IPR2019-01072

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**PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 9,893,215  
UNDER 35 U.S.C. §§ 311-319 AND 37 C.F.R. § 42.1-.80 & 42.100-.123**

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### Exhibit List

Exhibit #	Reference Name
1001	U.S. Patent No. 9,893,215 (the “215 Patent”)
1002	Original File History of 215 Patent
1003	Declaration of Dr. Sanjay Banerjee
1004	Curriculum Vitae of Dr. Sanjay Banerjee
1005	U.S. Patent Application Publication No. 2006/0102972 to Bhattacharyya et al.
1006	U.S. Patent Application Publication No. 2004/0112426 to Hagino
1007	Hoex, Bram, et al. "Ultralow surface recombination of c-Si substrates passivated by plasma-assisted atomic layer deposited Al <sub>2</sub> O <sub>3</sub> ." <i>Applied Physics Letters</i> 89.4 (2006): 042112
1008	Duerinckx, F., and J. Szlufcik. "Defect passivation of industrial multicrystalline solar cells based on PECVD silicon nitride." <i>Solar energy materials and solar cells</i> 72.1-4 (2002): 231-246
1009	Hoex, B., et al. "Industrial high-rate (~ 5 nm/s) deposited silicon nitride yielding high-quality bulk and surface passivation under optimum anti-reflection coating conditions." <i>Progress in Photovoltaics: Research and Applications</i> 13.8 (2005): 705-712
1010	Aiken, Peter. "Microsoft Computer Dictionary 2002." Microsoft Press, 7.87: 267
1011	Freedman, A. "The Computer Glossary: The Complete Illustrated Dictionary, 2001, p. 103
1012	U.S. Patent No. 5,428,244 to Segawa et al.
1013	Schmidt, Jan, Mark Kerr, and Andres Cuevas. "Surface passivation of silicon solar cells using plasma-enhanced chemical-vapour-deposited

Exhibit #	Reference Name
	SiN films and thin thermal SiO <sub>2</sub> /plasma SiN stacks." Semiconductor Science and Technology 16.3 (2001): 164
1014	Pierson, Hugh O. Handbook of chemical vapor deposition: principles, technology and applications. William Andrew, 1999
1015	Hezel, R. "Silicon nitride for the improvement of silicon inversion layer solar cells." Solid-State Electronics 24.9 (1981): 863-868
1016	Agostinelli, G., et al. "Rear surface passivation for industrial solar cells on thin substrates." 2006 IEEE 4th World Conference on Photovoltaic Energy Conference. Vol. 1. IEEE, 2006
1017	Soppe, Wim, Henk Rieffe, and Arthur Weeber. "Bulk and surface passivation of silicon solar cells accomplished by silicon nitride deposited on industrial scale by microwave PECVD." Progress in Photovoltaics: Research and Applications 13.7 (2005): 551-569
1018	Hofstetter, J., et al. "Optimisation of SiN <sub>x</sub> : H anti-reflection coatings for silicon solar cells." 2007 Spanish conference on electron devices. IEEE, 2007
1019	Yadavalli, Kameshwar K., et al. "Aluminum oxide tunnel barriers for single electron memory devices." Microelectronics journal 36.3-6 (2005): 272-276
1020	U.S. Patent No. 6,630,413 to Todd
1021	Hsieh, S. W., et al. "Properties of plasma-enhanced chemical-vapor-deposited a-SiN <sub>x</sub> : H by various dilution gases." Journal of applied physics 76.6 (1994): 3645-3655
1022	Kolodzey, James, et al. "Electrical conduction and dielectric breakdown in aluminum oxide insulators on silicon." IEEE Transactions on Electron Devices 47.1 (2000): 121-128
1023	Kerr, M. J., et al. "Surface recombination velocity of phosphorus-diffused silicon solar cell emitters passivated with plasma enhanced

Exhibit #	Reference Name
	chemical vapor deposited silicon nitride and thermal silicon oxide." Journal of Applied Physics 89.7 (2001): 3821-3826
1024	Dauwe, Stefan. Low-temperature surface passivation of crystalline silicon and its application to the rear side of solar cells. Diss. Verlag nicht ermittelbar, 2004
1025	U.S. Patent No. 5,270,248 to Rosenblum et al.
1026	Razavy, Mohsen. Quantum theory of tunneling. World Scientific, 2003.
1027	Salil K. Ghosal, "Introduction to Chemical Engineering," Tata McGraw-Hill Publishing Company Limited (2006)
1028	U.S. Patent No. 3,533,850 to Taneja et al.
1029	U.S. Patent No. 6,395,650 to Callegari et al.
1030	Jaehyun Kim et al., "Growth and Characterization of Hf-Silicate/ Al <sub>2</sub> O <sub>3</sub> Gate Stacks Grown on Si(100) by Self-Limiting Atomic Layer Deposition," Jpn. J. Appl. Phys. Vol. 45, No. 9A, pp. 7080-7083 (2006)
1031	U.S. Patent No. 6,551,893 to Zheng et al.
1032	CRC Handbook of Chemistry and Physics 85th Edition (2005)
1033	Sh. A. Furman and A.V. Tikhonravov, "Basics of Optics of Multilayer Systems," Editions Frontieres (1992)
1034	Eugene Hecht, "Optics," Addison-Wesley, 3rd Ed. (1998)
1035	Complainant's Notice of Priority Date, <i>In re Certain Photovoltaic Cells</i>
1036	Declaration of James L. Mullins, Ph.D
1037	Stannowski, Bernd. Silicon-based thin-film transistors with a high stability. Diss. 2002.

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Exhibit #	Reference Name
1038	Harrington, James A. "Infrared fibers and their applications." Bellingham, WA: SPIE, 2004.

## **I. INTRODUCTION**

Petitioners respectfully request that trial be instituted on claims 12-14 of the '215 Patent, and that those claims be cancelled as unpatentable.

The '215 Patent describes and claims a solar energy cell having a stack of two dielectric layers applied to the surface of a silicon substrate. The first dielectric layer is a thin layer of aluminum oxide, and the second dielectric layer is silicon nitride, silicon oxide, or silicon carbide embedded with hydrogen. The first dielectric layer is interposed between (i.e., in contact with and in between) the surface of the silicon substrate and the second dielectric layer.

During prosecution, claims corresponding to issued claims 12-14 of the '215 Patent were allowed over prior art rejections only after applicants added the limitation requiring the first dielectric layer to be interposed between the surface of the substrate and the second dielectric layer. The Patent Office, however, was not made aware of prior art describing this exact configuration in a solar cell.

Two patent applications, published more than a year before the '215 Patent's priority date, US2006/0102972 to Bhattacharyya et al. ("Bhattacharyya") and US2004/0112426 to Hagino ("Hagino"), describe such a solar cell. These two applications, alone or in view of a 2006 paper to Bram Hoex et al. ("Hoex 2006")



and/or a 2002 paper to Filip Duerinckx et al. (“Duerinckx”), render claims 12-14 of the ’215 Patent obvious.

Like the ’215 Patent, Bhattacharyya discloses a solar cell with a two layer dielectric stack that includes a “very thin” first layer of aluminum oxide in contact with and in between the surface of the silicon substrate and a second layer of semiconductor enriched insulator (i.e., dielectric) (either silicon nitride or silicon oxide). The semiconductor enriched insulator in Bhattacharyya is formed by Plasma Enhanced Chemical Vapor Deposition (“PECVD”), a process that was then routinely used to embed hydrogen into that layer.

Similarly, Hagino discloses a solar cell having a two layer dielectric stack, on top of a silicon substrate, consisting of a first aluminum oxide layer and a second silicon nitride layer. As Hagino explains, the first dielectric layer has a second dielectric layer on top of it that can comprise silicon nitride. Hagino further discloses a process that would necessarily form hydrogen embedded within the second dielectric layer.

The challenged claims require that the first dielectric layer have a thickness of less than 50 nm (claim 12) or less than 30 nm (claim 14). Bhattacharyya inherently discloses this limitation, and Hagino discloses that this layer can have a thickness between 3-30 nm. To the extent Patent Owner may argue that the specific numerical thickness limitations are not sufficiently disclosed or rendered

obvious by Bhattacharyya or Hagino alone, a thin aluminum oxide layer of less than 30 nm was well-known in the industry to be an ideal surface passivating material, and would have been an obvious design choice by 2006. For example, a paper published in 2006 – Hoex, Bram, et al. "Ultralow surface recombination of c-Si substrates passivated by plasma-assisted atomic layer deposited Al<sub>2</sub>O<sub>3</sub>."

Applied Physics Letters 89.4 (2006): 042112 ("Hoex 2006") – showed solar cells passivated by aluminum oxide layers of thicknesses ranging from 7-30 nm effectively passivating a silicon surface by reducing surface recombination losses.

To the extent Patent Owner may argue that Bhattacharyya or Hagino does not describe hydrogen being embedded in the silicon nitride layer, a paper published in 2002, Duerinckx, F., and J. Szlufcik. "Defect passivation of industrial multicrystalline solar cells based on PECVD silicon nitride." Solar energy materials and solar cells 72.1-4 (2002): 231-246, 232 ("Duerinckx"), discusses that hydrogenated layers of silicon nitride formed by PECVD were already being routinely used in the art.

Accordingly, regardless of whether the precise thickness of the first layer or hydrogenation of the second layer were expressly disclosed in the two layer stacks of Bhattacharyya or Hagino, such design choices would have been obvious in view of Hoex 2006 or Duerinckx.

None of these references was before the examiner. A mapping of Bhattacharyya and Hagino to the challenged claims, both alone and in view of secondary references, is provided below. That analysis demonstrates that, if Bhattacharyya or Hagino had been before the examiner, those claims would never have issued.

## **II. COMPLIANCE WITH REQUIREMENTS FOR INTER PARTES REVIEW**

### **A. Certification that Petitioners May Contest Claims 12-14 of the '215 Patent**

Petitioners certify that they are not barred or estopped from requesting *inter partes* review of the '215 Patent (EX1001). Neither Petitioners, nor any party in privity with Petitioners, have filed a civil action or a prior petition for *inter partes* review challenging the validity of any claim of the '215 Patent. Petitioners also certify this petition is filed within one year of the date of service of a complaint alleging infringement of a patent.

### **B. Fee for Inter Partes Review (§ 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 (37 CFR § 42.8(b))**

The real parties-in-interest of this petition are LONGi Green Energy Technology Co., LONGi Solar Technology Co., Ltd., Ltd., LONGi (H.K.) Trading Ltd., LONGi (Kuching) Sdn. Bhd., LONGi Solar Technology (Taizhou) Co., Ltd.,

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LONGi Solar Technology (Zhejiang) Co., Ltd., LONGi Solar Technology (Hefei), Co. Ltd., and LONGi Solar Technology (US), Inc. (collectively, “LONGi”).

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Service on Petitioners may be made by email ([LONGi-SidleyTeam@sidley.com](mailto:LONGi-SidleyTeam@sidley.com)), mail or hand delivery to: Sidley Austin LLP, 787 Seventh Avenue, New York, New York 10019. The fax number for lead and backup counsel is (212) 839 5599.

The '215 Patent is or has been the subject of, or relates to, the following proceedings:

- Certain Photovoltaic Cells and Products Containing Same, Inv. No. 337-TA-1151, filed on March 4, 2019;

- Hanwha Q CELLS & Advanced Materials Corporation v. LONGi Green Energy Technology Co., Ltd. et al., filed on March 5, 2019.

**D. Proof of Service (§§ 42.6(e) and 42.105(a))**

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

**III. IDENTIFICATION OF CHALLENGED CLAIMS**

Claims 12-14 of the '215 Patent are unpatentable over the prior art as follows:

- i. Claims 12-14 Are Obvious over Bhattacharyya (EX1005);
- ii. Claims 12-14 Are Obvious over Bhattacharyya in view of Duerinckx (EX1008) and/or Hoex 2006 (EX1007);
- iii. Claims 12-14 Are Obvious over Hagino (EX1006);
- iv. Claims 12-14 Are Obvious over Hagino in view of Duerinckx and/or Hoex 2006.

Petitioners' proposed construction of the contested claims, the evidence relied upon, and the precise reasons why the claims are unpatentable are provided in §§ IV-VII below.

**IV. LEVEL OF ORDINARY SKILL**

A person of ordinary skill in the art in the field of the '215 Patent (solar cell design or manufacture) in the 2007 time frame 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 designing, developing, or researching in the field.

EX1003¶46.

## **V. RELEVANT INFORMATION CONCERNING THE CONTESTED PATENT**

### **A. Priority Date and Critical Date**

The '215 Patent was filed as a PCT application on November 6, 2008. Thus, the critical date for prior art under 35 U.S.C. §102(b) is November 6, 2007.

Although the PCT application claims priority to a German application filed November 14, 2007, Patent Owner has claimed a priority date of October 12, 2007 for the '215 Patent in related litigation. EX1035, 1. For purposes of this IPR only, Petitioners apply (but do not concede or admit) a critical date of October 12, 2007 for prior art under 35 U.S.C. §§102(a). EX1003¶45.

### **B. Overview of the '215 Patent**

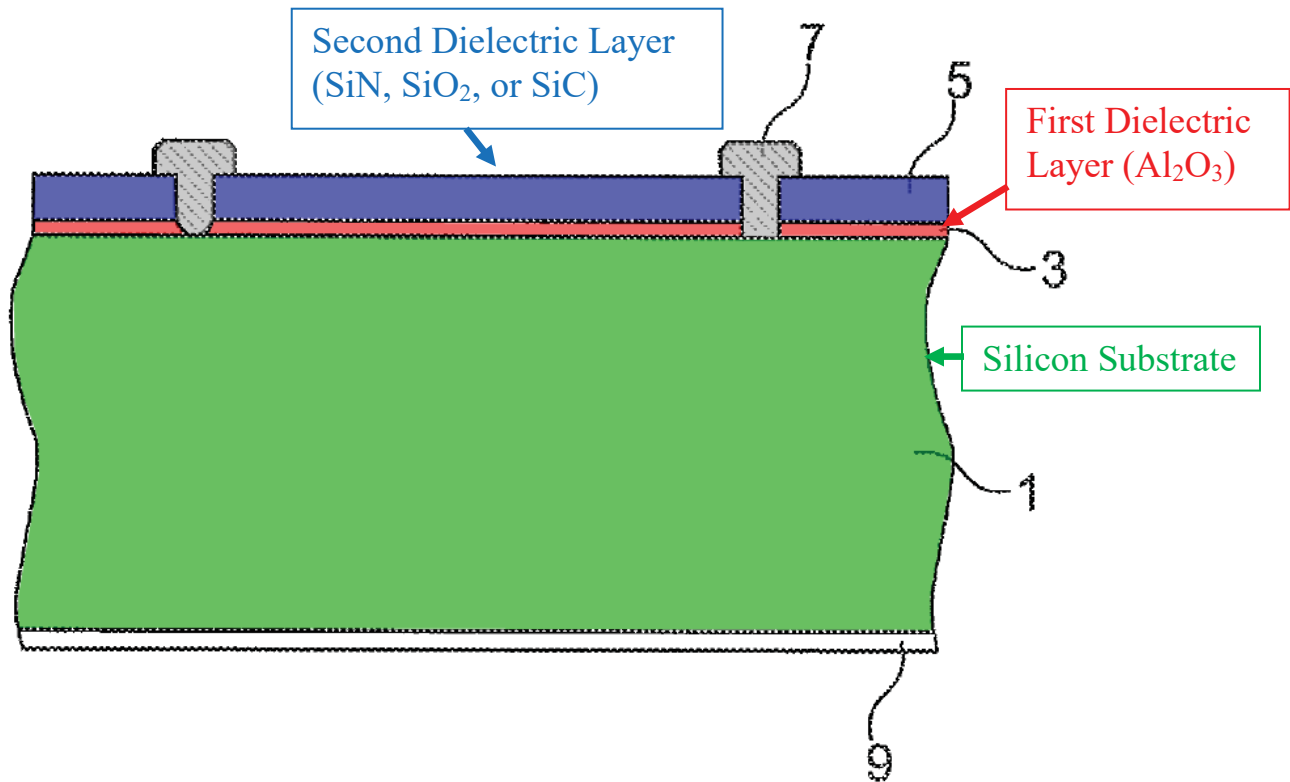
The '215 Patent describes “[a] solar cell with a dielectric double layer and also a method for the manufacture thereof.” EX1001, Abstract; EX1003¶47. The '215 Patent explains that “a key requirement for achieving high degrees of efficiency in solar cells is very effective suppression of surface recombination losses.” *Id.*, 1:14-16. The '215 Patent states that to achieve that goal, “the surface

of solar cells should be passivated as effectively as possible.” *Id.*, 1:16-17; EX1003¶48.

The ’215 Patent purports to achieve this by providing a device “with a dielectric passivating layer for reducing surface recombination losses.” EX1001, 2:59-60. The “dielectric passivating layer” is said to be “composed of two partial layers”: “a very thin aluminium oxide-containing layer” and “a thicker layer made of silicon oxide, silicon nitride, or silicon carbide.” *Id.*, 2:61-65; EX1003¶49-50.

The ’215 Patent touts this two layer dielectric structure as its invention. For example, the Title of the ’215 Patent is “solar cell with a surface-passivating dielectric **double layer**.” The Abstract recites a “solar cell [that] has a dielectric **double layer**.” The Summary of the Invention refers to the invention as containing “the dielectric **double layer** produced in the method **according to the first aspect**” of the invention. EX1001, 3:1-2. The “Field of the Invention” section also describes “the present invention” as relating to “a method for manufacturing a solar cell with a surface-passivating dielectric **double layer** and to a corresponding solar cell.” EX1001, 1:8-11; EX1003¶¶47, 51. And the “Detailed Description of Embodiments” section discloses only embodiments with two layers, and summarizes “the present invention” as “consisting of two partial layers”: the aluminum oxide layer and the silicon oxide-containing layer. *Id.*, 7:48-60; EX1003¶¶50, 55.

The '215 Patent has only one figure, which purports to describe the alleged invention and shows this double layer dielectric stack (3 and 5) on the silicon substrate (1):



EX1001, FIG. 1 (color and annotations added). The figure shows a “silicon wafer 1,” on the surface of which a first dielectric layer, “Al<sub>2</sub>O<sub>3</sub> thin layer 3,” is deposited. EX1001, 6:51, 7:8. EX1003¶54. The Summary of the Invention explains that the “interface” between the silicon substrate and the aluminum oxide layer (called the “Si/Al<sub>2</sub>O<sub>3</sub> interface”) is one of the “key” components to the “outstanding passivating effect” “according to the invention,” (*Id.*, 3:21-30) and teaches that the surface of the silicon substrate “can be thoroughly cleaned” to etch



away any “oxidized silicon oxide” before depositing the aluminum oxide layer.

*Id.*, 3:53-63; EX1003¶52.

The '215 Patent teaches that, after deposition, the  $\text{Al}_2\text{O}_3$  (aluminum oxide) thin layer is subsequently coated with a second dielectric layer, “thin layer 5,” which can comprise a layer of silicon oxide, silicon nitride, or silicon carbide. *Id.*, 7:32-43. The second dielectric layer is deposited by means of PECVD using reactant gases such as silane and ammonia, which purportedly cause the thin layer 5 to have a “very high hydrogen content” that “diffuses through the ultrathin  $\text{Al}_2\text{O}_3$  layer and passivates unsaturated silicon bonds ... at the Si/ $\text{Al}_2\text{O}_3$  interface.” *Id.*, 8:1-6; EX1003¶¶53,55.

Finally, the '215 Patent explains that the “dielectric double layer” allows “passivation of both high and low - doped regions of the solar cell surface of conduction type p or n.” *Id.* at 3:1-4, 6:18-19. EX1003¶51.

### C. Challenged Claims of the '215 Patent

12. A solar cell comprising:

a silicon substrate;

a first dielectric layer comprising aluminium oxide on a surface of the silicon substrate; and

a second dielectric layer directly on a surface of the first dielectric layer, materials of the first dielectric layer and the second dielectric layer differing and hydrogen being embedded into the second dielectric layer;

wherein the first dielectric layer has a thickness of less than 50 nm and is interposed between the surface of the silicon substrate and the second dielectric layer.

13. The solar cell according to claim 12, wherein the second dielectric layer comprises a material selected from the group consisting of silicon nitride, silicon oxide and silicon carbide.

14 . The solar cell according to claim 12, wherein the first dielectric layer has a thickness of less than 30 nm.

#### **D. Prosecution History**

The '215 Patent issued from Application No. 12/742,818 (the '818 Application), which was filed on July 2, 2010, and is a national stage entry of PCT/EP2008/065067, filed on November 6, 2008. The PCT Application claimed priority to a German patent application filed on November 14, 2007. EX1002, 1040. EX1003¶56.

In an office action mailed on June 28, 2013, the relevant claims of the '818 Application (including the claims corresponding to issued claims 12-14) were initially rejected as anticipated by Fujisaki. EX1002, 840-45. Applicants

responded on September 25, 2013, arguing that Fujisaki did not anticipate the claims because that reference disclosed an “ultra-thin silicon nitride layer [] inserted between a silicon substrate and an aluminum oxide layer,” in contrast to the “Si/Al<sub>2</sub>O<sub>3</sub>/SiN” of the invention. *See* EX1002, 759; EX1003¶57.

In a second non-final rejection dated November 21, 2013, the examiner maintained the rejection over Fujisaki, EX1002, 738. Applicants amended the claims in a response filed on February 19, 2014 in an effort to overcome Fujisaki, requiring the aluminum oxide layer to be “directly” on a surface of the substrate. *Id.* at 658; EX1003¶58.

The examiner responded on March 13, 2014 with a third non-final rejection based on new art, WO 2006/097303 to Agostinelli et al. EX1002, 600, 603. In response, applicants amended the claims to require that the thickness of the first dielectric layer be less than 50 nm, arguing Agostinelli did not disclose an aluminum oxide layer of that thickness. EX1002, 589. The examiner responded with a final rejection on July 3, 2014, arguing that the claims would have been obvious in view of Agostinelli and “Excellent passivation of highly doped p-type Si surfaces by the negative-charge-dielectric Al<sub>2</sub>O<sub>3</sub>” to Hoex et al. (“Hoex 2007”) (which the examiner noted taught a dielectric layer of aluminum oxide less than 30 nm). *Id.*, 575; EX1003¶59.

The examiner maintained his rejections in actions filed on March 6, 2015 and October 21, 2015. *Id.* at 425, 450. In response, on February 2, 2016, applicants amended the claims and substituted the limitation that the first dielectric layer be “directly” on the substrate with the limitation that the first dielectric layer (i.e., the aluminum oxide layer) be “interposed between the surface of the silicon substrate and the second dielectric layer.” *Id.* at 394. The applicants then argued that unlike the purported two layer dielectric stack recited in the amended claims, Agostinelli disclosed a “three layer” stack of materials on top of the silicon substrate as follows: Si / thin (<30 nm) high quality Al<sub>2</sub>O<sub>3</sub> / thick (>100 nm) low quality Al<sub>2</sub>O<sub>3</sub> / SiN. *Id.* at 400. Because the high quality Al<sub>2</sub>O<sub>3</sub> layer of Agostinelli (purportedly analogous to the first dielectric layer of the claims) was not in contact with the SiN layer, the applicants argued that it was not “interposed between” the silicon substrate and the second dielectric layer. *Id.* at 401; EX1003¶60.

After an additional rejection on the same grounds, on September 27, 2016, applicants submitted a response, maintaining that the claims would not have been obvious in view of Agostinelli, and reiterating that Agostinelli discloses a three layer material stack on top of the silicon substrate as follows: Si / high quality Al<sub>2</sub>O<sub>3</sub> / low quality Al<sub>2</sub>O<sub>3</sub> / SiN, which applicants argued is different from the claimed invention. Applicants further argued that even if the high quality Al<sub>2</sub>O<sub>3</sub>

layer of Hoex 2007 were substituted for the high quality Al<sub>2</sub>O<sub>3</sub> layer of Agostinelli, it “would be positioned between the substrate and the low-quality thick dielectric layer, not between the substrate and the hydrogenated layer as claimed.” *Id.*, 218. Hence, applicants relied on the language “interposed between” in the claims as requiring the first dielectric layer to be in contact with both the silicon substrate and second dielectric layer that it is between. *Id.* The examiner nevertheless maintained his rejection in a final office action submitted on December 16, 2016. EX1002, 173-92; EX1003¶61.

After some additional back and forth, applicants submitted substantially the same arguments in an appeal brief filed on June 12, 2017. In this appeal, applicants maintained their prior position that Agostinelli’s three-stack layers did not render the claims obvious because “the high-quality layer would be positioned between the substrate and the low-quality thick dielectric layer, not between the substrate and the hydrogenated layer as claimed.” EX1002, 103; EX1003¶62.

In response to the appeal brief, the examiner issued a notice of allowance on October 2, 2017. In the notice, the examiner amended the claims. EX1002, 60-63. Specifically, the examiner made an amendment to claim 9 (corresponding to issued claim 12) to clarify the “interposed between” limitation, requiring the claim to explicitly state that the second dielectric layer be placed directly on the surface of the first dielectric layer. *Id.*, 61. The examiner indicated that this limitation was

not expressly disclosed by the combination of Agostinelli in view of Hoex 2007.

*Id.*, 64; EX1003¶63.

#### E. **Claim Construction**

We apply the *Phillips* claim construction standard in accordance with 37 CFR § 42.100(b). The applicants' description of the invention in the specification, as well as limiting statements from the prosecution history, both inform the proper scope of the claims. *See Verizon Servs. Corp. v. Vonage Holdings Corp.*, 503 F.3d 1295, 1308 (Fed. Cir. 2007) ("When a patent thus describes the features of the 'present invention' as a whole, this description limits the scope of the invention."); *Microsoft. v. Multi-Tech*, 357 F.3d 1340, 1347 (Fed. Cir. 2004) ("A patentee may . . . limit the claims by disclaiming a particular interpretation during prosecution.")

While ultimately not believed to be necessary to the resolution of the issues in this IPR, the phrase "*wherein the first dielectric layer ... is interposed between the surface of the silicon substrate and the second dielectric layer,*" in the context of these claims, should be construed to require that the two layer dielectric stack has a first dielectric layer that is in between and in contact both with the surface of the silicon substrate and with a second dielectric layer. This is consistent with the specification's description of the invention as a dielectric double layer throughout the disclosure (*see* EX1001, Title, Abstract, 1:8-11, 2:59-60, 3:1-2, 3:21-30, 7:48-60; *see also* § V.B above), and is confirmed by the applicants' repeated arguments

in the prosecution history that the first dielectric layer of the two layer stack is not “interposed between” the substrate and the second dielectric layer unless it is in contact with each of those adjacent layers. *See* EX1002, 102, 218, 400; § V.D above. EX1003¶66.

Notably, this limitation was added by the applicants in a Reply to an Office Action dated February 2, 2016. EX1002, 394. There, applicants attempted to distinguish the claims from the disclosures of the Agostinelli prior art reference, which the applicants admitted discloses a “three layer stack” on the silicon substrate as follows: Si / thin (<50 nm) high quality Al<sub>2</sub>O<sub>3</sub> / thick (>100 nm) low quality Al<sub>2</sub>O<sub>3</sub> / SiN. *Id.*, 400. Applicants argued on three occasions that the high quality aluminum oxide layer in Agostinelli is not “interposed between” the silicon substrate and the silicon nitride layer, but rather, it is “interposed between” the silicon substrate and the layer of low quality aluminum oxide. *See, e.g.*, EX1002, 102, 218, 400. With these statements, applicants confirmed that “interposed between” requires that the claimed first layer to be in between and in contact with both the surface of the silicon substrate and the claimed second layer. EX1003¶67.

A determination of whether such a construction should be adopted is, however, unnecessary here because, even assuming the extent Patent Owner argues that the construction should be broader, the prior art renders the challenged claims unpatentable even under Petitioners’ narrower construction. The dielectric stacks

in the primary references discussed herein both have only two layers, where the first layer is in between and in contact both with the surface of the substrate and with the second layer. Thus, broader or narrower, the claims are unpatentable.

EX1003¶67.

**F. Known Technologies**

As the Examiner found, by November of 2007, surface passivation of solar cells using two-layer stacks of dielectric materials was known in the art (*see, e.g.*, EX1002, 400), as was the use of thin layers of aluminum oxide and hydrogenated layers of silicon nitride as the two layers of the dielectric stack (*see, e.g.*, EX1002, 600, 603 (citing Agostinelli and Hoex 2007 as disclosing these limitations)). The Examiner noted in the reasons for allowance that the references before him did not expressly disclose “a second dielectric layer directly on a surface of the first dielectric layer” in conjunction with other aspects of the claims. But this feature was disclosed by Bhattacharyya by 2006. Bhattacharyya teaches a solar cell having a dual layer dielectric stack with a silicon nitride layer on the surface of a very thin aluminum oxide layer. EX1005, FIG. 6, [0082]-[0085]. This feature was also disclosed by Hagino by 2004, which teaches a solar cell having a two layer stack comprising an antireflective/dielectric layer that can be silicon nitride in contact with a first dielectric layer comprising aluminum oxide. EX1006, [0027], [0055]; EX1003¶69.



Numerous other references separately disclose the use in a solar cell of hydrogenated silicon nitride layers, as well as thin aluminum oxide layers. For example, by 2002, “hydrogen containing silicon nitride layers [were] becoming widely introduced in industrial crystalline silicon solar cell processes thanks to the unique possibility of combining in one processing step an antireflection coating deposition along with surface and bulk passivation.” EX1008, 232. Common methods of depositing these hydrogen-containing silicon nitride layers on solar cells were through the use of APCVD, LPCVD, and PECVD by reacting silane and ammonia gases; each of these processes produces hydrogenated silicon nitride. *Id.*<sup>1</sup> “The resulting silicon nitride layers are usually nonstoichiometric and contain up to 40 at[omic]% of hydrogen and are usually denoted in the literature as  $\text{SiN}_x\text{:H}$ .” *Id.*; EX1003¶70.

By 2005-2006, even the inventor of the '215 Patent, Dr. Hoex, acknowledged that the use of  $\text{SiN}_x\text{:H}$  had become the “state of the art” that “dominate[d the] solar cell market.” EX1009, 706. He also acknowledged that “[h]ydrogenated amorphous silicon nitride a- $\text{SiN}_x\text{:H}$  [was] ***routinely*** applied in solar cell production.” EX1007, 1; EX1003¶72.

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<sup>1</sup> That hydrogen is produced in the reaction of silane and ammonia using chemical vapor deposition has been known for more than 20 years before the '215 Patent. See EX1015, 864; EX1003¶71.

Likewise, the use of a very thin aluminum oxide layer to passivate the surface of the silicon substrate in solar cells was well known by 2006. In the same 2006 publication, inventor Hoex showed that a 7 nm thin aluminum oxide layer provides effective surface passivation to prevent recombination losses. EX1007, Abstract; EX1003¶73.

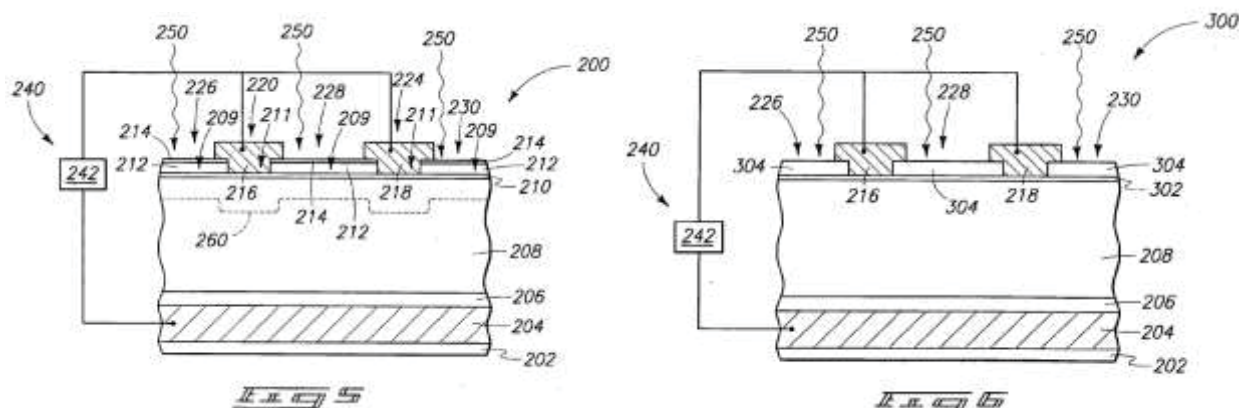
At most, claims 12-14 are obvious implementations of a solar cell that recite various well-known features, functioning in predictable combinations, as a Skilled Artisan would have expected at the '215 Patent's priority date. EX1003¶74.

## **VI. OVERVIEW OF THE PRIOR ART**

### **A. Bhattacharyya (EX1005)**

Bhattacharyya is a U.S. Patent Application published on May 18, 2006. Having been published before the alleged priority date of October 12, 2007, and the critical date of November 6, 2007, it is prior art to the '215 Patent under 35 U.S.C. §§ 102(a) or (b).

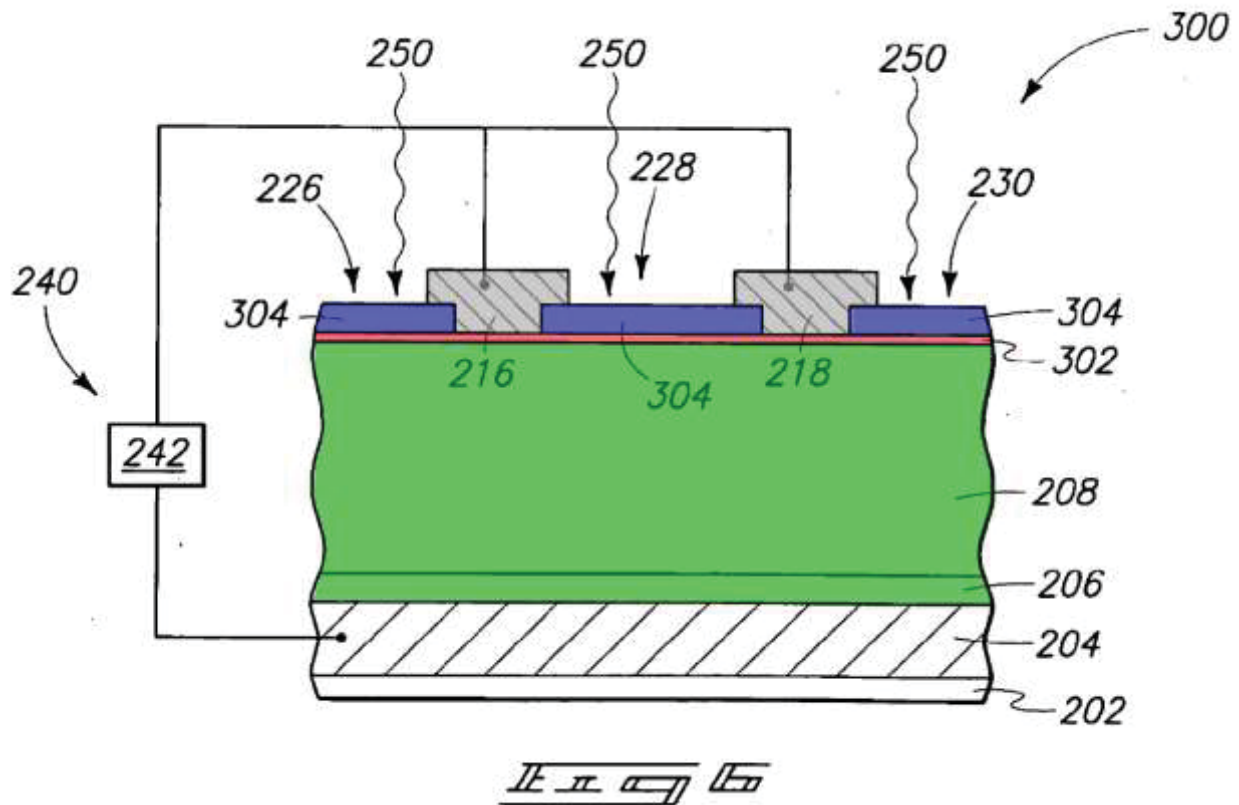
Bhattacharyya describes optoelectronic devices, and methods for making optoelectronic devices and solar cells. EX1005, Title, Abstract. Bhattacharyya seeks to improve the “robustness” of the solar cell and discloses various solar cell embodiments in FIGS. 5-8. *Id.*, EX1003¶76. The solar cell embodiments of FIGS. 5 and 6 are related, with FIG. 6 being a “modification of the solar cell ... relative to solar cell 200 of FIG. 5.” *Id.*, ¶[0086].



EX1005, FIGS. 5, 6. EX1003¶77.

FIG. 6 depicts a solar cell having a two layer dielectric applied to the silicon substrate (206, 208)<sup>2</sup> and a two layer dielectric stack (302, 304) applied to the top surface of the silicon substrate, as shown below:

<sup>2</sup> While Bhattacharyya does not explicitly disclose how its “semiconductor material 206” is formed, a Skilled Artisan would have understood that it would be formed by diffusion of dopants into the “semiconductor material 208.” Accordingly, a Skilled Artisan would have understood that the claimed “*silicon substrate*” of the ’215 Patent corresponds to the combination of “semiconductor material 206” and “semiconductor material 208.” *See, e.g.*, EX1025, Abstract (“Silicon solar cells are made by subjecting semiconductor substrates to a diffusion junction forming process ... to cause the dopant to diffuse *into* the substrates”), 5:14-51, FIGS. 1A-1E; EX1003¶80.



EX1005, FIG. 6 (color and annotations added); [0082]. EX1003¶78.

Elements 206 and 208 [silicon substrate, shown in green] are doped layers of “semiconductor material” that can comprise “single crystal or polycrystalline silicon.” EX1005, [0082]-[0083], [0086]; EX1003¶79. Element 302 [first dielectric layer, shown in red] is a “*very thin* dielectric material” that is in “direct physical contact” with the surface of semiconductor layer 208. EX1005, [0083], [0084].<sup>3</sup> Bhattacharyya further discloses that for applications in which

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<sup>3</sup> All emphasis herein added unless otherwise indicated.

semiconductor layers 206 and 208 are n-type doped, “dielectric material 302 can comprise, consist essentially of, or consist of aluminum oxide ( $\text{Al}_2\text{O}_3$ ).” *Id.*

Element 304 [second dielectric layer] is a “semiconductor-enriched insulator” described as being in “direct physical contact” with “dielectric material 302,” i.e., aluminum oxide layer. *Id.*, [0084]. The semiconductor-enriched insulator is described to “comprise, consist essentially of, or consist of one or both of silicon enriched silicon nitride and silicon-enriched silicon oxide.” *Id.*, [0085]. This silicon nitride or silicon oxide layer is deposited by LPCVD or PECVD, as was known in the art, resulting in “excellent physical/electrical properties.” *Id.* [0024]. Bhattacharyya further teaches that by adjusting the amount of silicon enrichment (as was known in the art), the reflectivity of the silicon-enriched silicon nitride can be adjusted, allowing it to serve as an anti-reflective material. *Id.* [0021], [0072]; *see* EX1008, 236-237, FIG. 2. EX1003¶78.

Bhattacharyya explains that the design of the solar cell in FIG. 6 “creates a thin interface layer of dielectric material (which can be aluminum oxide or silicon dioxide in exemplary aspects of the invention) to reduce surface recombination and to enhance collection and thereby also enhance solar cell efficiency.” *Id.* [0087]. In the context of solar cells, surface recombination velocity of the semiconductor substrate is a measure of photogenerated carrier loss due to leakage of current from

the cell. Minimization of this quantity through surface passivation enhances the efficiency of the device. EX1003¶82.

Claim 86 included with the Bhattacharyya publication indicated that this solar cell has a two layer dielectric stack, stating that “the dielectric material [consisting of aluminum oxide] is the only material between the second layer of semiconductor material [i.e. silicon substrate] and the layer of semiconductor enriched insulator.” *Id.*, Cl. 86; EX1003¶83.

**B. Hagino (EX1006)**

Hagino is a U.S. Patent Application published on June 17, 2004. Having been published before the alleged priority date of October 12, 2007, and the critical date of November 6, 2007, it is prior art to the '215 Patent under 35 U.S.C. §§ 102(a) and (b).

Hagino discloses solar cells and methods of manufacturing its solar cells. EX1006, Title, Abstract. Hagino discloses three exemplary embodiments for manufacturing its solar cells. EX1006, [0043]-[0072]; EX1003¶85.

The “first embodiment” involves manufacturing a solar cell having a two layer stack of dielectric materials on a silicon substrate as shown in Hagino’s FIG. 1 (which is identical to FIG. 3F), reproduced below. EX1006, [0043]-[0057], FIG. 1, FIGs. 3A-3F; EX1003¶86.

FIG.1

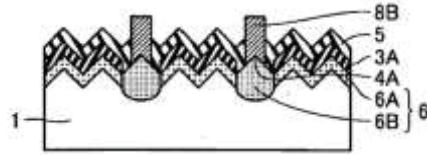
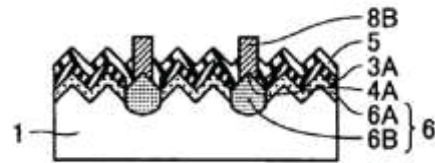
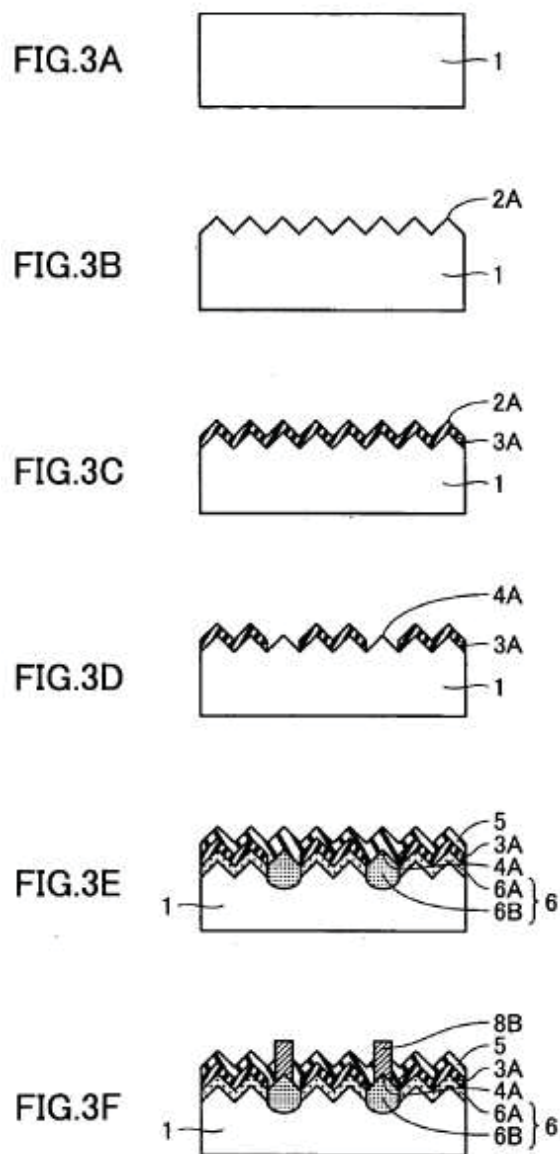


FIG.3F



The above solar cell has a “passivation film 3A” on the light-receiving surface of the “silicon wafer 1” (which includes a “dopant diffusion region 6A”), and an “antireflection film 5” on the “passivation film 3A.” EX1006, [0026]-[0039], [0043]-[0057], FIG. 1, FIG. 3F. FIGs. 3A-3F (reproduced below) show various steps involved in manufacturing the above solar cell. EX1003¶87.



Hagino explains that the “passivation film 3A” is formed on the surface of the “silicon wafer 1.” EX1006, [0028] (explaining that a “light-receiving surface *passivation film 3A* [is formed] on a texture etching surface 2A that is a light-receiving *surface of silicon wafer 1*, as shown in FIG. 3C.”), FIG. 3C (showing



that the “passivation film 3A” is formed on the surface of the “silicon wafer 1”).

EX1003¶91



Despite describing the specific “passivation film 3A” in FIG. 1 to be “silicon oxide,” Hagino repeatedly teaches that the passivation layer can also be made of “aluminum oxide.” EX1006, [0027] (“*Any passivation film may be employed as long as it serves as a barrier against dopant diffusion. A silicon oxide film, an amorphous silicon film, a silicon nitride film, a titanium oxide film, or **an aluminum oxide film** is preferable*”), [0030], [0031]. Hagino also discloses that its “passivation film 3A” can have a thickness of “approximately 3 nm – 30 nm.” EX1006, [0048]; EX1003¶92.

After the “passivation film 3A” is deposited on the surface of the “silicon wafer 1,” dopant is diffused into the “silicon wafer 1” at high temperature to form a “dopant diffusion layer 6A” as shown in FIG. 3E. EX1006, [0050], [0051], [0054]; *see also* EX1006, [0004] (“diffusing the dopant *into the wafer* in a high temperature furnace to form a PN junction”), [0014]. Accordingly, after the “passivation film 3A” is deposited on the top surface of the silicon wafer, the top region of the “silicon wafer 1” is changed from a p-type silicon wafer region into

an n-type silicon wafer region (by diffusing n-type dopants into the silicon wafer through the top of the silicon wafer) to form a PN junction, and this changed region is labeled as “dopant diffusion layer 6A.” *Id.*; EX1003¶¶93-94.

After the “dopant diffusion” step, an “antireflection film 5” is formed on the “passivation film 3A.” EX1006, [0054], [0056], FIG. 3E; EX1003¶95.



Hagino explains the “antireflection film” includes “silicon nitride.” EX1006, [0055] (“The antireflection film includes, other than titanium dioxide, aluminum oxide, tin oxide, *silicon nitride*, tantalum oxide, or the like.”) EX1003¶96.

Hagino further explains that the “silicon nitride” layer is formed by “CVD [or chemical vapor deposition] using silane, ammonia, hydrogen and the like as a base material,” EX1006, [0029]. EX1003¶97.

### C. **Hoex 2006 (EX1007)**

Hoex 2006 is a paper that was published in the journal Applied Physics Letters on July 27, 2006, and was publically accessible no later than early September of 2016. EX1036, 15-18, Attachments 1A-1D. It is therefore prior art to the '215 Patent under 35 U.S.C. § 102(b). Hoex 2006 is a different article from

the Hoex 2007 article relied on by the Examiner during prosecution of the '818 Application.

Hoex 2006 describes surface passivating techniques for solar cells. EX1007, Abstract. Hoex 2006 explains that “[s]urface passivation of crystalline silicon (c-Si) is of key importance for the performance of high efficiency industrial solar cells.” EX1007, 1. Like Bhattacharyya, Hoex 2006 seeks to improve the efficiency of the solar cell by minimizing “surface recombination” of the semiconductor substrate via surface passivation. *Id.*, Title, Abstract, 1; EX1003¶163.

Hoex 2006 discloses the use of “ultrathin” “high bandgap dielectric Al<sub>2</sub>O<sub>3</sub> as a surface passivation layer” and shows that it provides excellent passivation on both n and p-type silicon substrates. EX1007, 2. Hoex 2006 tests “Al<sub>2</sub>O<sub>3</sub> films with a thickness of 7–30 nm,” and shows that even a “7 nm thin Al<sub>2</sub>O<sub>3</sub> film still yields an effective surface recombination velocity.” *Id.*, Abstract. “Effective surface recombination velocity” quantifies “[t]he level of surface passivation” at the silicon/aluminum oxide interface. *Id.*, 1. EX1003¶164.

**D. Duerinckx (EX1008)**

Duerinckx is a paper that was published in the journal *Solar Energy Materials & Solar Cells* on April 1, 2002, and was publically accessible no later

than the end of April, 2002. EX1036, 18-22, Attachments 2A-2D. It is therefore prior art to the '215 Patent under 35 U.S.C. § 102(b).

Duerinckx describes the state of the art of hydrogenated silicon nitride layers for enhancing surface passivation of solar cells as of 2002. EX1008, Title, Abstract, 232. Duerinckx explains that “[l]ow surface recombination velocity and significant improvements in bulk quality are key issues for efficiency improvements of solar cells.” EX1008, Abstract. Duerinckx discloses that “[d]efects, impurities and segregated impurities on extended defects [on the silicon substrate] can be passivated by hydrogen,” and that “[t]here are several techniques developed for hydrogen passivation of silicon bulk and surfaces. The best known [method includes] deposition of H-containing silicon nitride layers ( $\text{SiN}_x\text{:H}$ )” using chemical vapor deposition of silane and ammonia by means of APCVD, LPCVD, or PECVD. *Id.*, 232. EX1003¶145. Duerinckx explains that “[t]he hydrogen containing silicon nitride layers [were] becoming [at that time] widely introduced in industrial crystalline silicon solar cell processes thanks to the unique possibility of combining in one processing step an antireflection coating deposition along with surface and bulk passivation.” *Id.* In this way, Duerinckx discloses that hydrogenated silicon nitride layers were known to provide excellent surface passivation of the semiconductor substrate of a solar cell by reduction of the surface recombination velocity at the surface of the semiconductor substrate. *Id.*,

Abstract; EX1003¶146. Indeed, by 2005-2006, hydrogenated silicon nitride deposited by PECVD was the “state-of-the-art” that “dominate[d the] solar cell industry.” *See* EX1009, 706.

## VII. PRECISE REASONS FOR REQUESTED RELIEF

### A. Claims 12-14 Are Obvious over Bhattacharyya

#### 1. Claim 12

##### a. *Preamble*

Claim 12 recites “[a] solar cell comprising.”

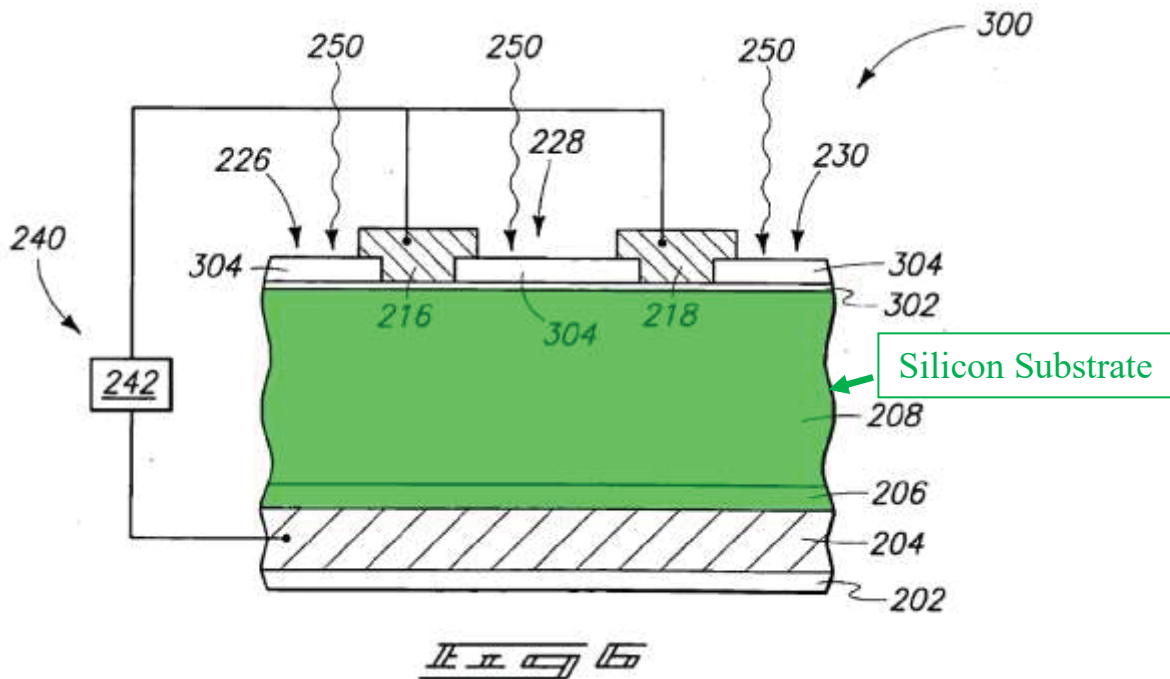
The Board need not decide whether the preamble is limiting, because Bhattacharyya describes “methods of making solar cells,” EX1005, Title, and “**solar cells** containing one or more layers of semiconductor-enriched insulator.” EX1005, Abstract; EX1003¶101. FIG. 6 of Bhattacharyya illustrates a solar cell 300. EX1003¶102.

##### b. *Silicon Substrate*

Claim 12 also requires “a silicon substrate.”

As recognized in the ’215 Patent, a silicon substrate is a “silicon wafer” on which the first aluminum oxide dielectric layer is deposited. EX1001, 3:34-36, 6:51, FIG. 1; EX1003¶105. The ’215 patent specification discloses that the silicon substrate can be either n-type or p-type doped silicon. EX1001, 3:1-4, 6:18-19. EX1003¶106.

Bhattacharyya discloses in FIG. 6 that the solar cell includes semiconductor layers 206 and 208, which satisfy the limitation “a silicon substrate” in the same way as the ’215 Patent. Specifically, semiconductor layers 206 and 208 are described as a “first layer of semiconductor material” and a “second layer of semiconductor material” that “can comprise, for example, single crystal or polycrystalline silicon.” *Id.*, [0082], [0086]. Bhattacharyya similarly discloses that semiconductor layers 206 and 208 can either be “n-type or p-type doped.” *Id.* [0083]; EX1003¶107. Similar to the ’215 Patent’s silicon substrate, the surface of semiconductor layer 208 of Bhattacharyya has aluminum oxide layer 302 placed on it, as discussed below:

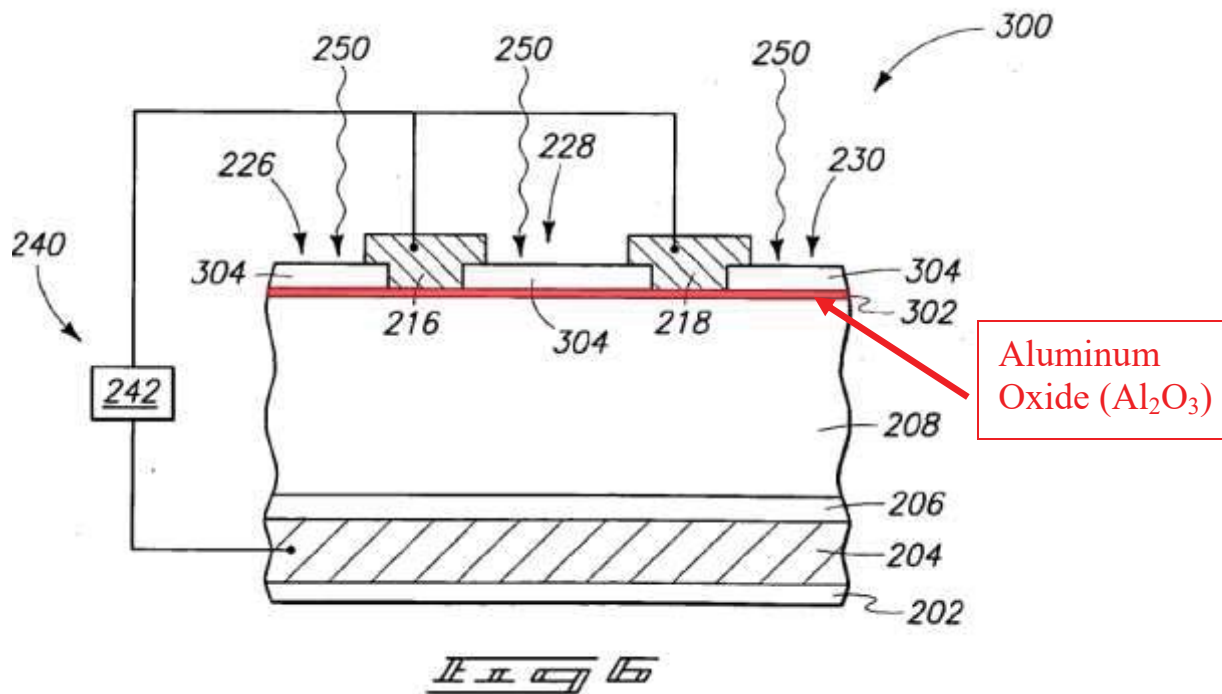


EX1005, FIG. 6 (color and annotations added); EX1003¶107.

### c. *First Dielectric Layer*

Claim 12 requires “a *first dielectric layer comprising aluminium oxide on a surface of the silicon substrate.*”

Bhattacharyya discloses exactly this. The solar cell described in FIG. 6 has the following structure:



EX1005, FIG. 6 (color and annotations added). EX1003¶111. Bhattacharyya further describes layer 302 as “a very thin dielectric material.” *Id.*, [0083]. And Bhattacharyya explains that dielectric layer 302 can be “aluminium oxide.” EX1005, [0083].<sup>4</sup> Specifically, the specification states that “dielectric material 302 can comprise, consist essentially of, or consist of aluminum oxide (Al<sub>2</sub>O<sub>3</sub>).” EX1005, [0083]; EX1003¶112.

Bhattacharyya also explains that the dielectric layer 302 is on a surface of the silicon substrate. In FIG. 6, dielectric layer 302 is shown to be in contact with

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<sup>4</sup> A Skilled Artisan would have understood that “aluminium” is a British spelling for the material aluminum and that the terms can be used interchangeably. EX1003¶112.

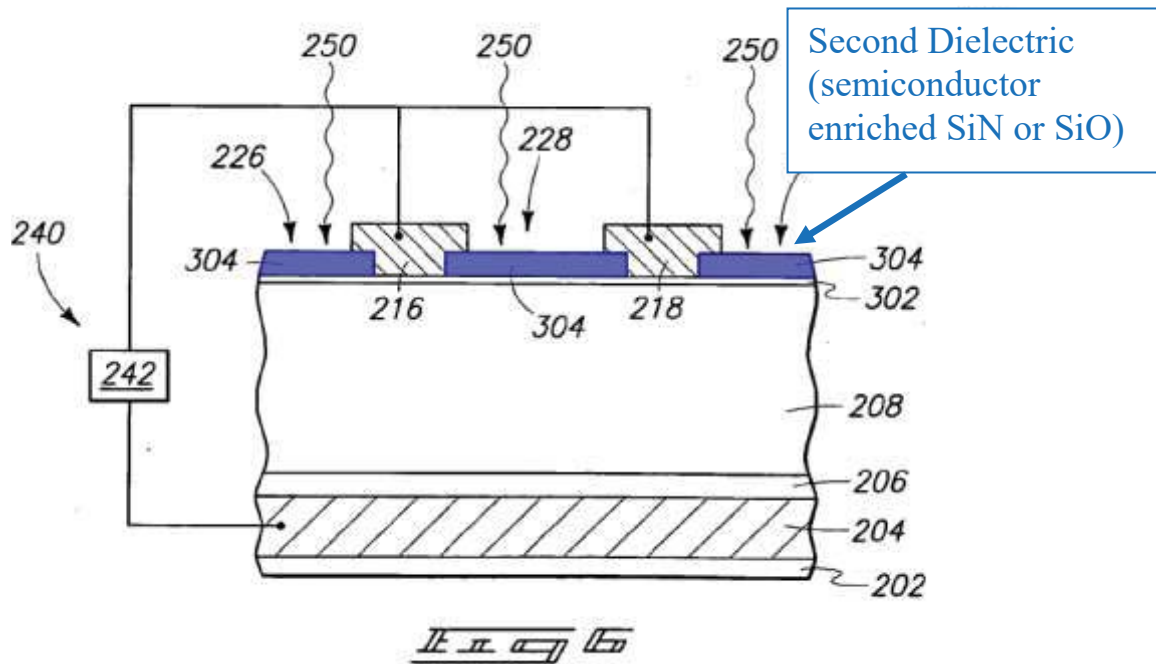


the surface of semiconductor layer 208 (the surface of the silicon substrate) and Bhattacharyya expressly describes it to be so. *Id.*, [0084]; EX1003¶113.

d. *Second Dielectric Layer*

Claim 12 requires “a second dielectric layer directly on a surface of the first dielectric layer.”

Bhattacharya satisfies this limitation as it discloses a second dielectric layer, described as a “semiconductor enriched insulator” 304 in “direct physical contact” with the aluminum oxide dielectric layer 302.



EX1005, FIG. 6 (color and annotations added); [0083]-[0084]; EX1003¶116, 117, 119. This “semiconductor-enriched insulator 304” is described as “compris[ing], consist[ing] essentially of, or consist[ing] of one or both of silicon enriched silicon

nitride and silicon-enriched silicon oxide.” EX1005, [0085]. Cf ’215 Patent, claim 13 (“the second dielectric layer comprises a material selected from a group consisting of silicon nitride, silicon oxide, and/or silicon carbide”). EX1003¶121.

A Skilled Artisan would have understood that the terms “insulator” and “dielectric,” as used in Bhattacharyya, are synonyms. *See also* EX1010, 156 (defining dielectric as an “insulating material, such as rubber or plastic, that does not conduct electricity”); EX1011, 103 (defining dielectric as “an insulator (glass, rubber, plastic, etc.) Dielectric materials can be made to hold an electrostatic charge, but current cannot flow through them.”); EX1003¶117.

That layer 304 is described as “silicon enriched” silicon nitride or silicon oxide does not change that understanding, as “semiconductor enriched” silicon nitride or silicon oxide remain dielectrics. *See* EX1012 (“The present invention provides a sixth means. In accordance with this means, the ***Si-rich dielectric layer is a silicon nitride layer whose stoichiometric composition formula is  $Si_3N_4$  with an excessive silicon content.***”). Indeed, one of the inventors of the ’215 Patent, Dr. Jan Schmidt, acknowledged in 2001 that “silicon-rich SiN films” were known by then to provide excellent surface passivation. EX1013, 164; EX1003¶122.

Moreover, the ’215 Patent does not disclose that the silicon nitride is stoichiometric (having the ratio of  $Si_3N_4$ ); rather, it explains that the layer would be “ $SiN_x$ .” EX1001, 3:26. A Skilled Artisan would have understood this to indicate

that the silicon nitride layer is non-stoichiometric, meaning that the ratio of silicon to nitrogen in the layer is not fixed at 3:4. A layer of silicon nitride with an excess of silicon would be within the disclosure of the “SiN<sub>x</sub>” dielectric layer described by the ’215 Patent. *Id.*; EX1003¶123.

e. *Differing Materials*

Claim 12 requires “*materials of the first dielectric layer and the second dielectric layer differing.*”

Bhattacharya discloses that the “dielectric material 302 can comprise, consist essentially of, or consist of aluminum oxide (Al<sub>2</sub>O<sub>3</sub>)” and that “the semiconductor-enriched insulator 304 will comprise, consist essentially of, or consist of one or both of silicon enriched silicon nitride and silicon-enriched silicon oxide.” EX1005, [0083]-[0084]; EX1003¶126. The ’215 Patent, Claim 13 defines aluminum oxide to be a different material from either silicon nitride or silicon oxide. EX1003¶127.

f. *Hydrogen*

Claim 12 requires “*hydrogen being embedded into the second dielectric layer.*”

“[A] patent can be obvious in light of a single prior art reference if it would have been obvious to modify that reference to arrive at the patented invention.” *Arendi S.A.R.L. v. Apple Inc.*, 832 F.3d 1355, 1361 (Fed. Cir. 2016). It would have

been obvious to a Skilled Artisan to have hydrogen embedded in the semiconductor-enriched insulator layer 304 shown in FIG. 6 because that was the state of the art at that time. EX1003¶130-131. Specifically, Bhattacharrya states that the “semiconductor-enriched insulators” can be formed by any suitable methodology such as LPCVD (low pressure chemical vapor deposition) and PECVD (plasma enhanced chemical vapor deposition). EX1005, [0024]. EX1003¶130. A Skilled Artisan would have understood that PECVD is a type of Chemical Vapor Deposition (CVD), which is a process used to deposit thin films onto a substrate that relies on a chemical reaction with a precursor material to form the desired film. *See, e.g.*, EX1014, 26; EX1003¶132.

At the time of Bhattacharrya’s filing and publication, hydrogenated silicon nitride formed using LPCVD and PECVD was the industry standard passivation material, known since at least 1981. EX1015, 864; EX1003¶130, 133. Bhattacharrya was filed in November 2004 and published in May 2006. Even before that, those skilled in the art recognized that “hydrogen containing silicon nitride layers are becoming widely introduced in industrial crystalline silicon solar cell processes.” EX1008, 231-33; EX1003¶133. By 2005, “[s]ilicon nitride (a-SiN<sub>x</sub>:H) ha[d] become the state-of-the-art anti-reflection coating for crystalline silicon solar cells as, ideally, this coating not only reduces reflection losses, but simultaneously provides surface and bulk passivation.” EX1009, 705. It

“dominate[d]” the solar cell market. *Id.*, 706. EX1003¶134. Similar to Bhattacharyya (and the ’215 Patent), the disclosure of “SiN<sub>x</sub>” in these references refer to a non-stoichiometric silicon nitride having an excess of silicon.

EX1003¶135. *See* EX1008, 232; EX1009, 705.

Other authors similarly noted that hydrogenated silicon nitride layers were standard in the industry by 2006. *See, e.g.*, EX1016, Abstract; EX1017, 552; EX1018, Abstract; EX1003¶136-138. Thus, it would have been obvious to utilize the existing industry standard of forming hydrogenated silicon nitride layers using PECVD or LPCVD in the design of Bhattacharyya. EX1003¶139.

A Skilled Artisan would also have recognized that the most practical and widely used processes for forming silicon nitride using PECVD would use reactants that contain and produce hydrogen. *See, e.g.*, EX1020, 1:43-45 (“Thermal CVD methods that utilize [hydrogen containing compounds such as] ammonia and silane are apparently favored because those precursors are widely available and relatively inexpensive,”) 1:58-59, 2:25-27; EX1003¶140.

Utilization of these industry standard reactants that contain hydrogen would have resulted in embedding hydrogen into the grown film. *See, e.g.*, EX1021, 3645, FIG. 3(c); EX1003¶141. It was well-known that utilization of chemical vapor deposition processes (e.g., PECVD) that made use of hydrogen containing compounds such as ammonia and silane would result in silicon nitride layers that

“contain up to 40 at% of hydrogen.” EX1008, 232; EX1003¶142. A Skilled Artisan would have thus understood that the state of the art methods used to form the semiconductor-enhanced silicon nitride film by PECVD would use a process that utilizes a hydrogen containing precursor, which would necessarily embed hydrogen into the silicon nitride layer. EX1003¶143.

g. *Thickness of First Dielectric Layer*

Claim 12 requires “*wherein the first dielectric layer has a thickness of less than 50 nm.*”

A Skilled Artisan would have understood that based on the disclosures in Bhattacharyya, the dielectric layer 302 in FIG. 6 must be less than 50 nm for at least two reasons. EX1003¶154.

*First*, Bhattacharyya describes the aluminum oxide layer in FIG. 6 as “very thin,” and not just “thin.” In the two embodiments that describe a “thin layer,” the thickness of those layers can be less than 50 nm, and is described as either 10 nm, or in the range of 1 nm to 100 nm. Although Bhattacharyya does not expressly provide a thickness for the “very thin” layer, a Skilled Artisan would have understood that a “very thin” layer is thinner than a “thin” layer, and that in the context of Bhattacharyya, it would be less than 10 nm. EX1003¶155, 156.

For example, when describing the optoelectronic device of FIG. 2, Bhattacharyya states that “Device 50 comprises a *thin electrically conductive layer*

52” that “can have a thickness of for example, *approximately 10 nanometers.*”

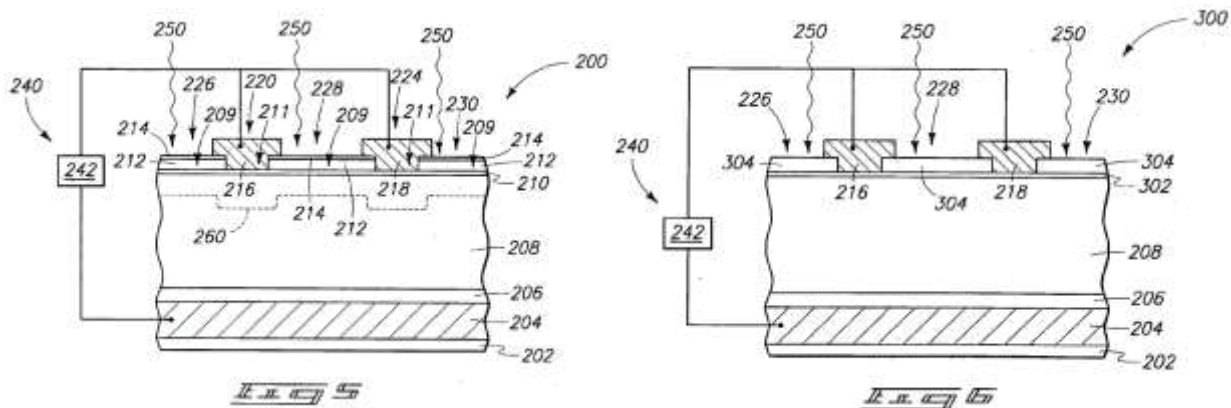
EX1005, [0047]. Further, in FIG. 5, layer 210 is described as a “*thin layer* of semiconductor-enriched insulator” that “preferably has a thickness of *from about 1 nanometer to about 100 nanometers.*” *Id.* at [0071], [0080]. A Skilled Artisan would have thus expected a layer described as a “thin layer” in Bhattacharyya to be either around 10 nm, or in the range of 1-100 nm. EX1003¶155.

When describing the embodiment of FIG. 6, Bhattacharyya explains that “[c]onstruction 300 differs from the construction 200 of FIG. 5 in that construction 300 comprises a *very thin* dielectric material 302 in direct physical contact with the second layer 208 of semiconductor material.” *Id.*, [0083]. A Skilled Artisan would have understood that a “very thin layer” as described in FIG. 6 would be even thinner than the “thin layer” 52 described in FIG. 2, or at the low end of the range described in FIG. 5 for “thin layer” 210. EX1003¶156. In particular, a Skilled Artisan would have expected a layer described as a “very thin layer” of dielectric material in Bhattacharyya to be less than 10 nm (i.e., less than the 10 nm of FIG. 2), which is at the low end of the range of 1-100 nm described in FIG. 5. In any scenario, the thickness of layer 302 would be less than the 50 nm required by Claim 12. EX1003¶156.

*Second*, a Skilled Artisan would have understood that due to the specific arrangement of the electrodes and dielectric material disclosed in FIG. 6, that

embodiment relies on the quantum tunneling effect to complete the circuit of the solar cell, and that the dielectric layer 302 must be very thin (i.e., less than 10 nm) to rely on that effect. EX1003¶157.

More specifically, the embodiments of FIGS. 5 and 6 are related and share a similar geometry:



FIGS. 5 and 6 both show that the electrodes 216 and 218 do not pierce through the semiconductor enriched insulator 210 in FIG. 5, or the dielectric layer 302 in FIG. 6. EX1005, FIGS. 5, 6. A Skilled Artisan would have recognized that in these figures, electrons generated in the silicon substrate from sunlight must move between semiconductor layer 208 and contacts 216 or 218, but that insulating layer 210 or dielectric layer 302 both have the property that they do not allow electric current to flow through them under normal circumstances (even at low applied voltages). EX1003¶158.

A Skilled Artisan would therefore have expected Bhattacharyya to be relying on the quantum mechanical phenomenon of quantum tunneling for



electrons to move between the semiconductor layer 208 and the contacts 216 and 218. *See* EX1026, xv. (“Quantum tunneling is a microscopic phenomenon where a particle can penetrate and in most cases pass through a potential barrier... such a motion is not allowed by the laws of classical dynamics”). Quantum tunneling would allow electrons to cross the potential barrier of insulator 210 or dielectric 302, even though they would not possess the energy to do so under classical mechanics. Bhattacharyya confirms that, in FIG. 5, “the electrons tunnel through the semiconductor enriched insulator 210 and get collected by the top electrode stripes 216 and 218.” EX1005, [0081]. A Skilled Artisan would have recognized that Bhattacharyya also relies on tunneling of electrons through the aluminum oxide layer 302 of FIG. 6 since the geometry of FIGS. 5 and 6 is the same, and layers 210 and 302 are both insulating or dielectric layers. EX1003¶159.

A Skilled Artisan would have recognized that as the tunneling layer is made thinner, the probability that electrons could tunnel between semiconductor layer 208 and the metal contacts 216 or 218 would increase. *See, e.g.*, EX1022, 126 (“tunneling occurs directly through the [aluminum] oxide with a probability that decreases exponentially with thickness”). In view of Bhattacharyya’s description of the relative thinness of the aluminum oxide layer 302 (being “very thin”) in comparison with the layers described in the embodiments of FIGS. 2 and 5, a

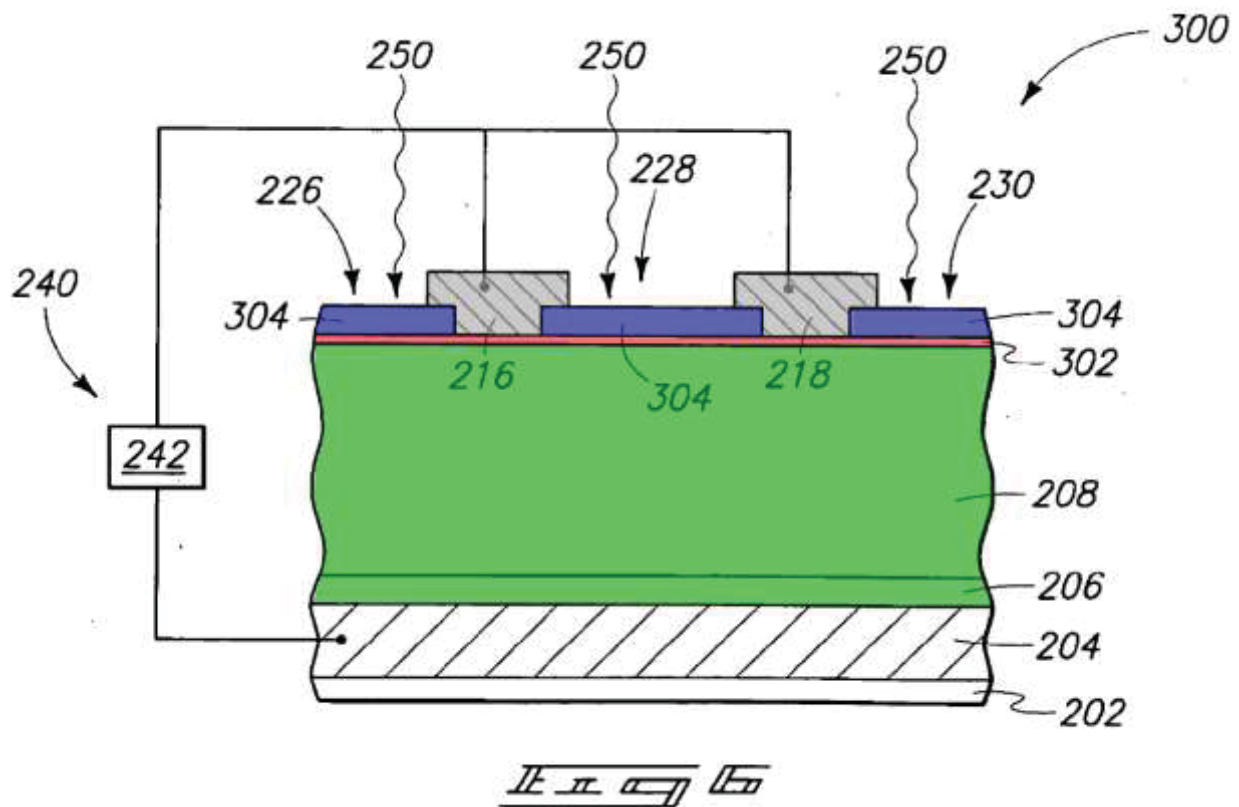
Skilled Artisan would have recognized that the geometry of FIG. 6 confirms that layer 302 would be less than 10 nm. *See* EX1019, 275-76; EX1003¶160.

To the extent one contends that Bhattacharyya does not disclose that the thickness of the aluminum oxide layer is less than 50 nm (which Bhattacharyya in fact does), it would have been obvious to keep the thickness of that layer much less than that value, because a Skilled Artisan would have recognized that the thickness of this layer would be inversely related to the efficiency of the solar cell. *See* EX1022, 126. Thus, a Skilled Artisan would have been motivated to maintain the thickness of layer 302 in FIG. 6 at a level of less than 10 nm. EX1003¶161; EX1019, 275-76.

h. *Interposed Between*

Claim 12 requires “*wherein the first dielectric layer ... is interposed between the surface of the silicon substrate and the second dielectric layer.*”

FIG. 6 of Bhattacharyya shows a stack of layers comprising semiconductor layer 208, aluminum oxide 302, and semiconductor enhanced silicon nitride 304, wherein the aluminum oxide layer is in between and in contact both with the surface of semiconductor layer 208 (which is the surface of the silicon substrate 206, 208) and with the silicon nitride layer:



EX1005, FIG. 6 (color added). Bhattacharyya further states that “[i]n the shown aspect of the invention, *dielectric material 302 is in direct physical contact with both semiconductor-enriched insulator 304 and second layer 208 of semiconductor material.*” *Id.*, [0084]. Thus, this limitation is also met and Claim 12 is obvious in view of Bhattacharyya. EX1003¶172.

## 2. Claim 13

Claim 13 recites “[t]he solar cell according to claim 12, wherein the second dielectric layer comprises a material selected from the group consisting of silicon nitride, silicon oxide and silicon carbide.”

This limitation is met because Bhattacharyya discloses that the second dielectric layer 304 “will comprise, consist essentially of, or consist of one or both of silicon enriched silicon nitride and silicon-enriched silicon oxide.” EX1005, [0085]; EX1003¶174.

### **3. Claim 14**

Claim 14 recites “[t]he solar cell according to claim 12, wherein the first dielectric layer has a thickness of less than 30 nm.”

As explained above, a Skilled Artisan would have understood that the dielectric layer 302 described in FIG. 6 would have been less 10 nm. *See* §VII.A.1.g above. Therefore, Bhattacharyya discloses that the first dielectric layer has a thickness of less than 30 nm. EX1003¶176.

## **B. Claims 12-14 Are Obvious over Bhattacharyya in view of Hoex 2006 and/or Duerinckx**

### **1. Hydrogen**

Even if Patent Owner argues that Bhattacharyya does not disclose that hydrogen is embedded in the second dielectric layer as required by Claims 12-14, it would have been obvious to a Skilled Artisan to do so because embedding hydrogen in the silicon nitride layer was the state of the art, as acknowledged by Duerinckx. EX1003¶144-145.

Duerinckx discloses various deposition techniques of hydrogenated silicon nitride for enhancing surface passivation of solar cells. EX1008, Title, Abstract,

232; *see* § VI.D above; EX1003¶145-146. By the time of Bhattacharyya's disclosure, silicon nitride layers with embedded hydrogen formed by PEVCD were well known. In the combined teaching of Bhattacharyya and Duerinckx, the semiconductor-enriched insulator (the silicon enriched silicon nitride) of the solar cell in the Bhattacharyya device would have been hydrogenated (as disclosed in Duerinckx) and formed on top of aluminum oxide (as disclosed in Bhattacharyya) to enhance passivation of the surface of the silicon substrate in the solar cell. The combination of Bhattacharyya and Duerinckx would improve surface passivation of the solar cell by saturating dangling bonds at the surface of the silicon substrate below the aluminum oxide layer, which would further reduce the surface recombination velocity at the interface between the silicon and aluminum oxide. Such an arrangement would be nothing more than the arrangements of old elements based on known technology readily made by a Skilled Artisan. EX1003¶147.

In such a combination, the hydrogen embedded in the silicon nitride layer would diffuse out of that layer (and through the aluminum oxide layer) to the surface of the silicon substrate to passivate the solar cell. Duernickx explains that "hydrogen can diffuse out of the [silicon nitride] layer into the cell and bind itself to dangling bonds." EX1008, 234; *see, also* EX1024, 17. It was known that hydrogen is small enough that it can diffuse through a layer of aluminum oxide to

the surface of a silicon substrate, EX1007, 3; EX1003¶148; *see also*, EX1023, 3822 (explaining that in a solar cell having a two layer passivation stack of silicon dioxide and silicon nitride, atomic hydrogen would diffuse through the silicon dioxide layer and passivate the surface of the substrate).

It would have been obvious to make such a combination for several reasons. Both Bhattacharyya and Duerinckx are analogous art to the '215 Patent because each is in the field of improved efficiency of photovoltaic energy cells, EX1001, 1:14-22; EX1005, [0003]; EX1008, Abstract, 234, and because both Bhattacharyya and Duerinckx are reasonably pertinent to the problem of preventing losses of photogenerated carriers, and concomitant loss of energy producing capability, at the surface of the silicon substrate in a solar cell that the inventors of the '215 Patent were trying to solve. EX1001, 1:14-22; EX1005, [0003]; EX1008, 234, 236-38; EX1003¶149. The embedding of hydrogen in the second dielectric layer of the solar cell of Bhattacharyya would have been an arrangement of old elements (a hydrogenated silicon nitride layer as described in Duerinckx with the solar cell in Bhattacharyya) with each performing the same function it had been known to perform (improving passivation of the silicon substrate surface of the solar cell) and yielding no more than what one would expect from such an arrangement (improved performance of the solar cell via reduction of the surface recombination velocity at the semiconductor/oxide interface). EX1003¶150.

Moreover, a Skilled Artisan would have been motivated to combine the solar cell of Bhattacharyya with the hydrogenated silicon nitride layer of Duerinckx.

Bhattacharyya teaches to use PECVD to deposit the semiconductor enriched insulator layer (the silicon nitride layer), EX1005, [0024], which is the same deposition technique that is the focus of Duernickx and which has already been widely introduced in the solar cell industry. EX1008, Title, Abstract;

EX1003¶151. A Skilled Artisan would have also been cognizant of the additional benefits provided by embedding hydrogen in the silicon nitride passivation layer, would have recognized that adding hydrogen using the disclosed PECVD technique was the industry standard, and would have therefore been motivated to embed hydrogen into the silicon nitride film described in Bhattacharyya.

EX1003¶152.

## **2. Thickness of First Dielectric Layer**

If Patent Owner argues that Bhattacharyya does not sufficiently disclose that thickness of the aluminum oxide layer is less than 50 nm as required by Claims 12 and 13, or less than 30 nm as required by Claim 14, it would have been obvious to a Skilled Artisan in any event to make it so based on the teaching of Bhattacharyya in view of Hoex 2006 (EX1007); EX1003¶162.

Bhattacharyya suggests using a “very thin” aluminum oxide layer. By 2006, a Skilled Artisan would have known that aluminum oxide layers of 7-30 nm would

still provide effective passivation. *See* EX1007, Title, Abstract, 1; *see also* § VI.C above; EX1003¶163-164. Just as in Hoex 2006, the use of the aluminum oxide layer in FIG. 6 of Bhattacharyya was to “reduce surface recombination and enhance collection and thereby also enhance solar cell efficiency.” EX1005, [0087]. Given that Hoex 2006 shows that even a 7 nm thin  $\text{Al}_2\text{O}_3$  film can reduce surface recombination and that it was known that the effectiveness of quantum tunneling increases with decreasing thickness, a Skilled Artisan would have been motivated to use less than 10 nm of aluminum oxide as explicitly taught by Hoex 2006 in the solar cell of Bhattacharyya. EX1003¶165.

In the combination of Bhattacharyya and Hoex 2006, the thickness of the aluminum oxide dielectric layer of the solar cell in Bhattacharyya system would be, for example, 7 nm (as in Hoex 2006), and be formed directly on top of the silicon substrate and under a layer of silicon nitride or silicon oxide (as in Bhattacharyya) to effectively passivate the solar cell using limited amounts of aluminum material. The combination would maintain excellent surface passivation of the solar cell while increasing the probability of quantum tunneling. Moreover, using a very thin layer like in Hoex 2006 would reduce the time required to deposit the aluminum oxide layer (since the deposition time is proportional to the thickness of the layer), as well as reducing the total amount of aluminum deposited, thereby reducing the cost of materials to be used. Such an arrangement would be nothing



more than the arrangements of old elements readily made by a Skilled Artisan.

EX1003¶166.

It would have been obvious to make such a combination for several reasons. Both Bhattacharyya and Hoex 2006 utilized aluminum oxide layers to reduce surface recombination at the surface of a silicon substrate. EX1003¶167.

Bhattacharyya and Hoex 2006 are both analogous art to the '215 Patent because each is in the field of improved efficiency of photovoltaic energy cells, EX1001, 1:14-22; EX1005, [0003]; EX1007, 1, and because both Bhattacharyya and Hoex 2006 are reasonably pertinent to the preventing losses of photogenerated carriers, and concomitant loss of energy producing capability, at the surface of the silicon substrate in a solar cell that the inventors of the '215 Patent were trying to solve. EX1001, 1:14-22; EX1005, [0003]; EX1007, 1; EX1003¶167.

The combination of Bhattacharyya and Hoex 2006 would have been an arrangement of old elements (the 7 nm aluminum oxide layer as described by Hoex 2006 with the solar cell in Bhattacharyya) with each performing the same function it had been known to perform (providing an efficiently surface-passivated solar cell) and yielding no more than what one would expect from such an arrangement (improved performance of the solar cell). EX1003¶168.

A Skilled Artisan would have been motivated to use the thin aluminum oxide layer of Hoex 2006 with the solar cell of Bhattacharyya. For example, Hoex

2006 teaches that the 7 nm thin layer of aluminum oxide causes the surface recombination velocity of electrons on the surface of the silicon substrate to fall to a level similar to that of a thicker layer of aluminum oxide. EX1007, 3. Hoex 2006 also teaches that making the layer as thin as possible would be advantageous because “total process, growth, and annealing would be significantly faster compared to the state-of-the-art passivation schemes applied presently.” *Id.* And Bhattacharyya teaches to make the aluminum oxide “very thin.” A Skilled Artisan would therefore have been motivated to use the very thin 7 nm layer in Hoex 2006 in the solar cell of Bhattacharyya to increase the effectiveness of the quantum tunneling in Bhattacharyya and also reduce the time required to deposit the film, as well as to reduce the total cost of materials required to deposit it. Such a combination would increase the efficiency of the Bhattacharyya solar cell and reduce the costs to create the solar cell and increase the volume of solar cells that could be produced in a certain time. EX1003¶169.

### **3. Hydrogen and Thickness**

To the extent one might argue that Bhattacharyya does not disclose either the embedding of hydrogen in the second dielectric layer or that the thickness of the first layer is less than 50 nm, it would have been obvious to include both of those elements in the solar cell of Bhattacharyya in view of Duerinckx and Hoex 2006 for the reasons mentioned in §VII.B.1 (for Duerinckx) and §VII.B.2 (for

Hoex 2006). All three references are analogous art because both Duerinckx and Hoex 2006 are analogous art to Bhattacharyya (as described above), and both are reasonably directed to the problem the '215 Patent was trying to solve. A Skilled Artisan would have been motivated to combine all three references because Bhattacharyya suggests the use of the LPCVD and PECVD (the same deposition methods disclosed in Duernickx), as well as the “very thin” (e.g., 7 nm) aluminum oxide layer of Hoex 2006. Moreover, hydrogenation of the surface of the silicon substrate would occur more quickly when the hydrogen from the second dielectric layer diffuses through a thinner barrier. Thus, a Skilled Artisan would have been motivated to keep the thickness of the aluminum oxide layer as low as possible to support electron tunneling as in Bhattacharyya’s solar design, and to allow the hydrogen to diffuse through that layer and better passivate the surface of the silicon substrate. EX1003¶170.

**C. Claims 12-14 Are Obvious Over Hagino**

**1. Claim 12**

**a. Preamble**

Claim 12 recites “[a] solar cell comprising.”

Again, the Board need not decide whether the preamble is limiting, because Hagino expressly discloses “a solar cell comprising.” Hagino is directed towards a “solar cell and method of manufacturing the same.” See EX1006, Title. FIG. 1 of

Hagino shows a “schematic cross-sectional view of a solar cell.” EX1006, [0018], FIG. 1. EX1003¶180.

b. *Silicon Substrate*

Claim 12 also requires “*a silicon substrate.*” The ’215 Patent states that the “silicon substrate provided may be a thin monocrystalline or multicrystalline silicon wafer or else a silicon thin layer.” EX1001 at 3:34-36; EX1003¶183.

Hagino discloses that its solar cell includes a “silicon wafer 1.” EX1006, [0043], FIG. 1, FIGs. 3A-3F. Initially, a Skilled Artisan would have understood that the terms “wafer” and “substrate” were used interchangeably in the field of “solar cell design or manufacture.” EX1003¶182; *see also* EX1025, 5:14-17. A Skilled Artisan have also understood that “wafers” or “substrates” in this context are made of semiconductor materials, and that a “silicon wafer” or a “silicon substrate” is merely a wafer/substrate made of silicon as the semiconducting material. EX1003¶182.

The ’215 Patent further teaches that its alleged invention can effectively passivate “both low and high *doped* n- and p-type silicon surfaces.” EX1001, 6:18-19; EX1003¶183. A Skilled Artisan would have known that one of the most common ways to create the conditions required for a semiconductor material to operate as a solar cell is to form a junction of p-type and n-type doped regions (a

PN junction) within its substrate by diffusion of dopants. *See, e.g.*, EX1025, Abstract, 5:14-51, FIGs 1A-1E; EX1003¶184.

The silicon substrate (that includes a PN junction) as taught in Hagino is the same type of “*silicon substrate*” that is disclosed in the ’215 Patent. EX1003¶192. Similar to the ’215 Patent, Hagino teaches that either a “p-type silicon wafer” or an “an n-type silicon wafer” may be used as the starting point for its “*silicon substrate*.” EX1006, [0036], [0045]; EX1001, 3:1-4, 6:17-23; EX1003¶182-183, 185, 187. Hagino then teaches that “an n-type dopant” is diffused into the “p-type monocrystalline silicon” to form a PN junction. EX1006, [0046], [0050], [0051]; *see also* EX1006, [0004], [0014]; EX1003¶188.

The dopant is “diffused” *into* the “silicon wafer” (and not “deposited” on the “silicon wafer”) in Hagino. *Id.*; *see also* EX1003¶189-190. The resulting “dopant diffusion layer 6A” is not a separate layer that is deposited or formed on top of the “silicon wafer,” but rather is a part of the silicon wafer. *Id.*

Accordingly, the “silicon wafer 1” and “dopant diffusion layer 6A” in FIG. 1 (*i.e.*, FIG. 3F) corresponds to the claimed “*silicon substrate*” under the plain and ordinary meaning of that term in view of the ’215 Patent. EX1003¶182-190; *see also* EX1025, 5:14-51 (explaining that the “n+ [dopant diffusion] region 16” extends down from the “upper surface of the [p-type] substrate” when exposed to a “dopant source” of n-type), FIGs 1A-1E, Abstract.



EX1006, FIG. 1 (color added); EX1003¶192.

In other words, what is labeled as “dopant diffusion layer 6A” in FIG. 1 of Hagino is in fact part of the “silicon wafer 1,” and hence part of the claimed “silicon substrate.” *Id.* This is confirmed by the fact that Hagino refers to the surface of the “dopant diffusion layer 6A” as the “surface of a silicon wafer.” EX1006, [0028], [0031], FIGS. 1 and FIG. 3F (showing that the “passivation layer 3A” is in contact with and hence functions to terminate defects in the “dopant diffusion layer 6A”); EX1003¶191.

As the '215 Patent admits, its alleged invention is to deposit a passivation dielectric layer that can passivate “both high and low-doped regions of the solar cell surface of conduction type p or n,” EX1001, 3:1-4, which is the claimed “*silicon substrate*.”

As such, the “silicon wafer 1” (e.g., p-type or n-type silicon) and the “dopant diffusion layer 6A” (e.g., n-type or p-type silicon, respectively) in FIG. 1 of Hagino satisfy the claimed “*silicon substrate*.” EX1003¶¶181-193.

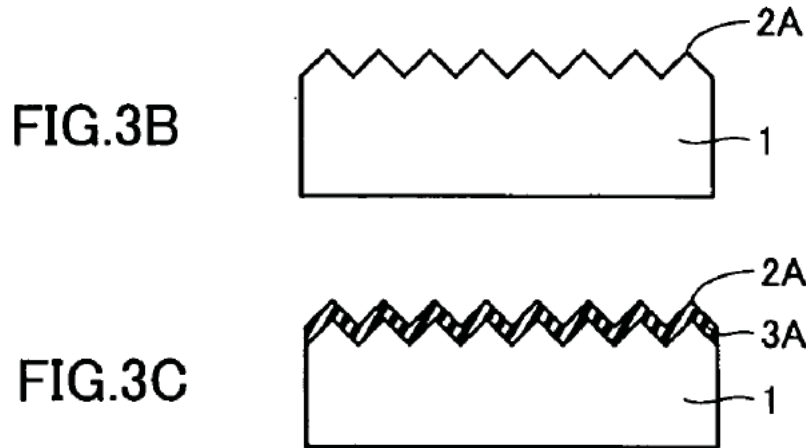
c. *First Dielectric Layer*

Claim 12 also requires “*a first dielectric layer comprising aluminium oxide on a surface of the silicon substrate.*”

Hagino satisfies the limitation “*a first dielectric layer comprising aluminium oxide.*” In particular, Hagino discloses that an “aluminum oxide film” is an example of its “passivation film 3A” (*i.e.*, “*first dielectric layer*”). EX1006, [0027], [0030], [0031]. EX1003¶195.

A Skilled Artisan would have understood that “aluminum oxide” as used in this context is a “dielectric” material. *See, e.g.*, EX1029, 11:57-12:2, 12:13-15 (referring to the “aluminum oxide” layer as a “dielectric” layer); EX1030, 7080 (“Alternative dielectrics such as ...  $\text{Al}_2\text{O}_3$  ... have been investigated”); EX1003¶196. Accordingly, Hagino’s “aluminum oxide film” corresponds to the first “*dielectric layer*,” as claimed. *Id.*

Hagino also discloses “*a first dielectric layer ... on a surface of the silicon substrate.*” Hagino teaches that its “passivation film 3A” is formed on the surface of the “silicon wafer 1.” EX1006, [0028] (explaining that a “light-receiving surface passivation film 3A [is formed] on a texture etching surface 2A that is a light-receiving *surface of silicon wafer 1*, as shown in FIG. 3C”), FIG. 3B, FIG. 3C (showing that the “passivation film 3A” is formed on the surface of the “silicon wafer 1”); EX1003¶197.



Although dopant is later “diffused” into the “silicon wafer” in Hagino, it does not change the fact that Hagino discloses “a first dielectric layer ... on a surface of the silicon substrate.” EX1003¶198.



EX1006, FIG. 1 (color added to show the “silicon substrate” in green and “first dielectric layer” in red); EX1003¶198.

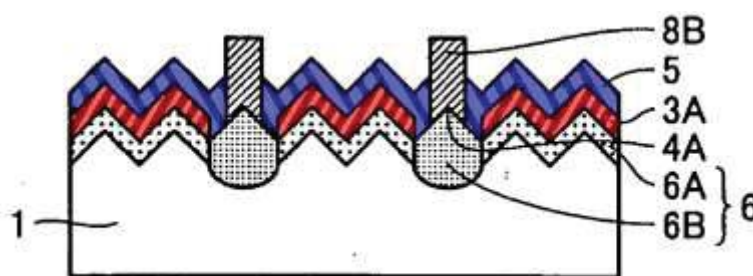
As explained above in connection with the limitation “silicon substrate,” the resulting “dopant diffusion layer 6A” is not a separate layer that is deposited on top of the “silicon wafer,” but rather is a part of the silicon wafer. *Id.*; EX1006, [0031]; EX1003¶¶181-193.



d. *Second Dielectric Layer*

Claim 12 also requires “a second dielectric layer directly on a surface of the first dielectric layer.”

FIG. 1 (*i.e.*, FIG. 3F) of Hagino shows depositing an “anti-reflection layer 5” (*i.e.*, “*second dielectric layer*”) directly on the surface of the “passivation layer 3A” (*i.e.*, “*first dielectric layer*”). EX1006, [0054], FIG. 1, FIG. 3F; EX1003¶200.



EX1006, FIG. 1 (color added to show the “*first dielectric layer*” in red and the “*second dielectric layer*” in blue); EX1003¶200.

Hagino also discloses using “silicon nitride” as the “antireflection film” (*i.e.*, “*second dielectric layer*”). EX1006, [0055]; EX1003¶201. A Skilled Artisan would have understood that “silicon nitride” is a “dielectric” material. *See, e.g.*, EX1031, 2:35-36, 2:60-63. Accordingly, Hagino discloses a “silicon nitride” film that corresponds to the claimed second “*dielectric layer*.” *Id.*; EX1003¶201.

e. *Differing Materials*

Claim 12 also requires “*materials of the first dielectric layer and the second dielectric layer differing.*”

Hagino discloses using an “aluminum oxide film” as the “passivation film 3A” (*i.e.*, “*first dielectric layer*”). EX1006, [0027], [0030], [0031]. Hagino further discloses using “silicon nitride” as the “antireflection film” (*i.e.*, “*second dielectric layer*”). EX1006, [0055]. Accordingly, Hagino discloses “*materials of the first dielectric layer and the second dielectric layer differing.*” EX1003¶203.

Any argument by Patent Owner that “*the first dielectric layer and the second dielectric layer*” in Hagino do not differ, because Hagino discloses that “the light-receiving surface passivation film also function as an antireflection film,” would be wrong. EX1006, [0027], [0032]; EX1003¶204. The claims merely require that the “*materials of the first dielectric layer and the second dielectric layer*” differ, not that the “*first dielectric layer and the second dielectric layer*” cannot have overlapping functions (e.g., passivation and/or antireflection). EX1001, claims 12-14. The “silicon nitride” Hagino discloses for use as the antireflection film (“*second dielectric layer*”) is not the same material as “aluminum oxide,” which Hagino discloses for use as the passivation layer (“*first dielectric layer*”). EX1006, [0055]; EX1003¶204.

f. *Hydrogen*

Claim 12 also requires “*hydrogen being embedded into the second dielectric layer.*”

Hagino discloses that the “silicon nitride” layer is formed by “CVD using silane, ammonia, hydrogen and the like as a base material,” EX1006, [0029], which would necessarily embed hydrogen into the silicon nitride film. EX1021, Section II.A (explaining that “[a] gas mixture of undiluted silane ( $\text{SiH}_4$ ) and pure ammonia ( $\text{NH}_3$ ) was used as the reaction gas”), FIG. 3 (showing hydrogen being embedded into the silicon nitride layer); EX1003¶206-207. A Skilled Artisan would have recognized that the use of hydrogen containing precursor materials in Hagino would embed hydrogen into that layer at a concentration at least as high as that disclosed in the ’215 Patent. *See* § VII.A.1.f above; EX1003¶206-210. That is, the concentration of the embedded hydrogen would be at least 5 atomic %, which is higher than the 1 atomic % described by the ’215 Patent and corresponds to the ’215 Patent’s “more prefer[red]” range. EX1001, 5:16-18; EX1008, 232; EX1021, FIG.3; EX1037, 41, 45-46; EX1003¶208-209. .

To the extent Patent Owner argues that Hagino’s explicit teaching in paragraph [0029] applies only to forming a “passivation film” rather than an “antireflection film,” a Skilled Artisan would have understood that similar CVD methods would have been used to form “silicon nitride” layers as “antireflection films.” EX1003¶211-212. Hagino also expressly teaches that the light-receiving surface passivation films “also function as antireflection films.” EX1006, [0027], [0032]. Accordingly, a Skilled Artisan would have understood that Hagino’s

disclosures in paragraph [0029] regarding formation of a “silicon nitride” film as a passivation film also would be applicable in forming a “silicon nitride” film as an antireflection film. EX1003¶212. As such, a Skilled Artisan would have found it obvious to deposit the silicon nitride antireflection film using the “CVD” process described in Hagino’s paragraph [0029]. *Id.*

Moreover, as discussed above, a Skilled Artisan would also have recognized that the most practical and widely used processes for forming silicon nitride would be to use reactants that contain and produce hydrogen. EX1003¶213. *See, e.g.*, EX1020; § VII.A.1.f above.

g. *Thickness of First Dielectric Layer*

Claim 12 also requires “*wherein the first dielectric layer has a thickness of less than 50 nm.*”

Hagino discloses that its “passivation film 3A” is “approximately 3 nm – 30 nm.” EX1006, [0048]; EX1003¶221.

Although this thickness was described in the context of a silicon oxide passivation layer, a Skilled Artisan would have understood Hagino as teaching a thickness of no more than “3 nm-30 nm” when aluminum oxide is used to form the passivation layer. EX1003¶222. This is so because the refractive index (in

wavelength ranges solar cells operate)<sup>5</sup> for aluminum oxide is higher than the refractive index for silicon oxide. *Id.*; EX1028, 1:70-2:4; EX1032, 1705 (showing 1.7673 as the “index of refraction” for aluminum oxide at a wavelength of 589 nm), 10-229 (showing 1.5442 as the “index of refraction” for silicon dioxide at a wavelength of 589 nm).

In particular, Hagino teaches that “the light-receiving surface passivation film also function[s] as [an] antireflection film.” EX1006, [0027], [0032]. Accordingly, a Skilled Artisan would have understood (or at the very least would have found it obvious) that the same optical properties should be maintained when replacing the silicon oxide passivation film with an aluminum oxide passivation film. EX1003¶223. Because the refractive index for aluminum oxide is higher than the refractive index for silicon oxide, EX1032, 1705, 1708, a Skilled Artisan would have used a thickness of the “aluminum oxide” passivation film that is no more than the disclosed thickness (*i.e.*, “3 nm-30 nm”) for the “silicon oxide” passivation film. EX1003¶223 (explaining that thinner “aluminum oxide” layer is optically equivalent to a thicker “silicon oxide” layer); *see also* EX1033, 27;

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<sup>5</sup> A Skilled Artisan would have understood that refractive index can change as a function of wavelength. EX1038, 31-34. Accordingly, it is important to use refractive indices in the wavelength ranges where the solar cells operate. EX1003¶222.

EX1034, 103 (explaining that wavelength is inversely proportional to the index of refraction, i.e., “ $\lambda = \lambda_0/n$ .”).

Accordingly, a Skilled Artisan would have understood Hagino to be teaching (or at the very least rendering obvious) a thickness of no more than “3 nm-30 nm” when aluminum oxide is used as “passivation film 3A.” EX1006, [0027]; EX1003¶222-224.

In addition, a Skilled Artisan would have found it obvious to apply a thickness of no more than “3 nm-30 nm” when aluminum oxide is used to form the passivation layer (instead of the silicon oxide with a thickness of “3 nm-30 nm”), because aluminum oxide has a higher density compared to that of a silicon oxide. EX1032, 740 (showing 3.97 as the “density” for aluminum oxide), 783 (showing 2.265 as the “density” for silicon dioxide); EX1027, Section 6.1.1 (explaining that the diffusion rate generally decreases as the density increases); EX1003¶225.

In particular, Hagino explains that the passivation layer 3A “serves as a barrier against dopant diffusion” and that “dopant concentration can be controlled by controlling the thickness of light receiving surface passivation film 3A.” EX1006, [0028]. Because a Skilled Artisan would have known that a material with higher density generally acts as a better barrier against diffusion, and also because aluminum oxide has a higher density compared to that of silicon oxide. EX1032, 4-39 (showing 3.97 as the “density” for aluminum oxide), 4-82 (showing 2.265 as

the “density” for silicon dioxide); EX1027, Section 6.1.1 (explaining that the diffusion rate generally decreases as the density increases), a Skilled Artisan would have found it obvious to apply an aluminum oxide film with thickness less than the disclosed “3 nm-30 nm” thickness for silicon oxide. EX1003¶226.

h. *Interposed Between*

Claim 12 also requires “*wherein the first dielectric layer ... is interposed between the surface of the silicon substrate and the second dielectric layer.*”

As explained above, the “silicon wafer 1” and the “dopant diffusion layer 6A” in FIG. 1 of Hagino corresponds to the claimed “*silicon substrate.*” EX1006, [0031]; EX1003¶181-193. As also explained earlier, a Skilled Artisan would have understood that Hagino’s “dopant diffusion layer 6” is a region of the silicon wafer that forms part of a PN junction. EX1003¶188-191, 234.

As shown in FIG. 3E, Hagino discloses that the “dopant diffusion layer ... 6A [will be] covered with the ... passivation film 3A,” after diffusing dopants into the silicon wafer 1. EX1006, [0051], FIG. 3E, FIG. 1. A Skilled Artisan would have understood that the surface of the “dopant diffusion layer 6A,” is in contact with the “passivation film 3A.” *Id.*; EX1003¶235.

Hagino teaches that “the antireflection film may be formed after the n-type dopant diffusion.” EX1006, [0056]. Hagino also discloses that “the antireflection film includes ... silicon nitride.” EX1006, [0055]. As shown in the figures, a

Skilled Artisan would have understood that the silicon nitride “antireflection film” is in contact with the aluminum oxide “passivation film 3A,” after CVD is used to deposit the silicon nitride layer on top of the aluminum oxide layer. EX1006, [0029], FIG. 3E, FIG. 1; EX1003¶236. Hagino’s “passivation layer 3A,” therefore, is interposed between the “antireflection layer 5” and the surface of the silicon wafer (*i.e.*, surface of the “dopant diffusion layer 6,” which is part of the silicon wafer). EX1006, [0031]; EX1003¶236.

Hagino therefore renders claim 12 obvious.

## **2. Claim 13**

Claim 13 recites “[t]he solar cell according to claim 12, wherein the second dielectric layer comprises a material selected from the group consisting of silicon nitride, silicon oxide and silicon carbide.”

Hagino discloses that the second dielectric layer comprises silicon nitride. For example, Hagino explains that the “antireflection film 5” can be “silicon nitride.” EX1006, [0055] (“The antireflection film includes, other than titanium dioxide, aluminum oxide, tin oxide, **silicon nitride**, tantalum oxide, or the like.”).

For the reasons set forth above and in connection with claim 12, Hagino renders claim 13 obvious. EX1003¶238-240

## **3. Claim 14**



Claim 14 recites “[t]he solar cell according to claim 12, wherein the first dielectric layer has a thickness of less than 30 nm.”

As explained above, Hagino explains that the “passivation film 3A” is “approximately 3 nm-30 nm thick.” EX1006, [0048] The analysis set forth above for claim 12 in connection with the “*thickness of less than 50 nm*” limitation applies equally to claim 14. In other words, a Skilled Artisan would have understood Hagino to be teaching that the “passivation film 3A” is no more than “approximately 3 nm-30 nm thick” when aluminum oxide is used as its “passivation film 3A.” *Id.*; EX1003¶242.

For the reasons set forth above and in connection with claim 12, Hagino renders claim 14 obvious. EX1003¶241-243.

**D. Claims 12-14 Are Obvious over Hagino in view of Duerinckx and/or Hoex 2006**

**1. Hydrogen**

To the extent Patent Owner argues that Hagino does not sufficiently disclose (which it does) that hydrogen is embedded in the second dielectric layer as required by Claims 12-14, it would have been obvious to a Skilled Artisan to do so because embedding hydrogen in the silicon nitride layer was the state of the art, as acknowledged by Duerinckx and others. EX1003¶214-219.

As explained in § VII.B.1, Duerinckx discloses various deposition CVD techniques for surface passivation of solar cells using hydrogenated layers of

silicon nitride. EX1008, Title, Abstract, 232; *see also* § VI.D above. In the combined teaching of Hagino and Duerinckx, the “antireflection film 5” of the solar cell in the Hagino system would be hydrogenated (as in Duerinckx) and be formed on top of the aluminum oxide (as in Hagino). EX1003¶215-216. As described in Duernickx, the silicon nitride layer formed using precursors such as silane and ammonia could contain up to 40 at% of hydrogen. EX1003¶215-216; EX1008, 232

It would have been obvious to make such a combination for several reasons. EX1003¶217. Hagino and Duerinckx are analogous art to the '215 Patent because each is in the field of improved efficiency of photovoltaic energy cells, EX1001, 1:14-22; EX1006, [0002]; EX1008, Abstract, 234, and because both Hagino and Duerinckx are reasonably pertinent to the problem of preventing losses of electrical energy at the surface of the silicon substrate in a solar cell that the inventors of the '215 Patent were trying to solve. EX1001, 1:14-22; EX1006, [0002]; EX1008, 234, 236-38; EX1003¶217. Both disclose the use of CVD to deposit the silicon nitride layer.

The use of the Duerinckx hydrogenated silicon oxide layer in the solar cell of Hagino would have been an arrangement of old elements (a hydrogenated silicon nitride layer as described in Duerinckx with the solar cell in Hagino) with each performing the same function it had been known to perform (improving

passivation of the silicon substrate surface of the solar cell) and yielding no more than what one would expect from such an arrangement (improved performance of the solar cell via reduction of the surface recombination velocity at the semiconductor/oxide interface). EX1003¶218.

A Skilled Artisan would have had reason to make the combination. EX1003¶219. For example, by the time the '215 Patent was filed, it was well-known that hydrogen embedded in a passivating layer would naturally diffuse into the surface of the silicon substrate, saturating dangling bonds of the silicon and reducing surface recombination of charge carriers. *See, e.g.*, EX1008, 234; EX1024, 17. Given that hydrogen is one of the smallest atoms, a Skilled Artisan would also have understood that hydrogen could diffuse through intermediate layers (i.e., the aluminum oxide layer of Hagino) to passivate the surface of the silicon substrate. EX1023, 3823; EX1003¶216, 219. The combined system would improve surface passivation of the solar cell by saturating dangling bonds at the surface of the silicon substrate below the aluminum oxide layer, which would further reduce the surface recombination velocity at the interface between the silicon and aluminum oxide. Such an arrangement would be nothing more than the arrangements of old elements readily made by a Skilled Artisan. EX1003¶216. A Skilled Artisan would therefore have been motivated to utilize hydrogenated

silicon nitride layer of Duerinckx to provide further passivation enhancements to the solar cell proposed by Hagino. EX1003¶219.

## **2. Thickness**

To the extent Patent Owner argues that Hagino does not sufficiently disclose that the thickness of the aluminum oxide layer is less than 50 nm as required by Claims 12 and 13, or less than 30 nm as required by Claim 14, it would have been obvious to a Skilled Artisan make it so based on the teaching of Hagino in view of Hoex 2006 (EX1007). EX1003¶227-231.

By 2006, one of ordinary skill in the art would have known that very thin aluminum oxide layers of 7-30 nm would still provide effective passivation. *See* Hoex 2006; §§ VI.C, VII.B.2 above; EX1003¶228. Combining Hagino and Hoex 2006, a Skilled Artisan would be able to use a 7 nm thick aluminum oxide dielectric layer (as in Hoex 2006) in the solar cell of Hagino that is formed directly on top of the silicon substrate and under a layer of silicon nitride or silicon oxide (as in Hagino) to effectively passivate the solar cell using limited amounts of aluminum material. EX1003¶228. The 7 nm thickness of the aluminum oxide layer in Hoex 2006 would be in the same range of 3-30 nm for the passivation layer 3A taught by Hagino. Moreover, combining Hagino with Hoex 2006 would provide a solar cell that maintain excellent surface passivation while reducing the time required to deposit the aluminum oxide layer (since the deposition time is

proportional to the thickness of the layer), as well as reducing the total amount of aluminum deposited, thereby reducing the cost of materials to be used. Such an arrangement would be nothing more than the arrangements of old elements readily made by a Skilled Artisan. EX1003¶228.

It would have been obvious to make such a combination for several reasons. EX1003¶229. Hagino and Hoex 2006 are analogous art to the '215 Patent because each is in the field of improved efficiency of photovoltaic energy cells, EX1001, 1:14-22; EX1006, [0002]; EX1007, 1. Both disclose aluminum oxide layers, and both Hagino and Hoex 2006 are reasonably pertinent to the problem of reducing costs and inefficiencies in a solar cell that the inventors of the '215 Patent were trying to solve. EX1001, 1:14-22; EX1006, [0002]; EX1007, 1, EX1003¶229.

The use of the Hoex 2006 7 nm aluminum oxide layer in the solar cell of Hagino would have been an arrangement of old elements (*e.g.*, the 7 nm aluminum oxide layer of Hoex 2006 with the solar cell in Hagino) with each performing the same function it had been known to perform (providing an efficiently surface-passivated solar cell) and yielding no more than what one would expect from such an arrangement (improved performance of the solar cell). EX1003¶230.

A Skilled Artisan would have had reason to make the combination. EX1003¶231. For example, it was known that making a dielectric material as thin as possible would reduce the materials cost of the device, as well as reduce the

time required to deposit the dielectric on the substrate. EX1003¶231. A Skilled Artisan would also have understood from the disclosures of Hoex 2006 that the 7 nm aluminum oxide layer would have had similar surface passivation qualities to a thicker layer of the same material. EX1007, 3. A Skilled Artisan would therefore have been motivated to utilize the thin aluminum oxide layer of Hoex 2006 in the solar cell proposed by Hagino at a lower cost. EX1003¶231.

### **3. Hydrogen and Thickness**

To the extent one might argue that Hagino does not disclose either the embedding of hydrogen in the second dielectric layer or that the thickness of the first layer is less than 50 nm (or 30 nm), it would have been obvious to include both of those elements in the solar cell of Hagino in view of Duerinckx and Hoex 2006 for the reasons mentioned in §VII.D.1 (for Duerinckx) and §VII.D.2 (for Hoex 2006). As explained above, all three references are analogous art, and all three are reasonably directed to the problem the '215 Patent was trying to solve. Further, the motivations to combine these references mentioned in §VII.D.1 (for Duerinckx) and §VII.D.2 (for Hoex 2006) also apply to the three-way combination. EX1003¶232.

## **VIII. NO SECONDARY CONSIDERATIONS EXIST**

In response to a declaration submitted by one of the applicants during prosecution, which argued five secondary considerations of nonobviousness, the

examiner correctly rejected each and every one of them as unfounded. EX1002, 464-66, 491, 500; EX1003¶245. In particular, the examiner noted that long-felt need “must not have been satisfied by another before the invention by applicant,” and found that the cited prior art “satisfied the long-felt need at the time of invention.” *Id.* The examiner also found “NO” skepticism of experts at the time of invention. *Id.* Regarding unexpected results, the examiner found that the cited prior art already recognized that “deterioration of passivation of aluminum oxide layer during the high-temperature step” could be “recovered ... using the additional layer of hydrogenated SiN.” *Id.* Regarding commercial success, the examiner found that no such evidence had been provided. *Id.* Finally, the examiner also found an “absence of evidence” for copying of others. *Id.*; EX1003¶246.

In addition, there is no evidence establishing the required nexus between the secondary considerations the applicants alleged were present and the claimed invention. In fact, claims 12-14 do not even mention an ALD process. *Id.* And there is no evidence of long felt need that was not already addressed by the teachings of Bhattacharyya or Hagino, alone or in combination with Duerinckx and Hoex 2006. *Id.* In addition, the results achieved in passivating the surface of solar cells using very thin aluminum oxide layers and hydrogen binding to dangling bonds at the surface of the silicon substrate were already expected based on the

teachings of these references. *Id.* And by 2006, a Skilled Artisan understood that very thin (<30 nm) aluminum oxide layers on silicon substrate were “ideal” surface passivating materials for solar cells (EX1016, Abstract), and that hydrogenated silicon nitride layer was the state of art used for surface passivating solar cells. *Id.* And the combination of the two was disclosed by both Bhattacharyya and Hagino more than one year before the priority date of the ‘215 Patent. *Id.*; EX1003¶247. Patent Owner reserves the right to address any further evidence that Patent Owner may provide regarding secondary considerations.

## **IX. CONCLUSION**

Petitioners therefore respectfully requests cancellation of Claims 12-14 of the ‘215 Patent.

Dated: May 13, 2019

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**CERTIFICATE OF COMPLIANCE**

I hereby certify that this petition complies with the type-volume limitations of 37 C.F.R. §42.24, because it contains 13,970 words (as determined by the Microsoft Word word-processing system used to prepare the Petition), excluding the parts of the Petition exempted by 37 C.F.R. §42.24.

Dated: May 13, 2019

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**PETITION FOR INTER PARTES REVIEW**

**OF U.S. PATENT NO. 9,893,215**

**Attachment A:**

**Proof of Service of the Petition**

**CERTIFICATE OF SERVICE**

I hereby certify that on May 13, 2019, a copy of the Petition, including all attachments, appendices, and exhibits thereto, has been served in its entirety on the patent owner and counsel for patent owner, via Federal Express, at the following:

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