

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Samsung Electronics Co., Ltd.,
Petitioner,

v.

SiOnyx, LLC,
Patent Owner.

Case No. IPR2025-00165
Patent No. 9,905,599

**PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 9,905,599
UNDER 35 U.S.C. §§ 311–319 AND 37 C.F.R. § 42.100 *et seq.***

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List of Exhibits

Exhibit	Description
1001	U.S. Patent No. 9,905,599 (the “’599 patent”)
1002	File History for U.S. Patent No. 9,905,599
1003	Declaration of Dr. Michael Lebby
1004	Curriculum Vitae of Dr. Michael Lebby
1005	Provisional Application No. 61/614,275 (’275 Provisional)
1006	Int’l Publication No. WO 2011/035188 A2 (Haddad188)
1007	U.S. Patent Application Publication No. 2012/0033119 (Shinohara)
1008	Japanese Patent Application Publication No. 2011-119558 (Mori)
1009	Certified English Translation of Japanese Patent Application Publication No. 2011-119558 (Mori)
1010	U.S. Patent No. 7,675,099 (Hwang)
1011	U.S. Patent No. 7,709,775 (Konno)
1012	Samsung’s Proposed Constructions, Inv. No. 337-TA-1403 (Aug. 27, 2024)
1013	SiOnyx’s Proposed Constructions, Inv. No. 337-TA-1403 (Aug. 27, 2024)
1014	Email from N. Subhedar re: Claim Construction M&C Follow-Up (Sept. 8, 2024)
1015	Joint Proposed Claim Construction Chart, Inv. No. 337-TA-1403 (Nov. 1, 2024)
1016	U.S. Patent Publication No. 2009/0160000 (Kim)
1017	E. Fred Schubert, LIGHT-EMITTING DIODES (2nd ed. 2006)
1018	Stanley Wolf, MICROCHIP MANUFACTURING (2004) (Excerpts)
1019	U.S. Patent Application Publication No. 2012/0025199 (Chen)
1020	U.S. Patent No. 8,288,836 (Oshiyama)
1021	Sadao Adachi, Optical Constants of Crystalline and Amorphous Semiconductors, Numerical Data and Graphical Information (1st Ed. 1999) (Excerpt)
1022	U.S. Patent No. 4,644,553
1023	George Hass & Calvin D. Salzberg, <i>Optical Properties of Silicon Monoxide in the Wavelength Region from 0.24 to 14.0 Microns</i> , Vol. 44 No. 3, JOURNAL OF THE OPTICAL SOCIETY OF AM., 181 (1954)
1024	F. Lopez & E. Bernabéu, <i>Refractive Index of Vacuum-Evaporated SiO Thin Films: Dependence on Substrate Temperature</i> , ELECTRONICS & OPTICS, 13 (1990)

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Exhibit	Description
1025	Japanese Patent Application Publication No. JP H11-330501 (Suzunaga)
1026	Certified English Translation of Japanese Patent Application Publication No. JP H11-330501 (Suzunaga)
1027	U.S. Provisional Patent Application No. 61/311,004 (the “’004” Application)
1028	Japanese Patent Application Publication No. 2009-188316 (Yamada)
1029	Certified English Translation of Japanese Patent Application Publication No. 2009-188316 (Yamada)
1030	Gier et al., <i>Controlling the optical properties of hafnium dioxide thin films deposited with electron cyclotron resonance ion beam deposition</i> , THIN SOLID FILMS 771 (2023)

I. INTRODUCTION

Samsung Electronics Co., Ltd. (“Petitioner”) petitions for *inter partes* review seeking cancellation of claims 1-36 (the “Challenged Claims”) of U.S. Patent No. 9,905,599 (Ex-1001, the “’599 patent”).

II. STANDING, MANDATORY NOTICES, AND FEE AUTHORIZATION

Grounds for Standing: Pursuant to 37 C.F.R. §42.104(a), Petitioner certifies that the ’599 patent is available for IPR and that Petitioner is not barred or estopped from requesting an IPR challenging the ’599 patent on the grounds identified in this petition.

Real Parties-in-interest: The real parties-in-interest are Samsung Electronics Co., Ltd., Samsung Electronics America, Inc., and Samsung Semiconductor, Inc.

Related Matters: Petitioner identifies the following related matters.

- *Sensors with Pixels and Products Containing the Same*, Inv. No. 337-TA-1403 (ITC) (the “Related Case”)
- *SiOnyx, LLC v. Samsung Electronics, Co., Ltd.*, 2:24-cv-00291 (E.D. Tex.)

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Service Information: Service information is provided in the designation of counsel above. Petitioner consents to service of all documents via electronic mail at the email addresses above and at Samsung-SiOnyx-IPR-Cov@cov.com.

Fee Authorization: The Office is authorized to charge all fees due in connection with this proceeding to Deposit Account No. 60-3160.

III. SUMMARY OF CHALLENGE

This petition presents the following claim challenges:

- **Ground 1:** Claims 19-20, 26-32, and 34-36 are rendered obvious based on Haddad188
 - **Ground 2:** Claim 33 is obvious based on Haddad188 and Shinohara

- **Ground 3:** Claims 1-14, 16-18, and 21-25 are obvious based on Haddad188 and Mori
 - **Ground 4:** Claim 15 is obvious based on Haddad188, Mori, and Shinohara
- **Ground 5:** Claims 19-23, 26-32, 34, and 36 are obvious based on Hwang and Konno
 - **Ground 6:** Claim 33 is obvious based on Hwang, Konno, and Shinohara
 - **Ground 7:** Claims 1-14, 16, 18, and 24-25 are obvious based on Hwang, Konno, and Mori
 - **Ground 8:** Claim 15 is obvious based on Hwang, Konno, Mori, and Shinohara

The '599 patent claims priority to Provisional Application No. 61/614,275, (Ex-1005, "'275 Application") filed on March 22, 2012. However, the '275 Application does not provide written support for, or enable, any of the '599 patent's claims because it contains no discussion or disclosure of any *reflective layer[s]*. Ex-1003, ¶¶50-54. Accordingly, the '599 patent is not entitled to claim priority to the filing date of the '275 Application, and the earliest date to which it could be accorded priority is March 15, 2013, the filing date of U.S. Patent No. 9,064,764, to which it

claims priority. Nevertheless, each asserted reference is prior art under pre-AIA 35 U.S.C. §102¹ based on either priority date, as shown below:

Exhibit	Reference	Date(s)	Availability as Prior Art²
1006	Int'l Publication No. WO 2011/035188 A2 (Haddad188)	March 24, 2011 (published)	§§102(a), (b)*
1007	U.S. Patent Application Publication No. 2012/0033119 (Shinohara)	February 9, 2012 (published)	§§102(a), (b)*, (e)
1008 (certified translation Ex-1009)	Japanese Patent Application Publication No. 2011-119558 (Mori)	June 16, 2011 (published)	§§102(a), (b)*
1010	U.S. Patent No. 7,675,099 (Hwang)	March 9, 2010 (issued)	§§102(a), (b), (e)
1011	U.S. Patent No. 7,709,775 (Konno)	May 4, 2010 (issued)	§§102(a), (b), (e)

None of the foregoing references were substantively considered by the Examiner during prosecution. Shinohara, Mori, and Hwang were not of record during prosecution. Although Haddad188 and the patent publication that led to Konno (U.S. Patent Publication No. 2008/0142686) were cited in an IDS during

¹ Because both priority dates are before March 16, 2013, pre-AIA statutes apply. *See* MPEP §2159.01.

² “*” Indicates additional prior art status based on March 15, 2013 priority date.

prosecution, the Examiner did not rely on either to reject any claims and thus did not meaningfully address them. Accordingly, the Board should not deny institution under §325(d) and *Advanced Bionics, LLC v. Med-El Elektromedizinische Geräte GmbH*, IPR2019-01469, Paper 6 at 8 (P.T.A.B. Feb. 13, 2020) (precedential).

In applying *Advanced Bionics*, the Board considers the “*Becton, Dickinson*” factors, *Becton, Dickinson & Co. v. B. Braun Melsungen AG*, IPR2017-01586, Paper 8 (P.T.A.B. Dec. 15, 2017) (precedential as to §III.C.5, first paragraph). “[I]f the record of the Office’s previous consideration of the art is not well developed or silent, then a petitioner may show the Office erred by overlooking something persuasive.” *Advanced Bionics*, IPR2019-01469 at 10. “An example of a material error may include misapprehending or overlooking specific teachings of the relevant prior art where those teachings impact patentability of the challenged claims.” *Id.* at 8, n.9.

Here, to the extent that the disclosures of Konno and Haddad¹⁸⁸ were before the Office during prosecution, the Examiner materially erred by overlooking or not appreciating their relevance to the challenged claims, as described herein. *See STMicroelectronics, Inc. v. Trustees of Purdue Univ.*, IPR2022-00309, Paper 14 at 12-13 (P.T.A.B. July 6, 2022) (finding that petitioner demonstrated examiner erred by not appreciating that IDS reference disclosed features recited in the challenged claims).

IV. OVERVIEW OF THE '599 PATENT

The '599 patent relates to elements for trapping light within image sensor pixels, and purportedly provides for “enhanced light detection properties.” '599 patent, 6:12-19. During prosecution, the applicant stated that the '599 patent's claims are directed towards the embodiment of Figure 6, shown below. Ex-1002, 92 (“Applicants elect the species 6 corresponding to FIG. 6 of Applicants' specification”). As shown below, this embodiment is a light sensitive pixel which uses a frontside *reflective layer*, in which an aperture is formed, as well as *backside* and *peripheral* light trapping materials to reflect light impinging thereupon from inside the pixel back into the pixel—thus purportedly improving efficiency and reducing cross-talk (interference) between pixel elements. *E.g.*, '599 patent, 11:64-12:3, 12:25-31, 6:28-34.

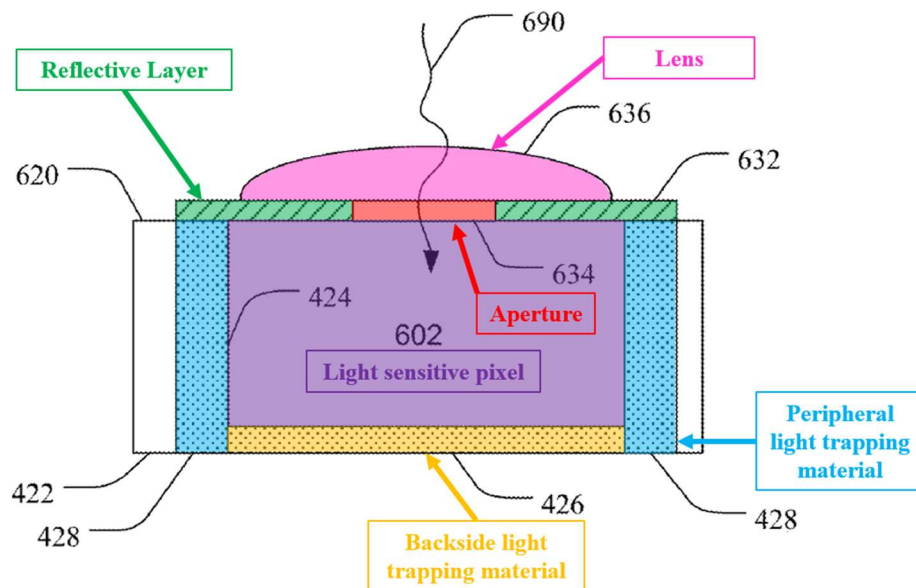


Fig. 6

'599 Patent, Fig. 6 (annotated); Ex-1003, ¶¶42-49.

V. LEVEL OF ORDINARY SKILL

A person of ordinary skill in the art (“POSITA”) as of March 2012 (as well as March 15, 2013) would have had a Bachelor’s degree in engineering, physics, or a related or equivalent field, and two or more years of experience researching, developing, designing, and/or evaluating image sensors using photonics. Ex-1003, ¶¶55-57. A person with less or different education but more relevant practical experience, or vice versa, may also meet this standard. *Id.*

VI. CLAIM CONSTRUCTION

For purposes of this petition, Petitioner does not believe that any specialized claim constructions are necessary. However, in the Related Case the parties have proposed constructions for certain terms, which are addressed as relevant below. *See* Ex-1012-1015.³

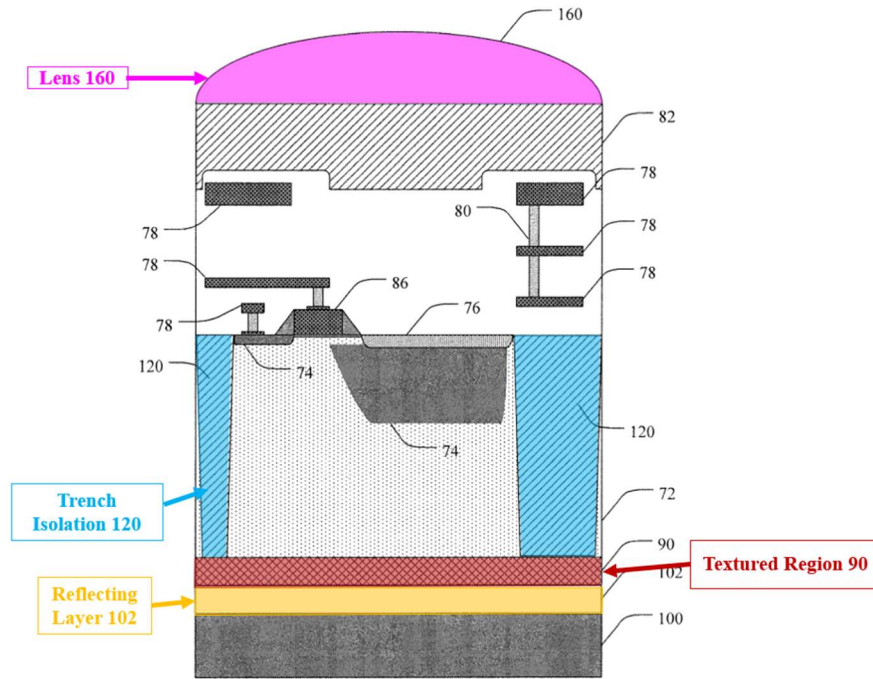
³ Petitioner notes that it raised in the Related Case contentions that certain claim terms are indefinite. For purposes of this proceeding, Petitioner adopts Patent Owner’s position that such terms are not indefinite.

VII. APPLICATION OF PRIOR ART TO THE CHALLENGED CLAIMS

A. Ground 1: Claims 19-20, 26-32, and 34-36 Are Obvious Based on Haddad188

1. Overview of Haddad188

Haddad188 (Ex-1006) is directed to an optoelectronic device, i.e., a photosensitive device. Haddad188, 1:24-30. Haddad188's Figure 16 "is a schematic view of a photosensitive pixel device," Haddad188, 4:21, and depicts, *inter alia*, a lens 160, trench isolation 120, and "[a] textured region 90 and a reflecting layer 102 ... coupled to the semiconductor substrate 72 opposite the lens to provide diffusive scattering and reflection of the incident electromagnetic radiation that passes through the semiconductor substrate." Haddad188, 25:5-9. Haddad188 also describes that "[a]n aperture 164 formed in a metal or other reflective material layer 166 [(not shown)] can increase the effectiveness of the optical cavity." Haddad188, 25:9-11.



Haddad188, Fig. 16 (annotated). Ex-1003, ¶¶60-62.

2. Claim 19

a. 19[pre]: “A light trapping device, comprising:”

Haddad188 teaches or suggests the preamble. Ex-1003, ¶¶63-65.

Haddad188 discloses “a front side illuminated (FSI) imager,” *see, e.g.*, Haddad188, Fig. 16, otherwise referred to as a “photosensitive pixel device,” *id.*, 25:4-5, 4:21-22. This imager includes various light trapping features in the form of a “reflecting layer 102” to provide “reflection of the incident electromagnetic radiation,” *id.*, 25:6-9, a “trench isolation 120” which is configured to reflect electromagnetic radiation, and a “reflective material layer 166” which “can increase

the effectiveness of the optical cavity,”⁴ *id.*, 25:9-11. These reflective layers allow Haddad188’s imager to trap light by reflecting light back into the pixel. Accordingly, Haddad188’s imager constitutes a *light trapping device*. Ex-1003, ¶¶63-65.

- b. 19[a]: “at least one light sensitive pixel having a light incident surface, a backside surface opposite the light incident surface, and a peripheral sidewall extending at least partially around the pixel periphery;”**

Haddad188’s imager includes *at least one light sensitive pixel*. Haddad188’s Figure 16 “is a schematic view of a photosensitive pixel device” which includes a photodiode formed in the semiconductor substrate 72. Haddad188, 22:9-20, 4:21-22, 25:4-11; Ex-1003, ¶¶66-72.

Haddad188’s pixel further includes *a light incident surface* and *a backside surface opposite the light incident surface*, as illustrated below:

⁴ The reflective material layer 166 is not shown in Figure 16 of Haddad188. Ex-1003, n.3. However, Haddad188 describes those elements as part of the front side illuminated imager of Figure 16. Ex-1003, n.3, ¶¶82-91. *See* Haddad188, 25:4-11.

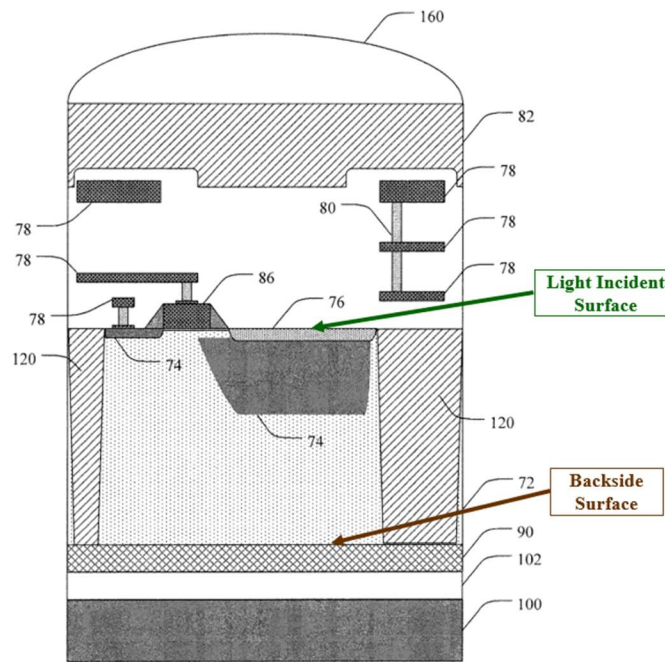


FIG. 16

Haddad188, Fig. 16 (annotated); Ex-1003, ¶68.

Light passes through the lens 160, through an aperture 164 (not shown), and through the top surface of the semiconductor substrate 72. *See* Haddad188, 25:4-11; Ex-1003, ¶69. A reflecting layer 102 is coupled to the bottom surface of the semiconductor substrate 72. *See* Haddad188, 25:6-9; Ex-1003, ¶69. Accordingly, the top surface of the semiconductor substrate 72 is a *light incident surface* and bottom surface of the semiconductor substrate 72 is a *backside surface opposite the light incident surface*. Ex-1003, ¶69.

Finally, each pixel includes a *peripheral sidewall* where the semiconductor substrate 72 meets trench isolation 120 (i.e., the side wall of trench isolation 120), as shown below:

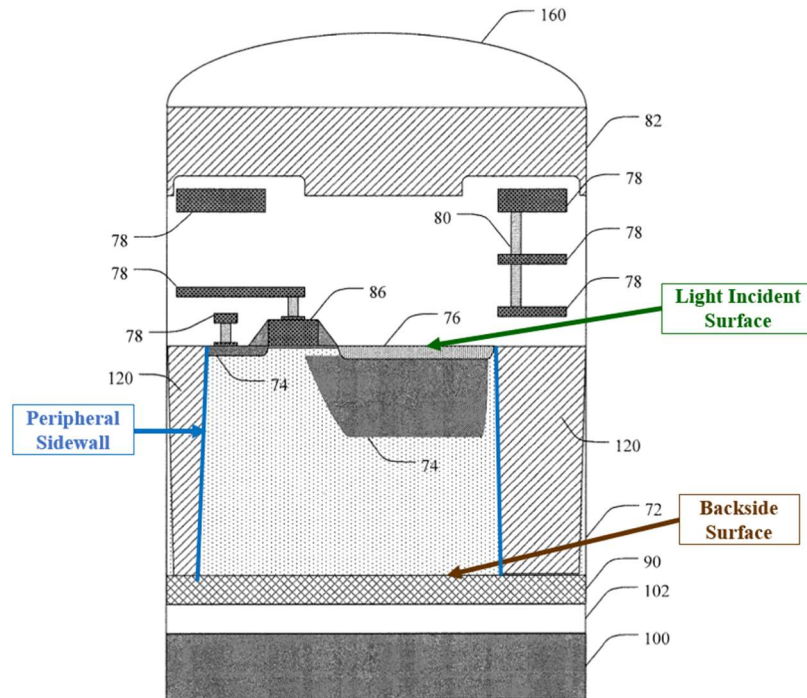


FIG. 16

Haddad188, Fig. 16 (annotated); Ex-1003, ¶70. While Haddad188 does not explicitly describe the function of the trench isolation in Haddad188’s description of Figure 16, elsewhere Haddad188 explains, “[t]rench isolation elements can maintain pixel to pixel uniformity by reducing optical and electrical crosstalk.” Haddad188, 22:23-24. Ex-1003, ¶71.

As shown above, Haddad188’s peripheral sidewall *extends at least partially around the pixel periphery*. Ex-1003, ¶72. This is consistent with the role of the trench isolation 120, e.g., reducing optical and electrical crosstalk. Ex-1003, ¶72. POSITAs would understand that the more that trench isolation 120 extends around

the periphery, the more the trench isolation will reduce optical and electrical crosstalk. Ex-1003, ¶¶71-72.

c. 19[b]: “a backside light trapping material at least partially covering the backside surface;”

Haddad188’s imager includes a “reflecting layer 102” which is “coupled to the semiconductor substrate 72 opposite the lens” and constitutes *a backside light trapping material at least partially covering the backside surface*. Haddad188, 25:6-7; Ex-1003, ¶¶73-75. This reflecting layer 102 constitutes a *backside light trapping material* because it “reflect[s] ... the incident electromagnetic radiation that passes through the semiconductor substrate.” *Id.*, 25:6-9; *see also id.*, 20:20-23; Ex-1003, ¶74.⁵ And as shown below, this reflecting layer 102 *at least partially covers the backside surface*:

⁵ All emphasis added except where otherwise noted.

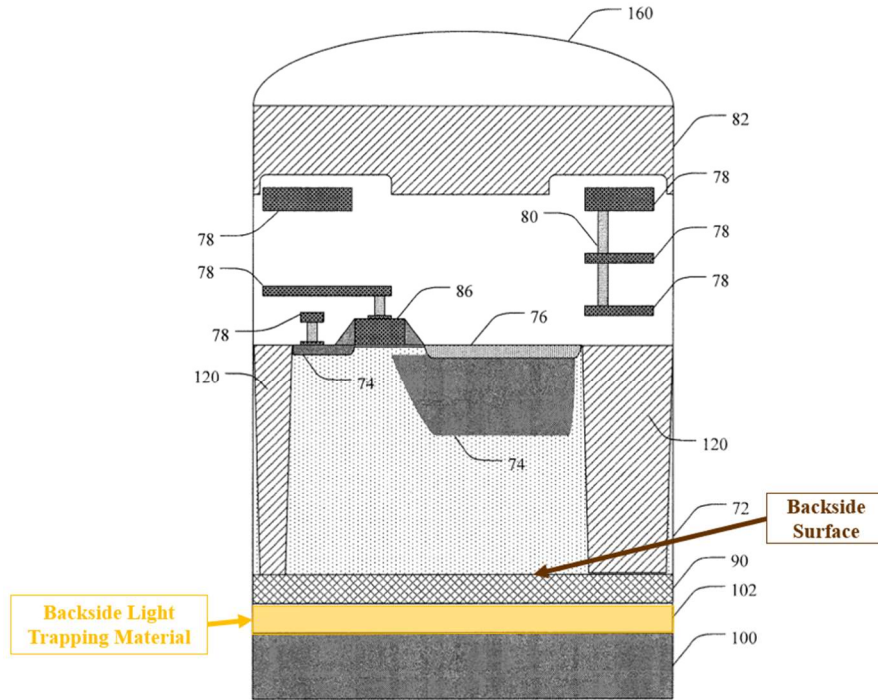


FIG. 16

Haddad188, Fig. 16 (annotated); Ex-1003, ¶75.

d. 19[c]: “a peripheral light trapping material substantially covering the peripheral sidewall;”

Haddad188’s imager includes *a peripheral light trapping material*, i.e., “trench isolation 120,” which “can be configured to reflect incident electromagnetic radiation until it is absorbed,” and thus trap light. *Id.*, 22:27-30; Ex-1003, ¶¶76-78; *see also* Haddad188 24:7-8. As shown below, the material comprising trench isolation 120 *substantially cover[s] the peripheral sidewall*:

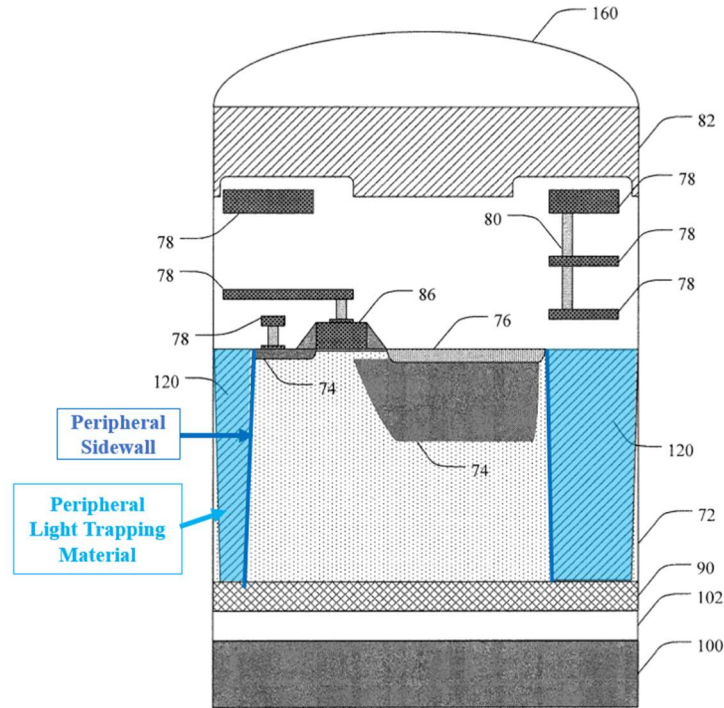


FIG. 16

Haddad188, Fig. 16 (annotated); Ex-1003, ¶78.

e. 19[d]: “a textured region positioned to interact with light incident thereon to increase quantum efficiency of the device; and”

Haddad188 teaches or suggests this limitation. Ex-1003, ¶¶79-81. Haddad188's imager includes a "textured region 90 and a reflecting layer 102 [that] are coupled to the semiconductor substrate 72 opposite the lens to provide diffusive scattering ... of the incident electromagnetic radiation." Haddad188, 25:6-9. Elsewhere, Haddad188 explains that "the textured region can function to diffuse electromagnetic radiation, to redirect electromagnetic radiation, and to absorb electromagnetic radiation, thus increasing the quantum efficiency of the device." *Id.*, 14:29-31; *see also id.*, 15:14-19, Ex-1003, ¶80.

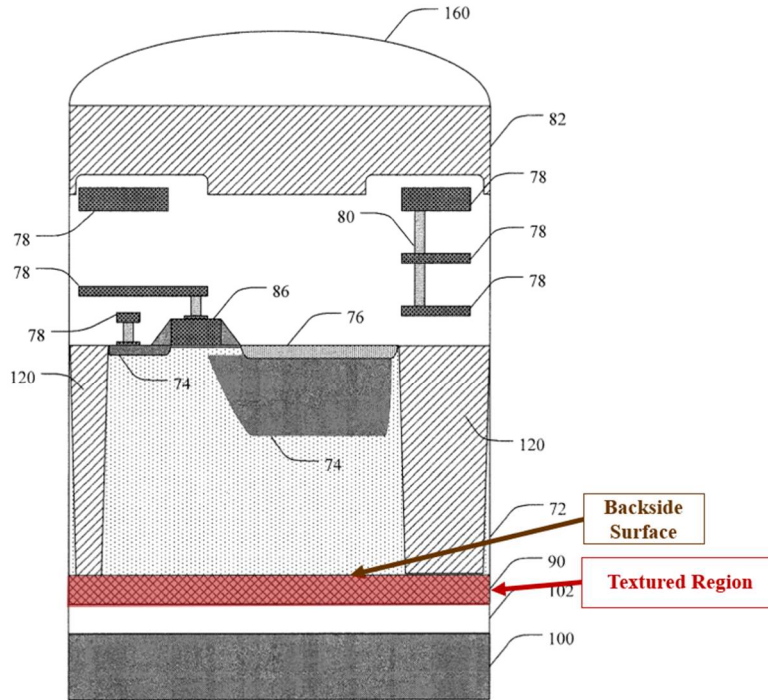


FIG. 16

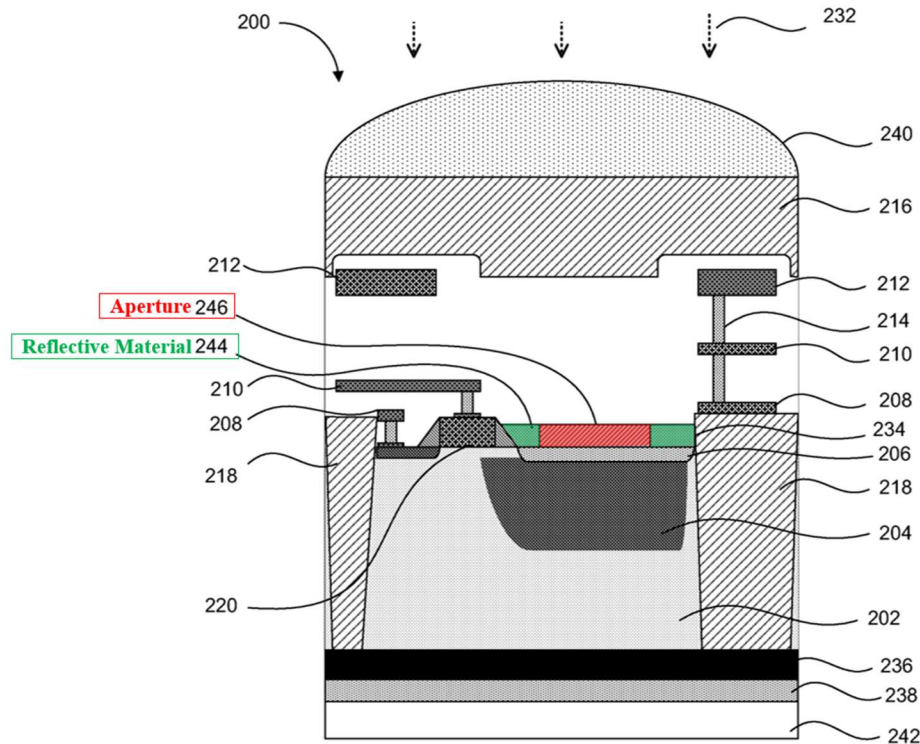
Haddad188, Fig. 16 (annotated); Ex-1003, ¶80.

f. 19[e]: “a reflective layer coupled to the light incident side and having an aperture to allow entry of light into the pixel;”

Haddad188 discloses *a reflective layer*, i.e., “a metal or other reflective material layer 166.” Haddad188, 25:9-10; *see also* Ex-1003, ¶¶82-88. This reflective material layer 166 *has an aperture to allow entry of light into the pixel*. Haddad188, 25:9-10 (“An aperture 164 formed in a metal or other reflective material layer 166 can increase the effectiveness of the optical cavity.”); *see also id.*, 25:10-11; Ex-1003, ¶¶82-88.

While Haddad188’s reflective material layer 166 is discussed in the text of the specification, it is not illustrated in Haddad188’s figures. Ex-1003, ¶85. However,

the '004 Application (Ex-1027), which is the provisional application that led to Haddad188 and which Haddad188 incorporates by reference, Haddad188, 1:4-8, depicts an analogous reflective material 244 and aperture 246. '004 Application, 9.



'004 Application, Fig. 10 (annotated); Ex-1003, ¶85.

POSITAs would understand that Haddad188's reflective material layer 166 and aperture 164 would be similarly located in the pixel device of Figure 16, as illustrated in the modified figure below, in order to allow lens 160 to focus electromagnetic radiation through the aperture and into the doped regions—i.e. *to allow entry of light into the pixel*—and in order to allow light from inside the pixel to reflect off of the reflective material layer 166 back into the pixel, thereby increasing the effectiveness of the optical cavity. Ex-1003, ¶86; Haddad188, 25:10-

11. Furthermore, as shown below, the reflective material layer 166 is *coupled to the light incident side*.

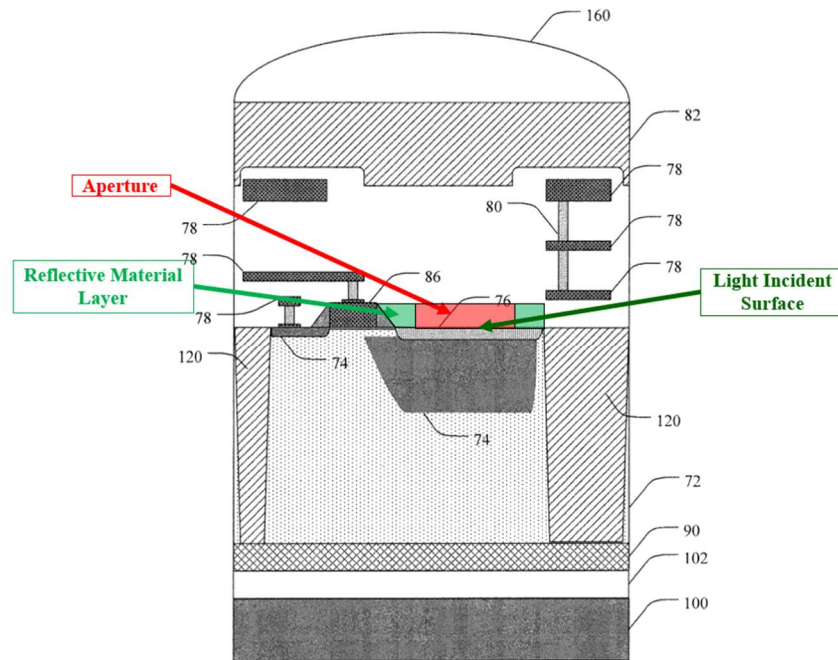


FIG. 16

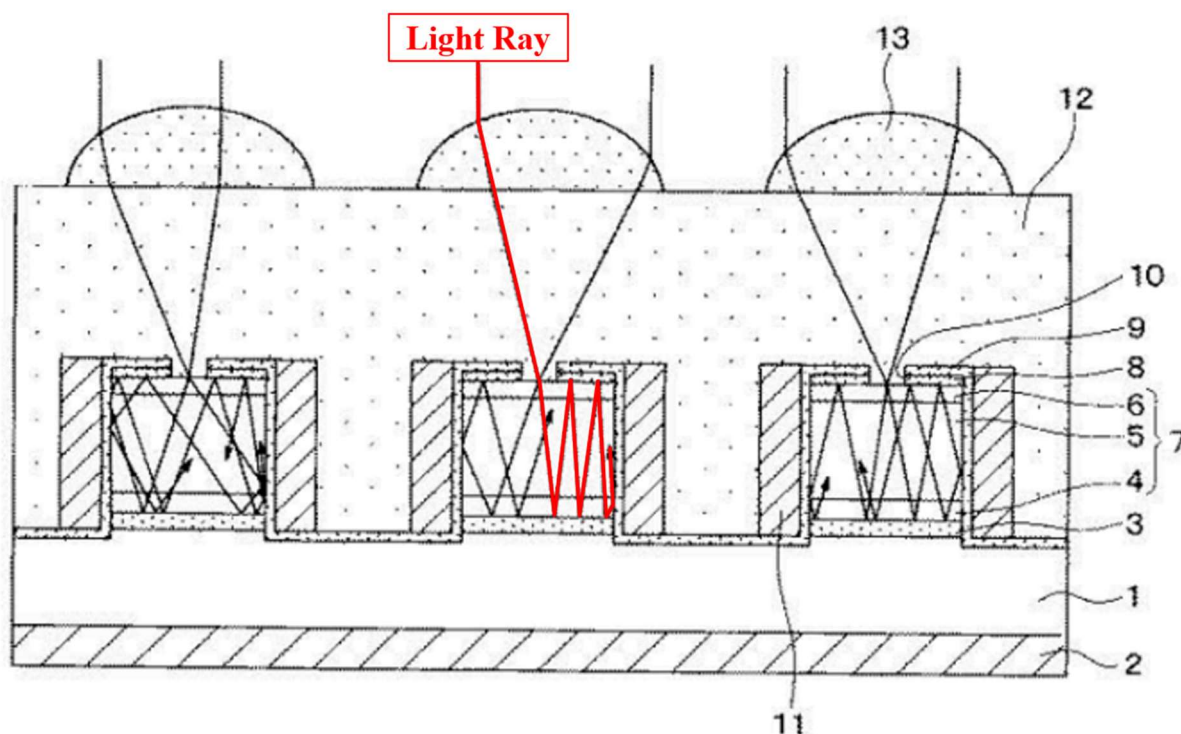
Haddad188, Fig. 16 (modified); Ex-1003, ¶86. In particular, the '004 Application's disclosure with respect to its Figure 10 is substantially similar to Haddad188's disclosures with respect to its Figure 16. Ex-1003, ¶¶87-88 (describing similarities).

g. 19[f]: “wherein the reflective layer is operable to reflect at least a portion of light impinging thereupon from inside the pixel back into the pixel back into the pixel.”

Haddad188's reflective material layer 166 (*i.e., reflective layer*) is operable to reflect at least a portion of light impinging thereupon from inside the pixel back into the pixel back into the pixel. See Ex-1003, ¶¶89-91. Haddad188's Figure 16

embodiment includes various reflective layers, such as a backside “reflecting layer 102”, a frontside “reflective material layer 166” on the light incident surface, and peripheral “trench isolation 120” which is also reflective. Ex-1003, ¶¶90. Haddad188’s reflective layers “maintain the electromagnetic radiation in the semiconductor substrate,” by “reflect[ing] incident light until it is absorbed.” *See, e.g.,* Haddad188, 2:29-31, 22:22-29, 20:19-25; Ex-1003, ¶¶90-91.

POSITAs would understand that Haddad188’s design, including reflective frontside, backside, and side surfaces is operable to reflect at least a portion of light multiple times off of the reflective material layer 166 (e.g., *back into the pixel back into the pixel*). Ex-1003, ¶91. Such reflection was well-known in the art, as illustrated for example in the below figure from Yamada (Ex-1029):



Yamada, Fig. 1 (annotated) (showing light ray reflected by first reflective film 3, second reflective film 8, and third reflective film 11); Ex-1003, ¶91.

3. Claim 20: “The device of claim 19, wherein at least one of the backside light trapping material and the peripheral light trapping material reflects light incident thereon back into the pixel.”

Haddad188’s *backside light trapping material* (Haddad188’s reflecting layer 102) *reflects light incident thereon back into the pixel*, i.e., provides “reflection of the incident electromagnetic radiation that passes through the semiconductor substrate.” Haddad188, 25:6-9; Ex-1003, ¶¶92-94; *see also* Haddad188, 20:19-22 (indicating function of reflecting layer is “to reflect electromagnetic radiation back into the device”).

Furthermore, Haddad188’s *peripheral light trapping material* (trench isolation 120) *reflects light incident thereon back into the pixel*, i.e., it “can be configured to reflect incident electromagnetic radiation, in some cases until it is absorbed.” Haddad188, 24:7-9; Ex-1003, ¶¶92, 94. POSITAs would understand that for Haddad188’s trench isolation to reflect incident electromagnetic radiation until it is absorbed, the trench isolation would have to reflect the electromagnetic radiation back into the pixel. Ex-1003, ¶94.

4. Claim 26: The device of claim 19, wherein the peripheral sidewall extends completely around the pixel periphery.

Haddad188's trench isolation is used to "maintain pixel to pixel uniformity by reducing optical and electrical crosstalk," i.e., to ensure that light and charge cannot move from one pixel to the next. Haddad188, 22:23-24; Ex-1003, ¶96. POSITAs would understand that the greater the coverage, the more the optical and electrical crosstalk could be reduced. Ex-1003, ¶96. Accordingly, it would be obvious to POSITAs to make the trench isolation extend completely around the pixel periphery to achieve Haddad188's stated goal of "maintain[ing] pixel to pixel uniformity by reducing optical and electrical crosstalk." Haddad188, 22:23-24; Ex-1003, ¶96.

This was a well-known technique at the time of the alleged invention. Ex-1003, ¶97. For example, Hwang (Ex-1010) discloses pixels comprising a *peripheral sidewall extending completely around the pixel periphery*, as shown below:

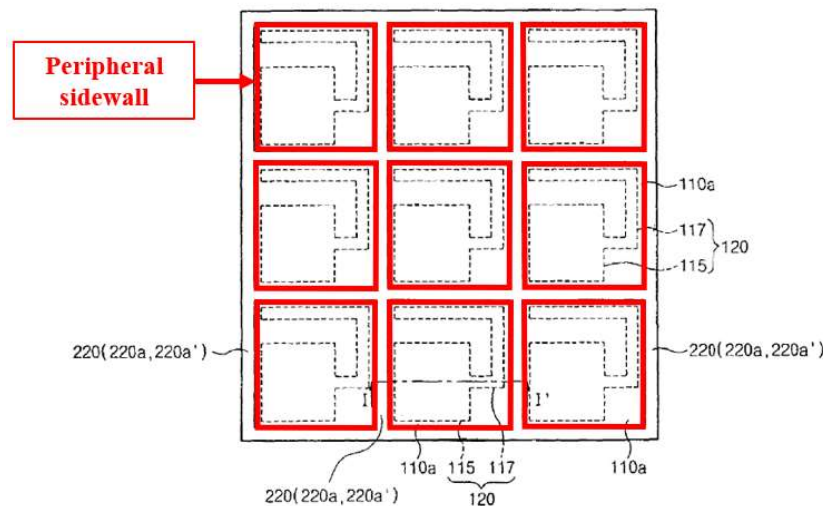


Fig. 1

Hwang, Fig. 1 (annotated); Ex-1003, ¶97; *see also* Hwang, 6:15-17, 10:23-27 (“In other words, the sidewall multi-layered reflection layer 220 minimizes incidence of the light incident on a photodiode 145 that it encloses being incident on other pixels.”).

Yamada (Ex-1029) similarly discloses that each of its embodiments “is configured such that the entire side surfaces of the PIN photodiode 7 is covered by the third reflective films 11,” i.e., peripheral light trapping material. Yamada, [0056]; Ex-1003, ¶98; *see also* Yamada, [0036].

5. Claim 27: “The device of claim 19, wherein the peripheral sidewall extends from the light incident surface to the backside surface.”

Haddad188 shows the *peripheral sidewall* (trench sidewall) *extend[ing] from the light incident surface to the backside surface*.

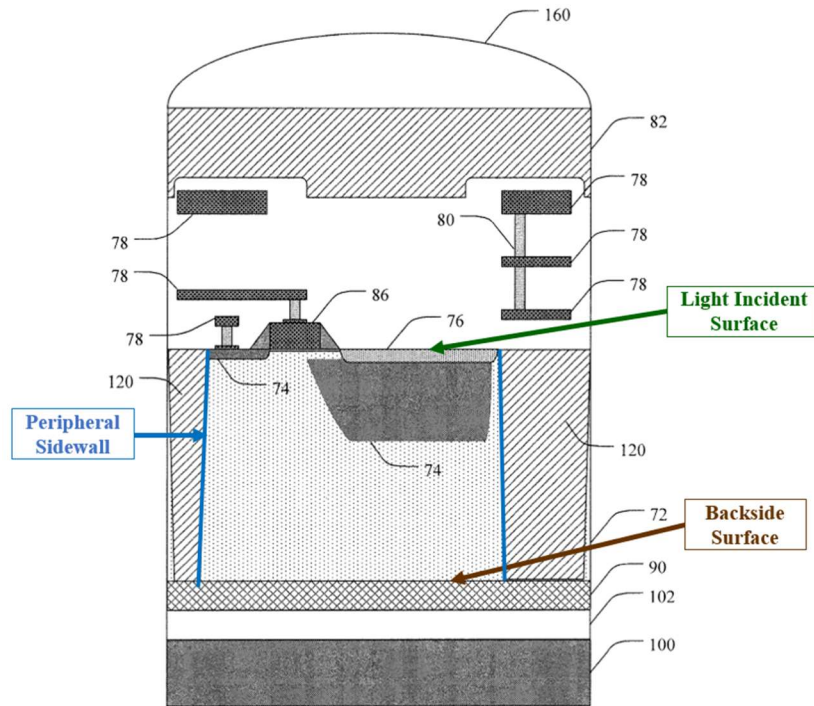


FIG. 16

Haddad188, Fig. 16 (annotated); Ex-1003, ¶¶100-101; *see also* Haddad188, 22:24-25.

6. **Claim 28:** “The device of claim 19, wherein said aperture has an effective surface area of less than about 90% of total area of the incident light surface.”

Although Haddad188 does not expressly specify its aperture’s effective surface area, it would have been obvious to form the aperture to have *an effective surface area of less than about 90% of total area of the incident light surface*. Ex-1003, ¶¶102-111.

As illustrated below, Haddad188’s imager is front-side illuminated and its light incident surface is covered by circuitry, including electrical transfer element 86

and metal regions 78, Haddad188, 22:21-23, which limits the amount of effective surface area available for incident light to enter the pixel, *id.*, 9:3-8.

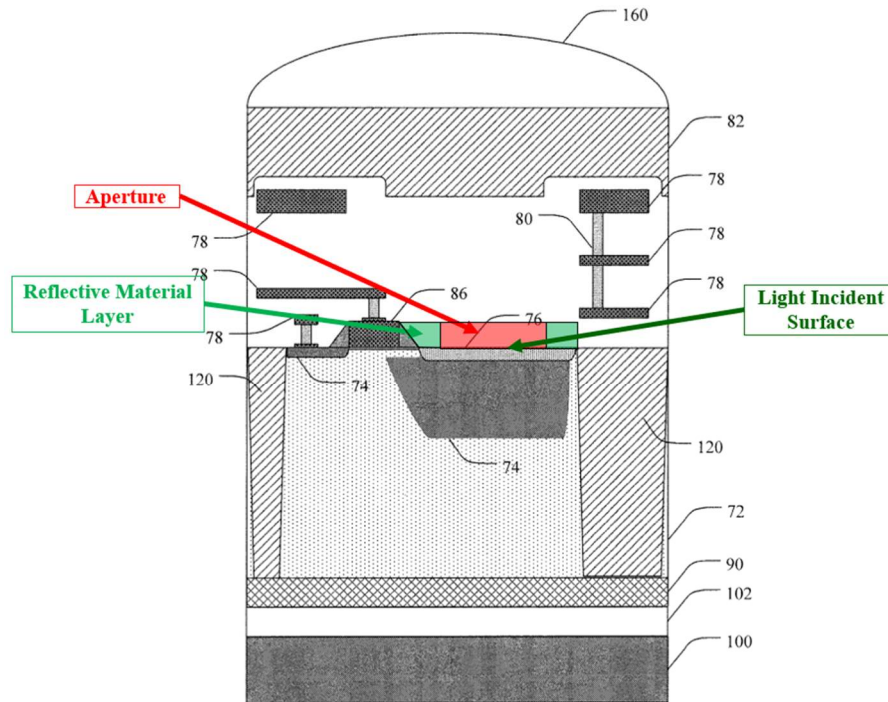


FIG. 16

Id., Fig. 16 (modified); Ex-1003, ¶¶103-104.

Haddad188's aperture is formed in a "reflective material layer," which "increase[s] the effectiveness of the optical cavity." Haddad188, 25:9-10. POSITAs would understand that the reflective material layer increases effectiveness by reflecting incident light back into the pixel to be further absorbed. Ex-1003, ¶105. Increasing the size of the aperture would allow more light to be collected, but if the aperture is too large, incident light will not be reflected back into the pixel but rather will escape through the aperture. Ex-1003, ¶105.

As of the time of the alleged invention, similar imagers had balanced the same competing considerations and implemented apertures with *an effective surface area of less than about 90% of total area of the incident light surface*. Ex-1003, ¶106. For example, Ex-1016 (“Kim”) discloses photodiodes containing an aperture (*i.e.*, opening 107) formed of reflective films 106 that reflects light back into the photodiodes, and discloses that “openings 107 can occupy between 70 to 90% of the uppermost surface area of photodiodes 102,” *i.e.*, the *incident light surface*. Ex-1003, ¶106. Kim, [0015]; *see also id.*, [0018] (“[l]ight 105 reflected from photodiodes 102 can return to photodiodes 102 after being reflected by reflective films 106”).

As illustrated below, Konno (Ex-1011) similarly discloses a photo-detector 101 comprising a reflecting layer 121 with a light entrance window 128 (*i.e.*, an *aperture*).

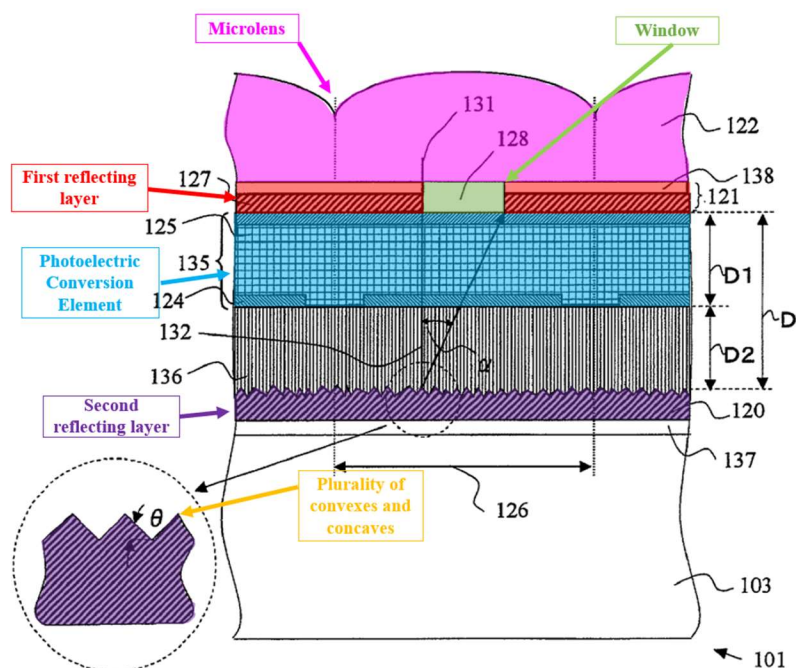


Fig.7

Konno, Fig. 7 (annotated); Ex-1003, ¶¶107-109. Konno's aperture has an effective surface area of less than about 90% of the total area of the incident light surface:

The width (diameter) of the light entrance window 128 [i.e., the width of the aperture] is appropriately determined on the basis of the relation to width 126 of the pixel [i.e., the width of the incident light surface], thickness of the transparent layer 136 to be explained later, and the like. For example, when the width 126 of pixel is 100 μm , it [i.e., the width of the aperture] is 20 μm .

Konno, 8:66-9:3; Ex-1003, ¶108-109.⁶

Thus, choosing an aperture area of less than about 90% would have been obvious, especially given that Haddad188 discloses a front-side imager device. Ex-1003, ¶110.

Nevertheless, designing the aperture to be less than about 90% of the incident light surface total surface area would be nothing more than a design choice, as evidenced by the '599 patent's failure to identify any particular benefit of doing so. *See* '599 patent, 12:9-14, Ex-1003, ¶111.

7. Claim 29: “The device of claim 19, further comprising a lens functionally coupled to the aperture and operable to focus incident light through the aperture and into the pixel.”

Haddad188 discloses a lens 160 *functionally coupled to the aperture and operable to focus incident light through the aperture and into the pixel*. Ex-1003, ¶¶112-114. Haddad188's “lens [160] focuses electromagnetic radiation through the aperture.” Haddad188, 25:10-11. As shown below, incident electromagnetic radiation must be focused through the aperture and into the pixel for it to be absorbed and converted into an electrical signal.

⁶ POSITAs would understand that the length of the aperture cannot be greater than the length of the pixel. Therefore, an aperture with Konno's dimensions must have an effective surface area of less than about 90% of total area of the incident light surface. Ex-1003, n.5.

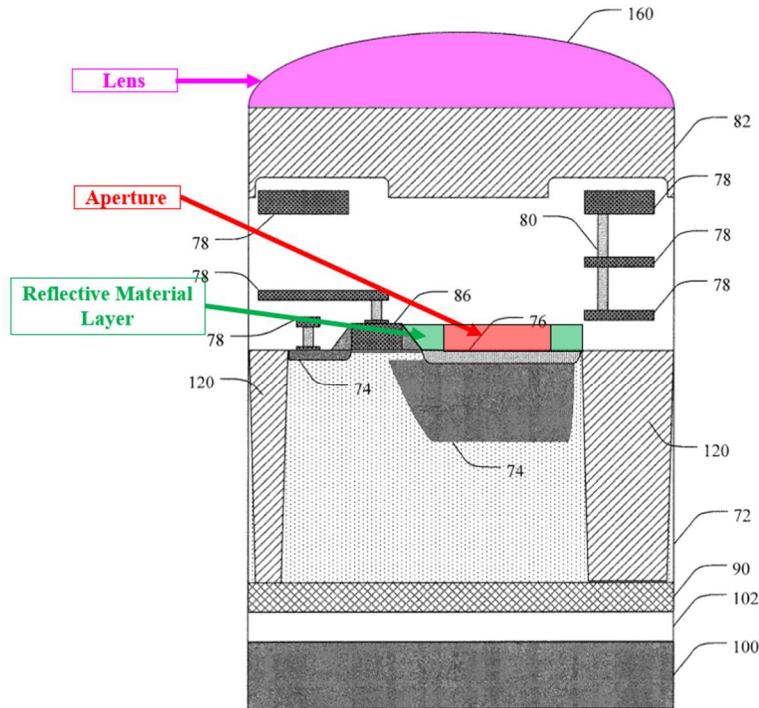


FIG. 16

Haddad188, Fig. 16 (modified); Ex-1003, ¶113.

8. **Claim 30:** “The device of claim 19, wherein at least one of the backside light trapping material and the peripheral light trapping material is a metal layer.”

Haddad188’s *backside light trapping material* (i.e., reflecting layer 102) “can be any reflective material that can be incorporated into such a device.” Haddad188, 23:24-25. Haddad188 specifically discloses “[n]onlimiting examples can include materials such as silver, aluminum, and the like,” i.e., a *metal layer*. Haddad188, 23:15-26; *see also* Ex-1003, ¶¶115-116.

9. Claim 31: “The device of claim 19, wherein said textured region comprises a textured film layer.”

Haddad188 teaches that its textured region can comprise *a textured film layer*, i.e., that “[t]he textured region can be formed by various techniques, including ... material deposition, and the like.” Haddad188, 15:20-29; Ex-1003, ¶¶117-120. Haddad188’s Figure 16 shows the textured region as a separate textured film layer:

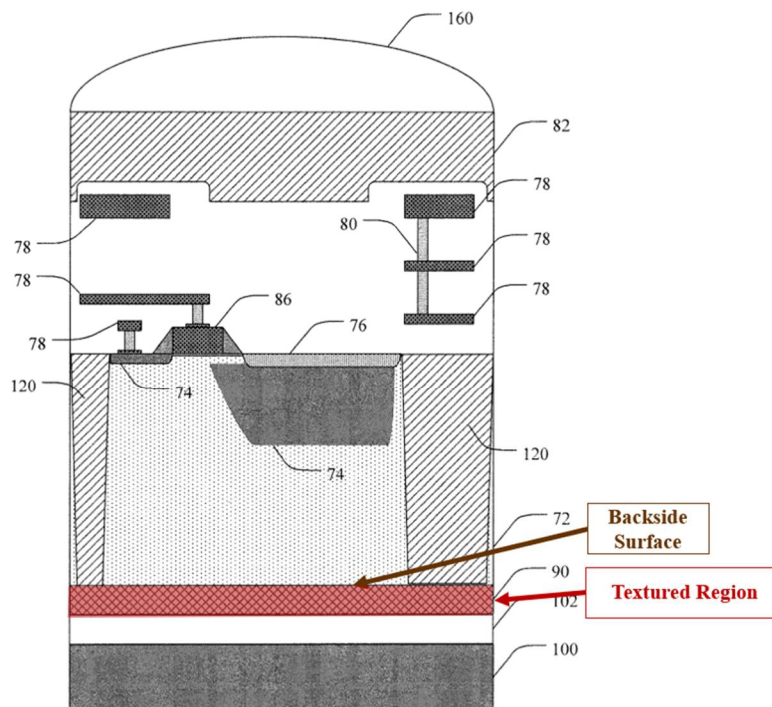


FIG. 16

Haddad188, Fig. 16 (annotated); Ex-1003, ¶118.

10. Claim 32: “The device of claim 31, wherein said textured film layer comprises any of silicon dioxide, silicon nitride, amorphous silicon, polysilicon, a metal and combinations thereof.”

Although Haddad188 does not expressly specify the material used for its textured region 90, it discloses that “[a] variety of semiconductor materials are

contemplated for use with [its] devices,” including “amorphous silicon (a-Si), microcrystalline silicon, multicrystalline silicon, and monocrystalline silicon.” Haddad188, 10:17-30. Haddad188 further discloses that its reflective layers can include metals. *See* Haddad188, 23:24-26. POSITAs, who are likely to already have extensive experience with amorphous silicon, polysilicon, or metal, would find it obvious to form the textured film layer out of these materials. POSITAs would understand that these materials are already being used in the manufacture of the device and that there are efficiencies that are gained in reusing the same materials, including, for example, costs, simplicity, ease of manufacturing, etc. Ex-1003, ¶¶121-122.

POSITAs would have expected success using these materials because, for example, Haddad188 separately discloses forming a textured region directly on the semiconductor substrate, *see, e.g.*, Haddad188, 3:2-5, which Haddad188 discusses being amorphous silicon or polysilicon. Ex-1003, ¶123. Further, all of these materials are compatible with Haddad188’s disclosure that the textured region 90 can be formed via, for example, “additional material deposition.” and such techniques have been widely used for many years prior. Haddad188, 15:20-22; Ex-1003, ¶¶123-124.

11. Claim 34: “The device of claim 19, wherein the backside light trapping material substantially covers the backside surface.”

As shown below, the *backside light trapping material* (i.e., the reflecting layer 102) *substantially covers the backside surface*, consistent with its role in reflecting incident electromagnetic radiation that passes through the semiconductor substrate. See, e.g., Haddad188, 25:6-9, 23:19-22, Ex-1003, ¶¶125-126.

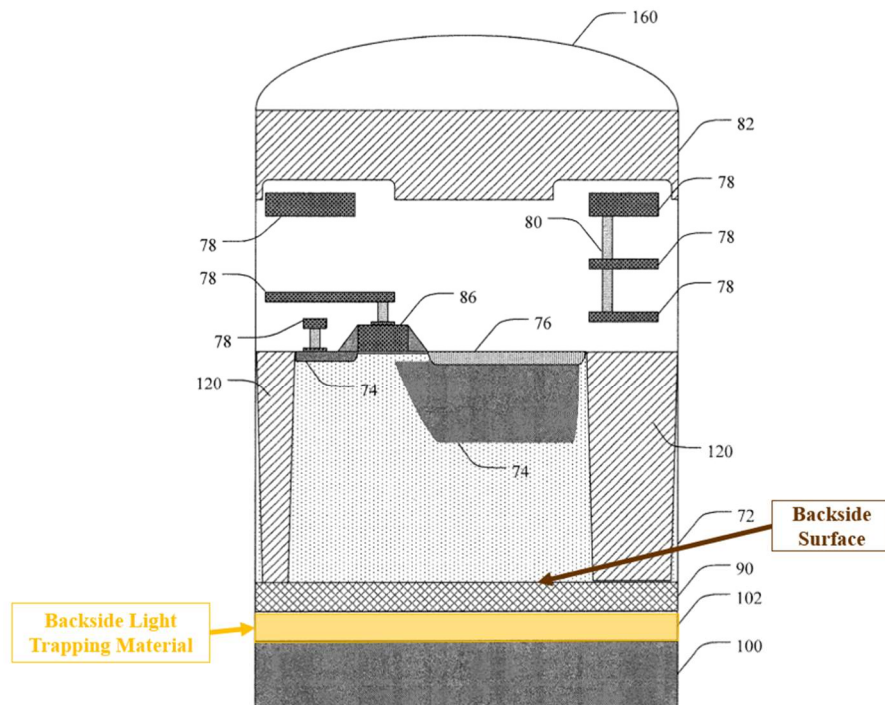


FIG. 16

Haddad188, Fig. 16 (annotated); Ex-1003, ¶126.

12. Claim 35: “The device of claim 19, wherein the backside light trapping material completely covers the backside surface.”

As shown below, the *backside light trapping material* (i.e., the reflecting layer 102) *completely covers the backside surface*, consistent with its role in reflecting incident electromagnetic radiation that passes through the semiconductor substrate,

and the fact that the Figure 16 embodiment is a front side illuminated imager. *See, e.g.,* Haddad188, 25:4-9, 23:19-22.

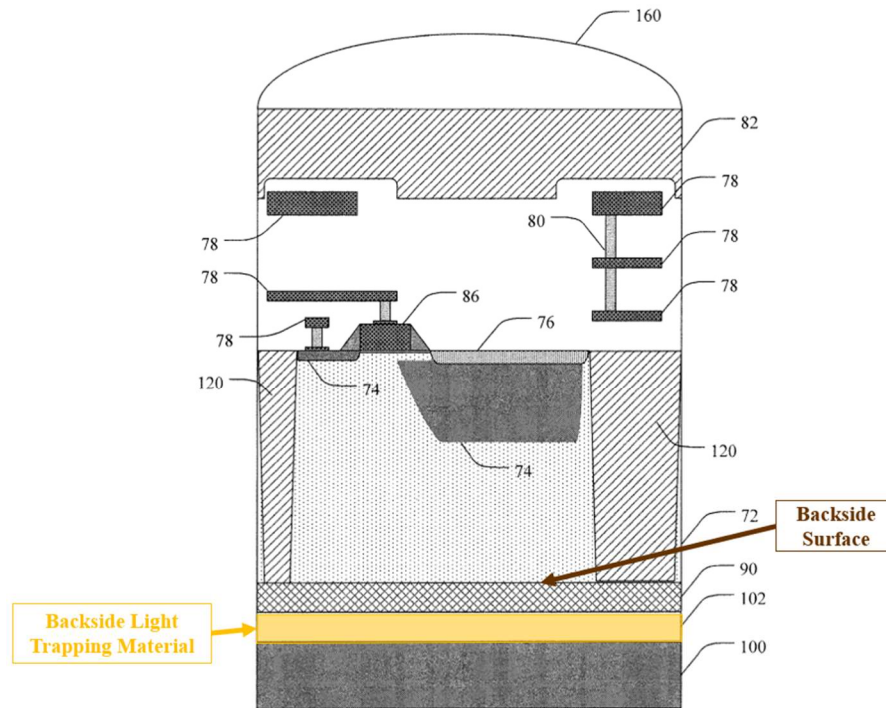


FIG. 16

Id., Fig. 16 (annotated); Ex-1003, ¶¶127-128.

13. **Claim 36:** “The device of claim 19, wherein said peripheral sidewall extends through the pixel substantially from the light incident surface to the backside surface.”

As shown below, the *peripheral sidewall* (i.e., trench sidewall) *extends through the pixel substantially from the light incident surface to the backside surface.*

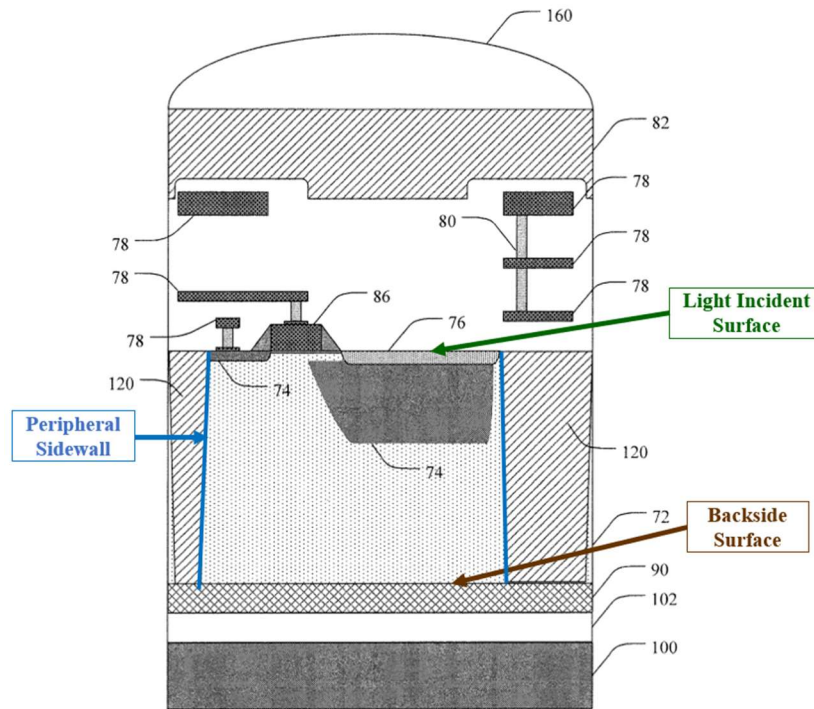


FIG. 16

Haddad188, Fig. 16 (annotated); Ex-1003, ¶¶129-130; *see also* Haddad188, 22:24-25 (“The trench isolation can be shallow (FIG. 7) or deep (FIG. 12) trench isolation.”).

B. Ground 2: Claim 33 Is Obvious Based on Haddad188 and Shinohara

1. Overview of Shinohara

Shinohara is directed to a “solid state imaging device,” including a number of pixels. Shinohara, Abstract. Like the ’599 patent, Shinohara describes “an element isolation region for isolating pixels from each other.” *Id.*, [0006]. Shinohara explains that selecting an insulating film 69 with a negative fixed charge, can enhance the operation of the device, as discussed in more detail below. *E.g., id.*, [0095].

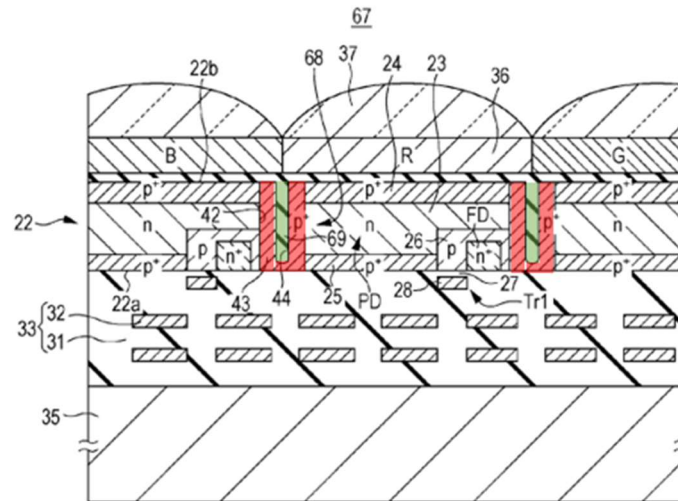
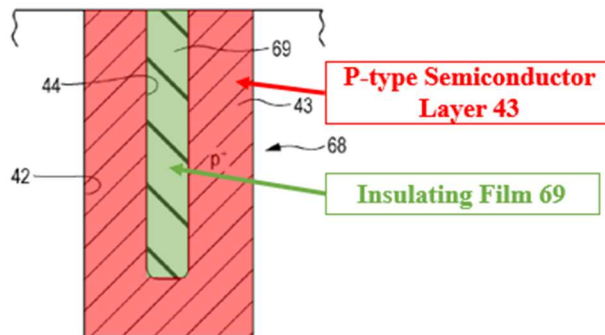


FIG. 9B



Id., Fig. 9 (annotated); Ex-1003, ¶¶131-133.

2. **Claim 33: “The device of claim 19, wherein the peripheral light trapping material comprises any of aluminum oxide and hafnium oxide.”**

Haddad188 in view of Shinohara teaches or suggests this limitation. Ex-1003, ¶¶134-138.

Shinohara discloses a *peripheral light trapping material that comprises any of aluminum oxide or hafnium oxide*. Ex-1003, ¶135. Specifically, Shinohara describes “an element isolation region 68 for isolating pixels” which is formed with

suppressed.” *Id.*, [0095]. Shinohara discloses examples of negative fixed charge materials such as “hafnium dioxide (HfO_2)” or “dialuminum trioxide (Al_2O_3).” *Id.*, [0091]. *See also* ’599 Patent, 9:53-59 (using “aluminum oxide” and “ Al_2O_3 ” interchangeably), 10:47-48 (“Hafnium oxide, which has a refractive index of about 1.9”).⁷ Ex-1003, ¶136.

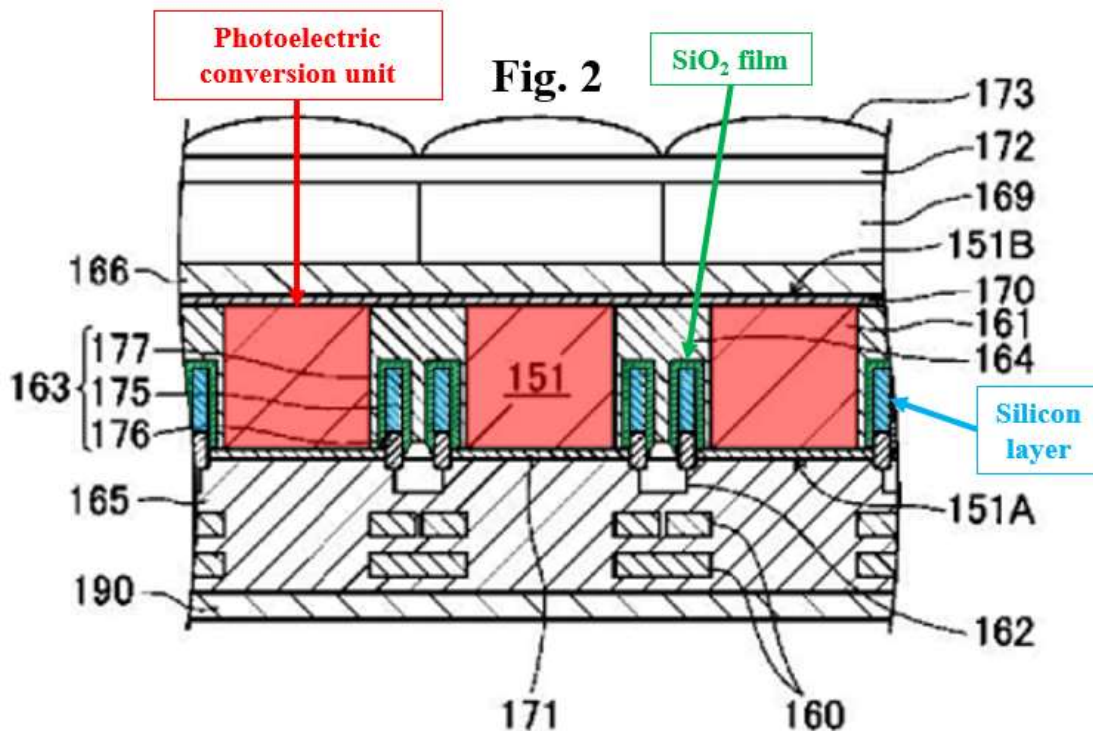
POSITAs would be motivated to use Shinohara’s isolation region 68—including either hafnium oxide or aluminum oxide—in place of Haddad188’s trench isolation 120 to limit dark current. Ex-1003, ¶137. Indeed, Haddad188 discloses that “[a] passivation layer can also be disposed on the photosensitive imager device to protect and/or reduce the dark current of the device.” Haddad188, 25:21-22; Ex-1003, ¶137. POSITAs would expect success doing so because Haddad188’s “trench isolation [120] can include various materials, including, without limitation, dielectric materials, reflective materials, conductive materials, light diffusing features, and the like.” Haddad188, 22:25-29; Ex-1003, ¶137. Furthermore, Shinohara’s isolation region 68 serves the same purpose as Haddad188’s trench isolation 120—reflecting light to prevent optical cross-talk. Shinohara [0094]; Ex-1003, ¶137.

⁷ POSITAs would recognize that “hafnium oxide” as used in the ’599 patent refers to HfO_2 given its stated refractive index of “about 1.9.” *See* Ex-1003, n.6.

C. Ground 3: Claims 1-14, 16-18, and 21-25 Are Obvious Based on Haddad188 and Mori

1. Overview of Mori

Mori is directed to a “solid-state imaging device,” i.e., an imager, having pixels separated by a “partition part” comprising silicon and silicon oxide layers. Mori, [0012]-[0013]. An exemplary embodiment is depicted below.



Mori, Fig. 2 (annotated); Ex-1003, ¶¶139-144. Figure 2 depicts three “[p]hotoelectric conversion units 161,” (i.e., pixels), Mori, [0022], and a multi-layered “partition part 163,” *id.*, [0023], (having a “silicon layer 175,” *id.*, [0028] and a “side SiO₂ film 177,” *id.*, [0030]) to reduce “color mixing [or ‘crosstalk’] due to obliquely incident light,” *id.*, [0027].

Mori teaches that this multi-layer Si/SiO₂ partition solves a problem in conventional imaging devices which use partitions “made of a light-reflective material such as tungsten.” Mori, [0005]. As Mori explains:

A single crystal epitaxial layer cannot easily be formed on the embedded member because metal and silicon have different lattice constants. ***Therefore, the silicon layer formed on the embedded member contains many crystal defects.*** As a result, the charge generated when dark increases, and the sensitivity of the solid-state imaging device decreases.

Mori, [0007]. That is, the crystal defects can cause what is known in the art as “dark current”—i.e., a “very small current when an electric charge (electron) [is] generated” when no light is incident on the photodiode (when the pixel should be “off”). Ex-1020, 1:25-28. Ex-1003, ¶142.

Mori therefore uses a Si/SiO₂ partition part, to reduce “crystal defects on the side surface of the groove for forming the partition part” and “charges generated when dark ... to achieve high sensitivity.” Mori, [0013].

Mori also discloses doping the SiO₂ film layer to further mitigate dark current stemming from crystal defects. Ex-1003, ¶¶143-144. As illustrated below, first, the side SiO₂ film 177 is “formed on the side surface of [a] partition groove 174.” Mori, [0036]. Next, “[i]n order to prevent charges generated when dark due to crystal defects in the partition groove 174 from flowing into the photoelectric conversion

unit 161, p-type impurities are preferably injected into the side walls of partition groove 174 after forming the side SiO₂ film 177.” Mori, [0036]. That is, the SiO₂ film 177 on the side walls is doped with p-type impurities, resulting in an excess of positively charged carriers (or “holes”). Ex-1003, ¶144. “Subsequently, a silicon layer 175 is formed in the partition groove 174,” to complete formation of the Si/SiO₂ partition. Mori, [0036].

Fig. 3(b)

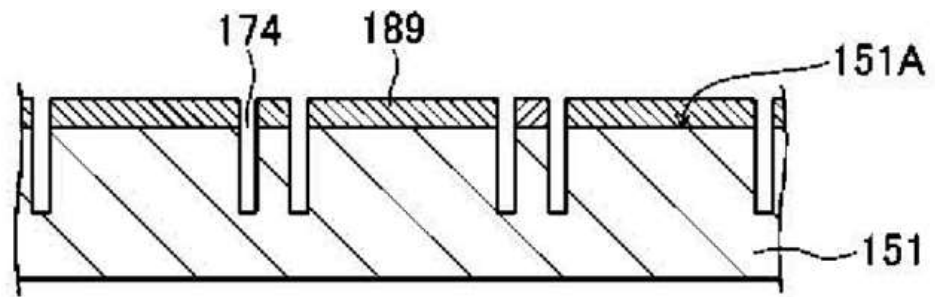
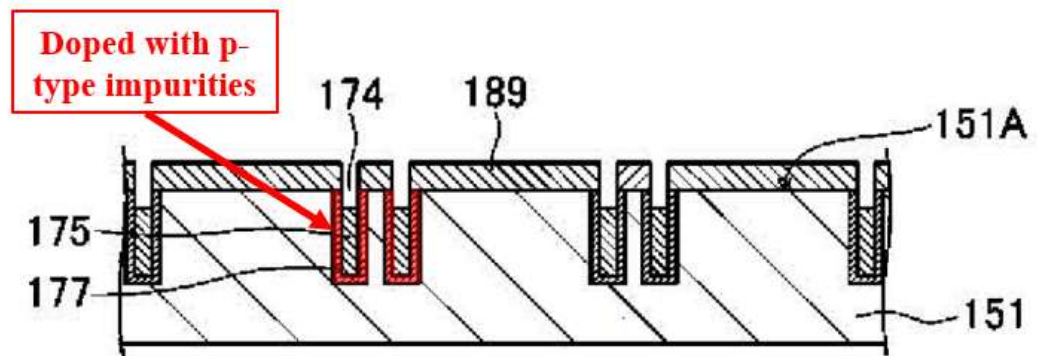


Fig. 3(c)



Mori, Figs. 3(b)-(c) (annotated); Ex-1003, ¶144.

2. Claim 1

a. Limitations 1[pre]-[b], [d]-[f]

Limitations 1[pre]-[b], [d]-[e] are identical to limitations 19[pre]-[b], [e]-[f],

respectively.⁸ As discussed in Ground 1, Haddad188 teaches or suggests these limitations. *Supra*, §VII.A.2, Ex-1003, ¶¶145-147, 156-157.

b. 1[c]: “a peripheral light trapping material substantially covering the peripheral sidewall, wherein said peripheral light trapping material is doped with a dopant to create a surface field; and”

This limitation is obvious based on Haddad188 in view of Mori. Ex-1003, ¶¶148-155.

Haddad188 teaches or suggests *a peripheral light trapping material substantially covering the peripheral sidewall* for the reasons discussed for Ground 1, claim 19[c] above. Ex-1003, ¶149.

Mori discloses a “partition part 163” that separates its pixels, and serves to reduce “color mixing [or ‘crosstalk’] due to obliquely incident light.” Mori, [0027]. Mori’s partition part 163 has a silicon layer (layer 175) “made of amorphous silicon or polycrystalline silicon,” *id.*, [0011], and a “side silicon oxide film [SiO₂ film 177] formed between the silicon layer and the semiconductor substrate” embedded in a semiconductor substrate, *id.*, [0013]. This configuration reduces “crystal defects on the side surface of the groove for forming the partition part” as well as “the charges generated when dark,” thereby increasing sensitivity. *Id.*, [0013], [0029]-[0030], Ex-

⁸ A listing of the challenged claims, including the labels for each limitation, is provided in the Claims Appendix at the end of this document.

1003, ¶151.

It would have been obvious to use an Si/SiO₂ isolation element like that of Mori in Haddad188's photosensitive pixel device (i.e., to serve as Haddad188's trench isolation element) to achieve Mori's stated benefit of reducing dark current and increasing sensitivity. Ex-1003, ¶152. POSITAs would have expected success doing so with predictable results. Ex-1003, ¶152; *see also* Suzunaga [0035]. In particular, Haddad188 teaches that its "[t]rench isolation can include dielectric materials, reflective materials, conductive materials, and combinations thereof, including textured regions and other light diffusing features." Haddad188, 24:5-7. Haddad188 further explains that "[t]hese trench isolation regions can be configured to reflect incident light until it is absorbed, thereby increase the effective absorption length of the device." *Id.*, 22:27-30.

It was well-known that layers of silicon and SiO₂, like those disclosed in Mori, could be used as reflectors, *see, e.g.*, Ex-1017, 163, 172 (explaining that Si/SiO₂ DBRs "yield high reflectivity"), 181 (explaining that Si and SiO₂ are "natural candidates" for omnidirectional reflectors.), and that the reflectivity of such reflectors could be increased by increasing the number of alternating layers of Si and SiO₂ in the isolation element, *see, e.g., id.* 170 ("DBR's reflectivity can be increased by increasing the number of reflector pairs...."); Ex-1003, ¶152. Indeed, Si/SiO₂ reflectors were commonly used as light trapping materials in similar imagers. *E.g.*,

Hwang, 10:48-55 (using silicon and silicon dioxide as alternating layers in its peripheral reflection layer). Accordingly, they would be well-suited for Haddad188's trench isolation 120. Ex-1003, ¶152.

Mori further teaches that “[i]n order to prevent charges generated when dark due to crystal defects ... p-type impurities are preferably injected into the side walls of partition groove 174 after forming the side SiO₂ film 177.” Mori, [0036]; Ex-1003, ¶153; *see also supra*, §VII.C.1 (Mori Overview). Accordingly, Mori teaches that its side SiO₂ film *is doped with a dopant to create a surface field* as set forth in this limitation. Ex-1003, ¶153.

The '599 patent does not explain how doping the peripheral light trapping material operates to create a surface field—its only disclosure relating to such doping is that:

[I]t can also be beneficial to dope the sidewalls to create a surface field that will improve electrical isolation between the pixels. In one aspect, it can also be beneficial to dope the low refractive index material of the Bragg-type reflectors to increase such electrical isolation.

'599 patent, 10:14-18; Ex-1003, ¶154. That is, the '599 patent teaches that doping in the same manner as in Mori increases electrical isolation via a surface field. Ex-1003, ¶154. Thus, Mori's doped SiO₂ film 177 along the side of its pixel (photoelectric conversion unit 161) would constitute a *peripheral light trapping material doped with a dopant to create a surface field* as contemplated by the limited

disclosure of the '599 patent. Ex-1003, ¶¶154-155.

Based on Mori's teaching, it would have been obvious to similarly dope the SiO₂ film as proposed above for use in Haddad188 to create a surface field. Doing so would help enhance Mori's stated benefit of reducing dark current. Ex-1003, ¶¶148-155.

3. Claims 2, 7-14, 16-18

These claims are obvious based on Haddad188 in view of Mori, Ex-1003, ¶¶158, 166-176. The additional limitations of claims 2, 7-14, 16-18 are identical to those of claims 20, 26-30, 19[d], 31-32, and 34-36, respectively (*i.e.*, claim 2 corresponds to claim 20, claim 7 corresponds to claim 26, claim 8 corresponds to claim 27, claim 9 corresponds to claim 28, claim 10 corresponds to claim 29, claim 11 corresponds to claim 30, claim 12 corresponds to claim 19[d], claim 13 corresponds to claim 31, claim 14 corresponds to claim 32, claim 16 corresponds to claim 34, claim 17 corresponds to claim 35, and claim 18 corresponds to claim 36). Haddad188 teaches or suggests these limitations for the reasons discussed for Ground 1 in Sections §§VII.A.2-VII.A.13.

4. Claim 3: "The device of claim 1, wherein said peripheral light trapping material has a refractive index of less than about 2.1."

This limitation is obvious based on Haddad188 in view of Mori. Ex-1003, ¶¶159-160. Using Mori's Si/SiO₂ films for Haddad188's trench isolation 120 would

satisfy this limitation, as it would entail using silicon dioxide in the peripheral light trapping material, which has a *refractive index of 1.46*. *Supra*, §VII.C.2 (claim 1[c]); Ex-1003, ¶¶160; Suzunaga, Table 1 (SiO₂ = 1.43-1.46); Hwang, 9:28-29; Ex-1017, 181.

- 5. Claim 4: “The device of claim 1, wherein said peripheral light trapping material includes a member selected from the group consisting of an oxide, a nitride, oxynitrides, a gas, at least a partial vacuum, and combinations thereof.”**

This limitation is obvious based on Haddad188 in view of Mori. Ex-1003, ¶161. Using Mori’s Si/SiO₂ films for Haddad188’s trench isolation 120 would satisfy this limitation, as it would entail using silicon dioxide—i.e., *an oxide*—in the peripheral light trapping material. *Supra*, §VII.C.2 (claim 1[c]); Ex-1003, ¶161.

- 6. Claim 5: “The device of claim 4, wherein said peripheral light trapping material is selected from the group consisting of silicon oxide, silicon nitride, silicon dioxide, and combinations thereof.”**

This limitation is obvious based on Haddad188 in view of Mori. Ex-1003, ¶162. Using Mori’s Si/SiO₂ films for Haddad188’s trench isolation 120 would satisfy this limitation, as it would entail using *silicon dioxide* in the peripheral light trapping material. *Supra*, §VII.C.2 (claim 1[c]); Ex-1003, ¶162.

- 7. Claim 6: “The device of claim 1, wherein the dopant is boron or antimony.”**

This limitation is obvious based on Haddad188 in view of Mori. Ex-1003, ¶¶163-165.

It would have been obvious in view of Mori to dope Haddad188's silicon dioxide layer with p-type impurities—i.e., a p-type dopant. *Supra*, §VII.C.2 (claim 1[c]); Ex-1003, ¶164. It further would be obvious to use boron as the p-type dopant, as boron is one of the most commonly used p-type dopants for Si-based systems. Ex-1003, ¶164. *E.g.*, Ex-1018, 27-28 (explaining silicon is commonly doped with Column-III-dopants (e.g., boron)). POSITAs would recognize that using boron as a p-type dopant for silicon-based systems is a known technique that would have yielded predictable results, particularly in light of boron's similar use as a p-type dopant in other similar light trapping devices. Ex-1003, ¶164. *E.g.*, Ex-1019, [0011] (“silicon substrate doped with a P-type dopant such as boron”). Furthermore, Haddad188 itself uses boron as a dopant. Haddad188, 18:5-7 (“non-limiting examples of dopant materials can include S, F, B, P, N, As, Se, Te, Ge, Ar, Ga, In, Sb, and combinations thereof”). Additionally, using boron would have been obvious to try, as POSITAs would have had a limited number of types of p-type dopants from which to choose. Ex-1003, ¶164.

8. Claims 21-25

These limitations are obvious based on Haddad188 in view of Mori. Ex-1003, ¶177-181. The additional limitations of claims 21-25 are identical to those of claims 3-5, 1[c], and 6, respectively (*i.e.*, claim 3 corresponds to claim 21, claim 4 corresponds to claim 22, claim 5 corresponds to claim 23, claim 1[c] corresponds to

claim 24, and claim 6 corresponds to claim 25). Haddad188 in view of Mori teaches or suggests these limitations for the reasons discussed above in this Ground 3, in Sections §§VII.C.4-VII.C.7.

D. Ground 4: Claim 15 Is Obvious Based on Haddad188, Mori, and Shinohara

1. Claim 15: “The device of claim 1, wherein the peripheral light trapping material comprises any of aluminum oxide and hafnium oxide.”

This limitation would have been obvious based on Haddad188 in view of Mori and Shinohara. Ex-1003, ¶¶182-186.

First, base claim 1 is obvious based on Haddad188 and Mori as discussed for Ground 3 above—i.e., as it would have been obvious to use Mori’s Si/SiO₂ films for Haddad188’s trench isolation 120 (*peripheral light trapping material*).

Second, as discussed for Ground 2 above, Shinohara discloses a *peripheral light trapping material that comprises any of aluminum oxide or hafnium oxide* and explains that such a *peripheral light trapping material* would help suppress the generation of dark current. *Supra*, §VII.B.2 (claim 33), Ex-1003 ¶¶182-184.

POSITAs would have been motivated to use either of Shinohara’s hafnium oxide or aluminum oxide in when forming an isolation element consistent with Mori’s teachings, to achieve the benefits described in Shinohara. Ex-1003, ¶185. Indeed, Haddad188 discloses that “[a] passivation layer can also be disposed on the photosensitive imager device to protect and/or reduce the dark current of the device,”

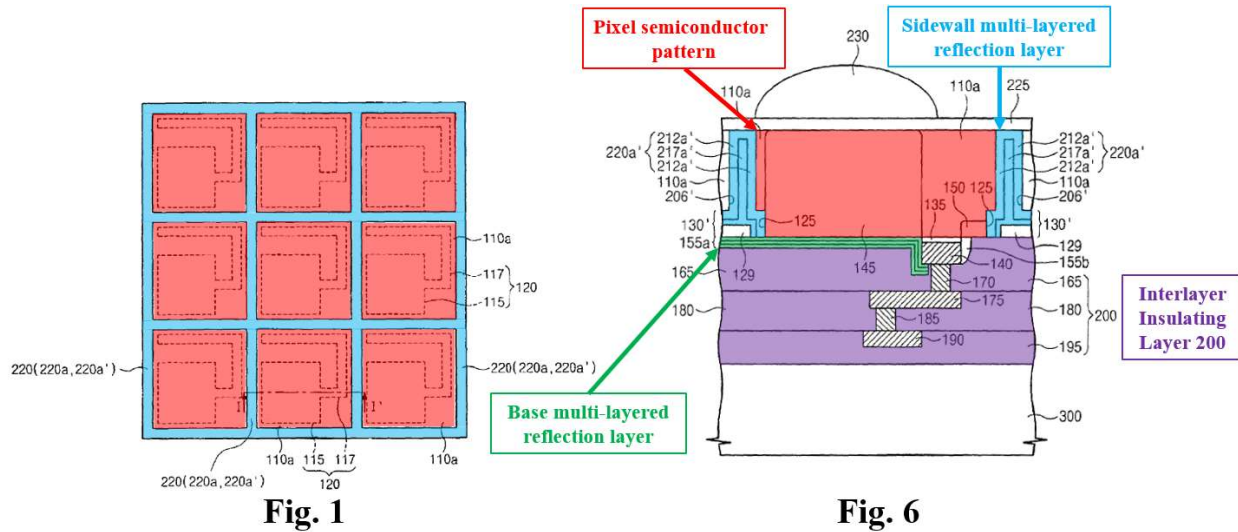
Haddad188, 25:21-22, and Mori's doping process is similarly directed at reducing dark current. *See* Mori, [0013], Ex-1003, ¶185.

POSITAs would have expected success in substituting Shinohara's hafnium oxide or aluminum oxide in place of the silicon in the Si/SiO₂ layers used according to the combination of Haddad188 and Mori discussed above, resulting in a trench isolation comprising layers of (i) SiO₂, (ii) aluminum oxide or hafnium oxide, and (iii) SiO₂. Ex-1003, ¶185. *E.g.*, Suzunaga, [0067] (“[T]he film having a high refractive index is not necessarily limited to a semiconductor material, but may be, for example, any one of ... Al₂O₃ ... and the like as depicted in Table 1, and may be combined with a film having a low refractive index, such as SiO₂....”). As discussed above, Shinohara surrounds its negative fixed charge material with a p-type semiconductor layer 43, and Mori's doping process similarly results in a more heavily doped p-type region in the corresponding location. Ex-1003, ¶185. Accordingly, POSITAs would recognize that the modification is structurally compatible. Ex-1003, ¶185.

E. Ground 5: Claims 19-23, 26-32, 34, and 36 Are Obvious Based on Hwang and Konno

1. Overview of Hwang

Hwang is directed to “an image sensor with an increased spectral sensitivity,” “capable of minimizing interference between neighboring pixels,” by using base and sidewall multi-layered reflection layers, as illustrated below. Hwang, 1:52-67.



Id., Figs. 1, 6 (annotated), 4:59-63; Ex-1003, ¶¶187-191.⁹ Like the '599 patent, Hwang concerns improving image quality by increasing the percent of incident light the photodiode absorbs. *E.g.*, *id.*, 1:31-36.

2. Overview of Konno

Konno is directed to a “solid-state imaging element” (i.e., an image sensor) that uses reflective surfaces to increase the amount of incident light absorbed by the photodiode. *See generally* Konno, Abstract, 2:49-55.

⁹ Figures 2 and 6 use differently arranged sidewall multi-layered reflection layers but are otherwise the same. *See* Hwang, 11:57-60; Ex-1003, n.8. Therefore, POSITAs would appreciate that Hwang’s disclosures for elements in Figure 2 (including layer 220 comprising layers 210 and 215) are pertinent to corresponding elements in Figure 6 (including layer 220a’ comprising layers 212a’ and 217a’).

As illustrated in Figure 7 below, Konno's sensor includes first and second reflecting layers 121 and 120 that "sandwich the ... photoelectric conversion element 135," *id.*, 8:22-25, thus "confining photons which entered into the solid-state imaging element [] between the both," *id.*, 8:31-33, and improving sensitivity by allowing for "most of the photons [to] be absorbed with the photoelectric conversion film 125," *id.*, 10:8-13. Konno explains that "second reflection layer 120," "can be formed by forming a thin film of a metal." *Id.*, 8:31-38. Konno also discloses a "microlens 122" that "concentrates photons which entered into the solid-state imaging element 110, and leads them to the light entrance window 128." *Id.*, 9:4-9.

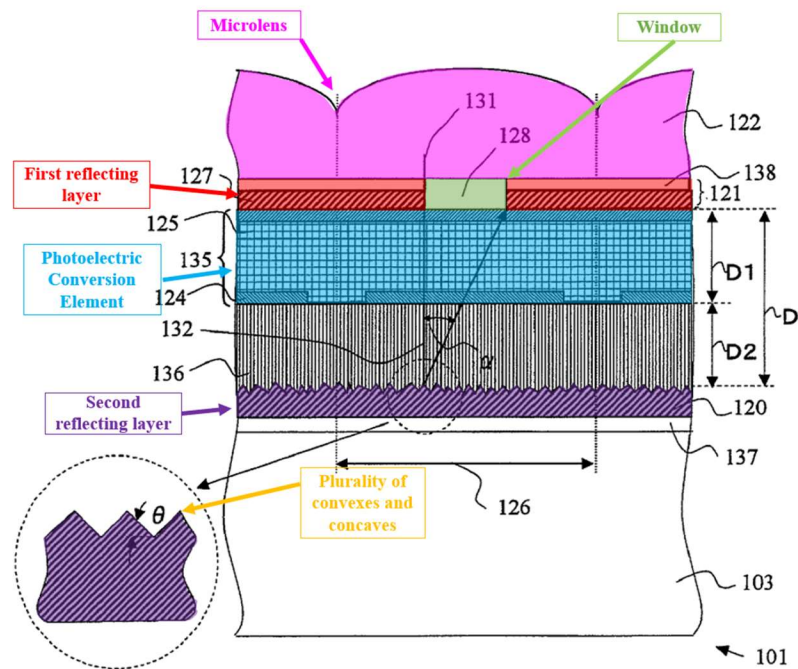


Fig.7

Konno, Fig. 7 (annotated); Ex-1003, ¶¶192-194.

Konno's sensor also includes "a transparent layer or layers disposed between

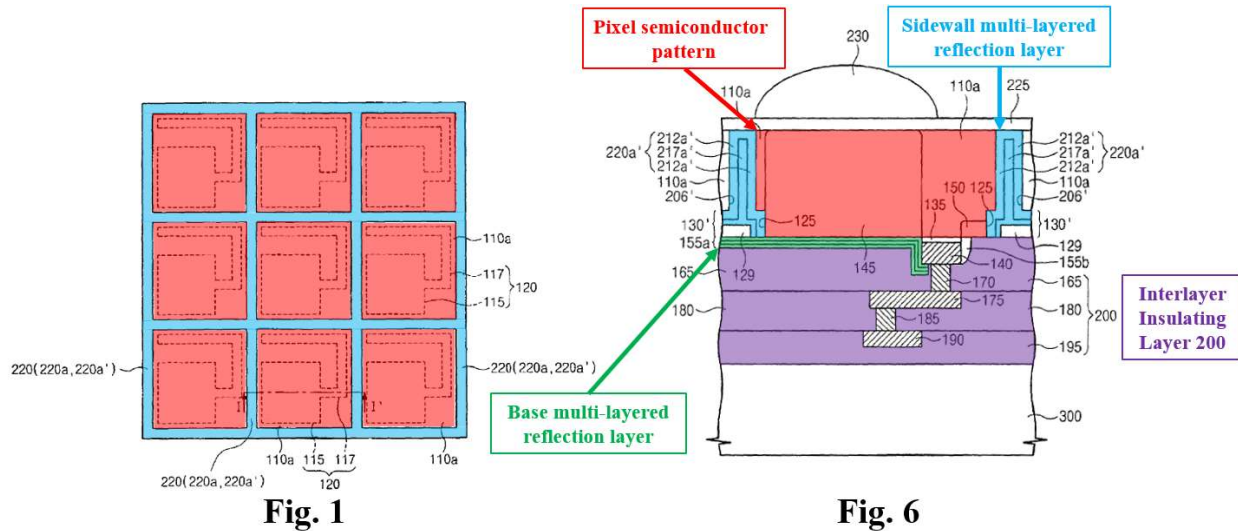
the first electrode and first reflecting layer and/or between the second electrode and the second reflecting layer.” Konno, 3:16–19. Konno explains that “by providing a transparent layer in the solid-state imaging element of the present invention, convexes or concaves or a structure effective for reflecting or scattering photons can be realized in the reflecting layer adjacent to the transparent layer.” *Id.*, 3:58–62. For example, Figure 7 above depicts an embodiment in which the transparent layer 136 is textured in order to scatter the incoming light.

Konno explains that the shape of the transparent and reflecting layers “makes it possible to reflect photons ... and therefore the amount of photons to be detected again by the photoelectric conversion film 125 can be increased.” Konno, 13:66–14:3. Konno discloses that this structure “can be manufactured by, for example, forming concaves and convexes on the surface of the transparent layer 136 ... and then depositing a metal thereon to produce the reflecting layer 120.” *Id.*, 14:38–45.

3. Claim 19

a. 19[pre]: “A light trapping device, comprising:”

Hwang teaches or suggests this preamble. Ex-1003, ¶¶195-198. As illustrated below, Hwang discloses an “image sensor that converts incident light to electrical signals,” Hwang, 1:14-18, using base and sidewall multi-layered reflection layers (155a and 220a’, respectively) for *trapping light* by reflecting light back into the

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Id., Fig. 1, 6 (annotated), 4:59-63; Ex-1003, ¶196.

b. 19[a]: “at least one light sensitive pixel having a light incident surface, a backside surface opposite the light incident surface, and a peripheral sidewall extending at least partially around the pixel periphery;”

Hwang’s image sensor comprises *at least one light sensitive pixel*. Ex-1003,
¶200. As depicted below, it includes “a plurality of pixel semiconductor patterns

110a,” Hwang 5:52-59 (each containing a “photodiode 145 disposed therein,” *id.*) to convert light to electrical signals, *id.*, 1:23-29.¹⁰

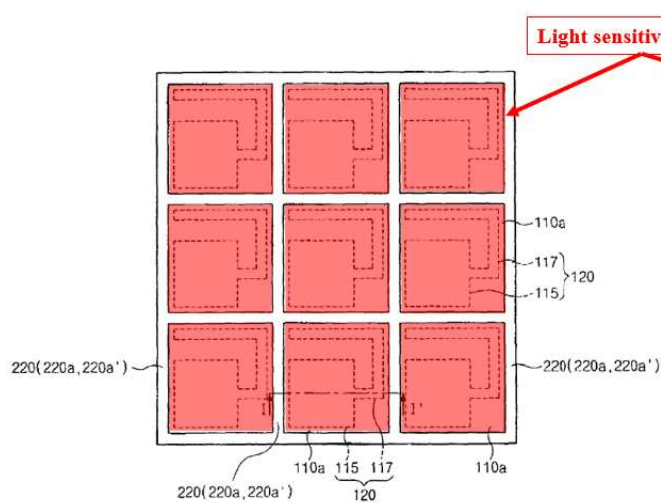


Fig. 1

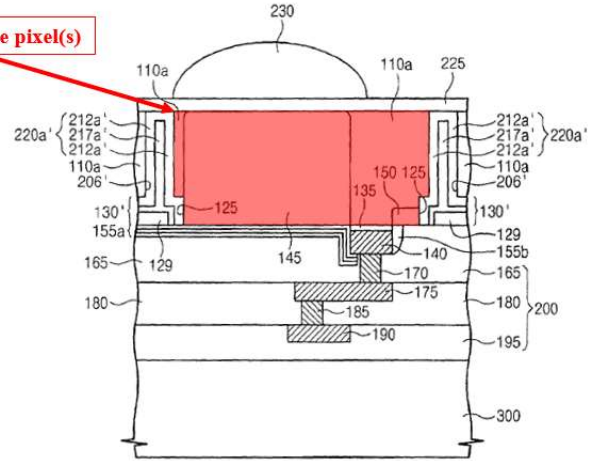


Fig. 6

Id., Fig. 1, 6 (annotated); Ex-1003, ¶200.

Each pixel (110a) further has a *light incident surface* and a *backside surface opposite the light incident surface*, as illustrated below.

¹⁰ While Hwang calls element 145 a “photodiode,” POSITAs would understand that term (i.e., the structure that converts light into an electrical signal) encompasses more than just element 145 and would further include the surrounding pixel semiconductor patterns 110a. Ex-1003, n.10. *See* Hwang, 5:52-6:6 (“photodiodes 145 form a PN junction with the pixel semiconductor pattern 110a”).

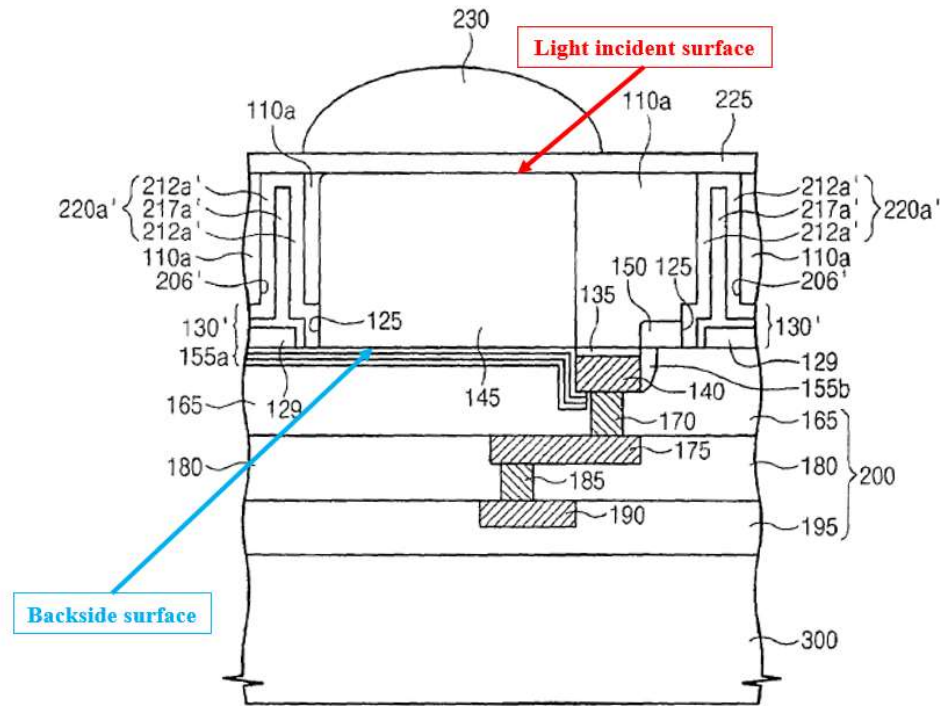


Fig. 6

Hwang, Fig. 6 (annotated); Ex-1003, ¶201. “The pixel semiconductor patterns 110a have first and second surfaces in parallel, i.e., that face one another,” where “the first surface ... is more proximate to the substrate 300 than is the second surface.” Hwang, 6:37-40. Hwang’s “second surface” constitutes a *light incident surface*, see Hwang, 8:17-22 (“[e]xternal light ... is incident on the second surface of the photodiode 145.”), and its “first surface” constitutes a *backside surface opposite the light incident surface*. Ex-1003, ¶¶201-204.

Each pixel further has a *peripheral sidewall*, as illustrated below.

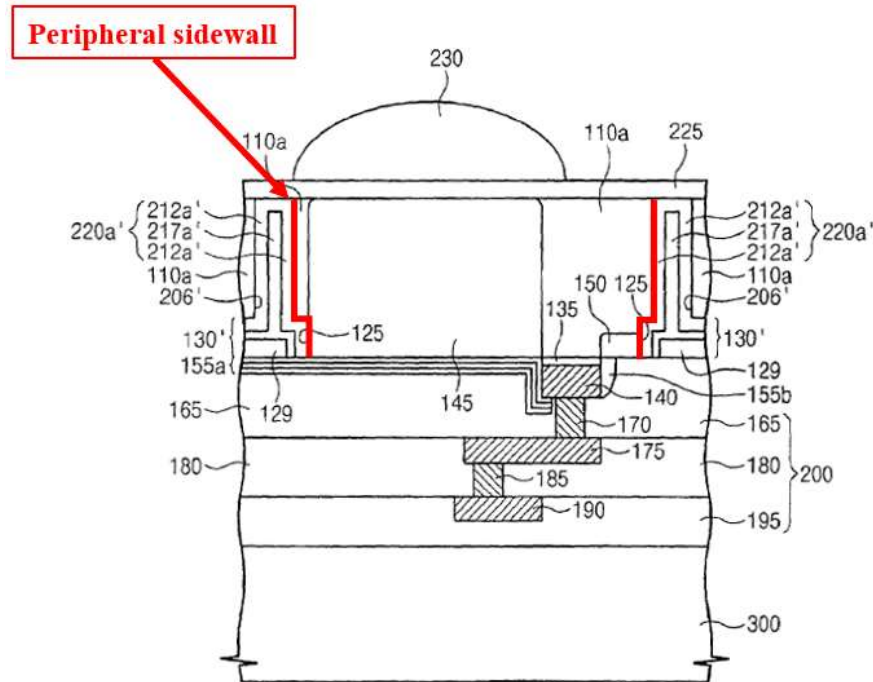


Fig. 6

Hwang, Fig. 6 (annotated); Ex-1003, ¶205.

Hwang’s “sidewall multi-layered reflection layer 220a’ is disposed within a groove 206’ formed between pixel semiconductor patterns 110a’.” Hwang, 11:64-66; *see also id.*, 6:7-9 (“sidewall multi-layered reflection layer 220 [220a’ in Figure 6] is provided between the side walls of the pixel semiconductor patterns 110a”). Thus, pixel (110a) includes a *peripheral sidewall* where it contacts the sidewall reflection layer 220a’. Ex-1003, ¶206.

The peripheral sidewall further *extend[s] at least partially around the pixel periphery*. Ex-1003, ¶207. As illustrated below, “sidewall multi-layered reflection layer 220 [220a’ in Figure 6] encloses the side walls of the pixel semiconductor patterns 110a.” Hwang, 6:15-17.

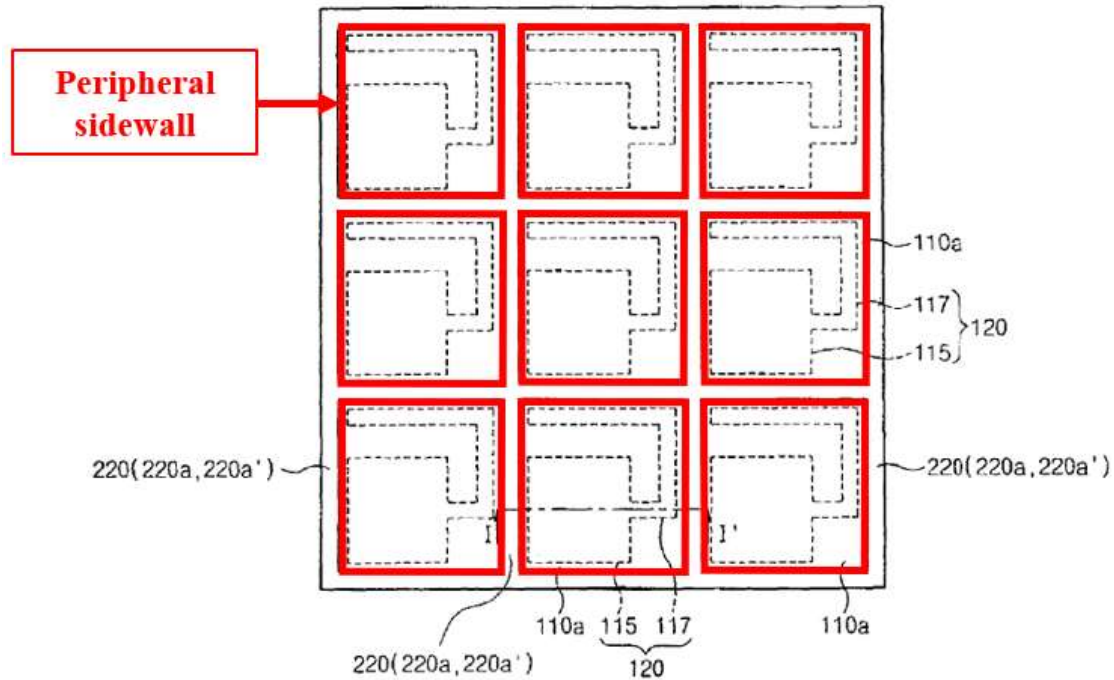


Fig. 1

Id., Fig. 1 (annotated); Ex-1003, ¶207. See Hwang, 11:61.

c. 19[b]: “a backside light trapping material at least partially covering the backside surface;”

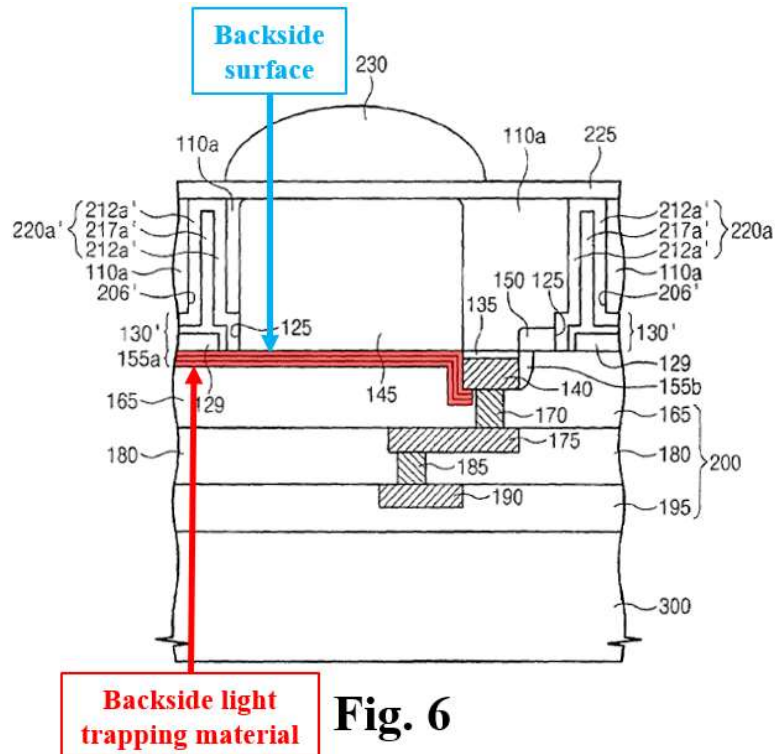
and

19[d]: “a textured region positioned to interact with light incident thereon to increase quantum efficiency of the device; and”

These limitations are obvious based on Hwang in view of Konno. Ex-1003, ¶¶209-221.

First, Hwang’s image sensor includes a *backside light trapping material at least partially covering the backside surface* as specified in limitation 19[b]. Ex-1003, ¶¶210-211. As illustrated below, Hwang’s “base multi-layered reflection layer

155a is interposed between the photodiode 145 and the interlayer insulating layer 200,” Hwang, 7:45-47, and “contacts the first surface [*backside surface*],” *id.*, 8:32-33.



Hwang, Fig. 6 (annotated); Ex-1003, ¶210.

This layer traps light, as “external light incident on ... photodiode 145 is reflected by ... base multi-layered reflection layer 155a,” and is therefore “incident again on the photodiode.” Hwang, 9:6-14; Ex-1003, ¶211.

Second, it would have been obvious to modify Hwang’s image sensor to incorporate Konno’s textured transparent layer 136 and second reflecting layer 120, resulting in a sensor that includes a *textured region* as specified in limitation 19[d] (Konno’s transparent layer 136), while still meeting the *backside light trapping*

material requirement of limitation 19[b] (via Konno’s reflecting layer 120). Ex-1003, ¶¶212-221.

In Konno’s Figure 7 embodiment, the transparent layer is textured by “forming concaves and convexes on the surface of the transparent layer 136.” Konno, 14:38–40. The textured surface “can be formed by a known technique such as sputtering and microlithography.” *Id.*, 14:43–45. Konno’s second reflective layer may then formed on the transparent layer by “depositing a metal” thereby forming concaves and convexes in the reflective layer. *Id.*, 14:38–43.

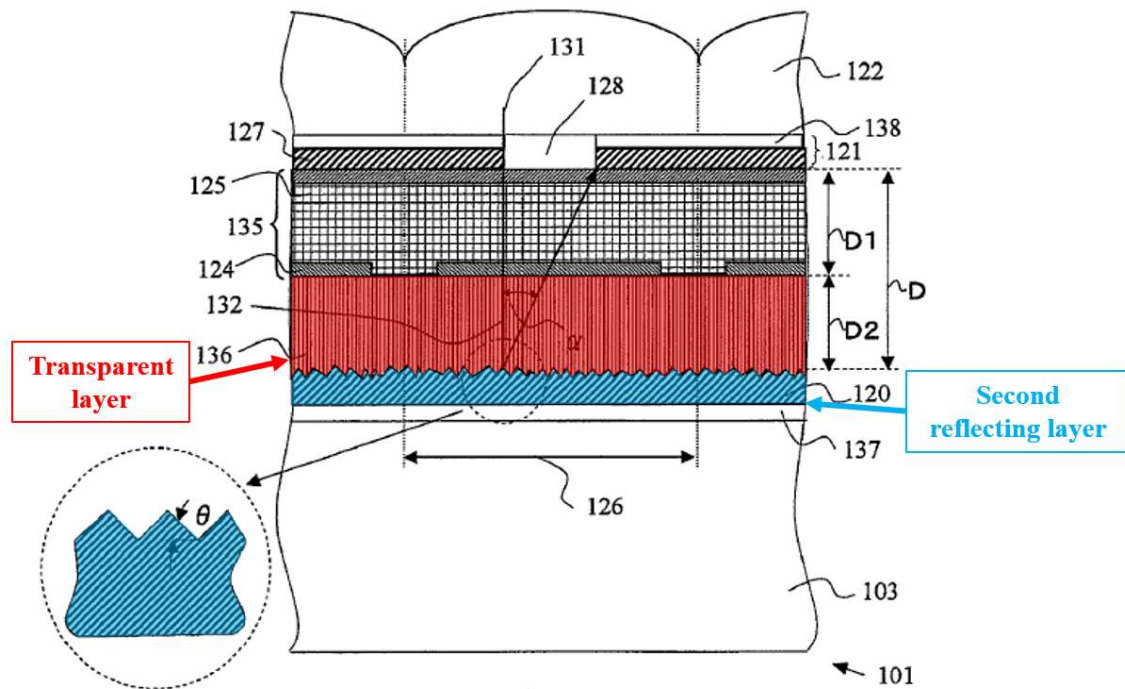


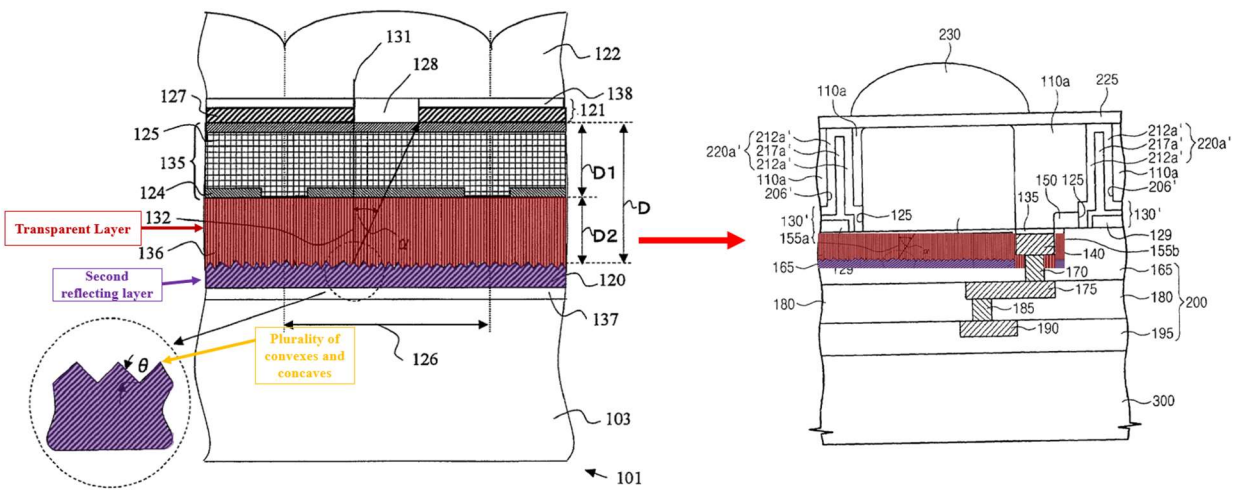
Fig. 7

Konno, Fig. 7 (annotated); Ex-1003, ¶212.

As shown above, Konno’s transparent layer is a *textured region positioned to interact with light incident thereon to increase quantum efficiency of the device*. See

Ex-1003, ¶213. The texturing of the transparent layer, and the resulting shape allows the second reflecting layer to reflect incident photons “with a large amount of horizontal components,” thereby increasing “the amount of photons to be detected again by the photoelectric conversion film 125” (*i.e., the quantum efficiency of the device*). *Id.*, 13:63–14:3; Ex-1003, ¶¶213-214. In particular, “[t]he photons not absorbed by the photoelectric conversion film 125 transmit ... the transparent layer 136 and reach the second reflecting layer.” Konno, 9:64–67. By transmitting the photons not absorbed by the photoelectric conversion film, the transparent layer is *positioned to interact with light incident thereon to increase quantum efficiency of the device*. Ex-1003, ¶¶213-214.

It would have been obvious to use Konno’s textured transparent layer in Hwang’s image sensor to improve efficiency in a similar manner, resulting in Hwang’s image sensor having a *textured region* (the transparent layer) *positioned to interact with light incident thereon to increase quantum efficiency of the device*.



Konno, Fig. 7 (annotated); Hwang, Fig. 6 (annotated, modified); Ex-1003, ¶¶216-217.

Additionally, this modification would still meet the requirement of a *backside light trapping material at least partially covering the backside surface* as specified in limitation 19[b]. That is, the modification would include a “second reflecting layer 120” as taught in Konno, which “can be formed by forming a thin film of a metal such as aluminum and silver by deposition or the like.” Konno, 8:31-38. *See* Ex-1003, ¶215. This layer further would at least partially *cover[] the backside surface* as illustrated above. *See* Ex-1003, ¶215, 217.

POSITAs would have been motivated to make this modification, as such a textured layer would redirect light to Hwang’s sidewall multi-layer reflection layer 220a’ to increase efficiency. Ex-1003, ¶¶216-221. Hwang discloses that “[l]ight that is reflected from the first and second boundary surfaces,” i.e. light that reflects off

of the base multi-layered reflection layer, “is also reflected by the third boundary surface and also the fourth boundary surface within the sidewall multi-layered reflection layer 220” and that, as a result, “the absorption efficiency of external light is increased.” Hwang, 10:28-35; *see also* Hwang, 8:61-9:14. Thus, both Hwang and Konno teach that it is desirable to configure the image sensor so that light that reflects off of the backside light reflecting material also reflects off of the peripheral light reflecting material in order to increase the path of the light and maximize the absorption efficiency of the pixel. POSITAs would therefore be motivated to implement Konno’s textured transparent layer in Hwang’s image sensor in order to achieve this mutually-recognized goal. POSITAs would be further motivated by Konno’s disclosures that using a metal reflecting layer 120 can reduce “error signals and noises generated in output signals of the photodetector.” Konno, 12:33-38, Ex-1003, ¶218.

POSITAs would reasonably have expected success in implementing Konno’s textured layer. Konno teaches that the transparent layer “is formed from a material which transmits photons, for example glass and plastics such as acrylic resins.” Konno, 9:35–41. Hwang teaches that base multi-layered reflection layer 155a comprises a layer of silicon dioxide (i.e. glass). POSITAs would understand that texturing Hwang’s silicon dioxide layer using the methods described in Konno requires nothing more than the use of known techniques that would have yielded

predictable results. Ex-1003, ¶¶219-221. The textured layer could be implemented after the manufacturing step shown in Hwang's Figure 22 or between the manufacturing steps shown in Hwang's figures 8/9 for a substantially similar embodiment. Ex-1003, ¶¶219.

d. 19[c]: “a peripheral light trapping material substantially covering the peripheral sidewall;”

Hwang's image sensor includes a *peripheral light trapping material substantially covering the peripheral sidewall*. Ex-1003, ¶¶222-226. As illustrated below, Hwang's “sidewall multi-layered reflection layer 220a” is disposed within a groove 206' formed between pixel semiconductor patterns 110a.” Hwang, 11:64-66. *See id.*, 9:41-43 (“sidewall multi-layered reflection layer 220 [220a' in Figure 6] is disposed between the side walls of the pixel semiconductor pattern 110a.”).

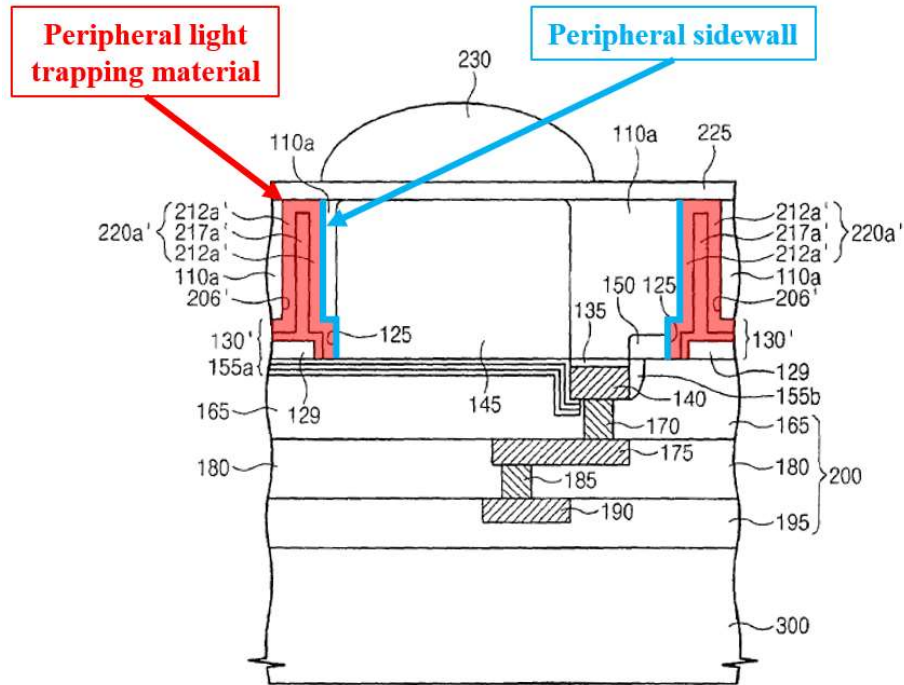


Fig. 6

Id., Fig. 6 (annotated); Ex-1003, ¶¶223. “The sidewall multi-layered reflection layer 220 [220a’ in Figure 6] encloses the side walls of the pixel semiconductor pattern 110a,” and can also “contact the side walls of the pixel semiconductor patterns 110a.” *Id.*, 6:15-17, 9:43-45. See Ex-1003, ¶¶223-224.

This layer traps light, as light is “reflected from ... the sidewall multilayered reflection layer 220 [220a’ in Figure 6],” and is therefore “incident again on the photodiode 145, so that the absorption efficiency of external light is increased.” Hwang, 10:28-35. Additionally, “sidewall multi-layered reflection layer 220 [220a’ in Figure 6] minimizes incidence of the light incident on a photodiode 145 that it encloses being incident on other pixels.” *Id.*, 10:23-27; Ex-1003, ¶¶223-224.

- e. 19[e]: “a reflective layer coupled to the light incident side and having an aperture to allow entry of light into the pixel;”

This limitation would have been obvious based on Hwang in view of Konno. Ex-1003, ¶¶227-234.

Konno’s solid-state imaging element includes a first reflecting layer 121 constituting a *reflective layer coupled to the light incident side and having an aperture to allow entry of light into the pixel*. Ex-1003, ¶¶227-234. As illustrated below, Konno’s “solid-state imaging element,” includes a “[*second reflecting layer*] 120,” and a “first reflecting layer 121” to improve detection sensitivity. Konno, 8:18-22. A “light entrance window 128 through which the incident photons 132 transmit is formed in the first reflecting layer 121.” Konno, 8:56-58.

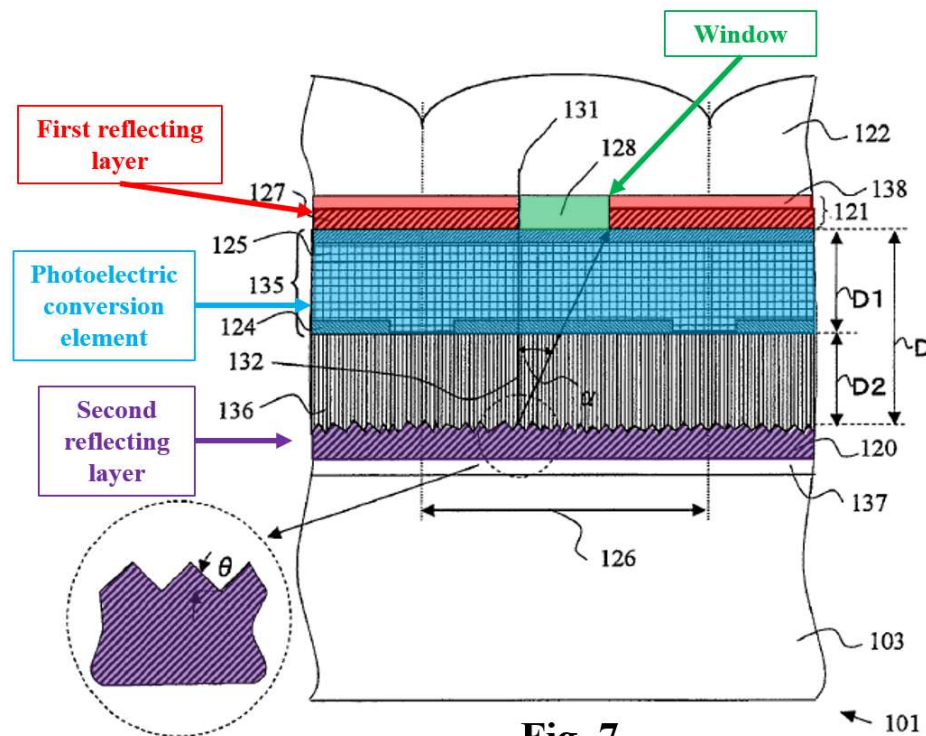
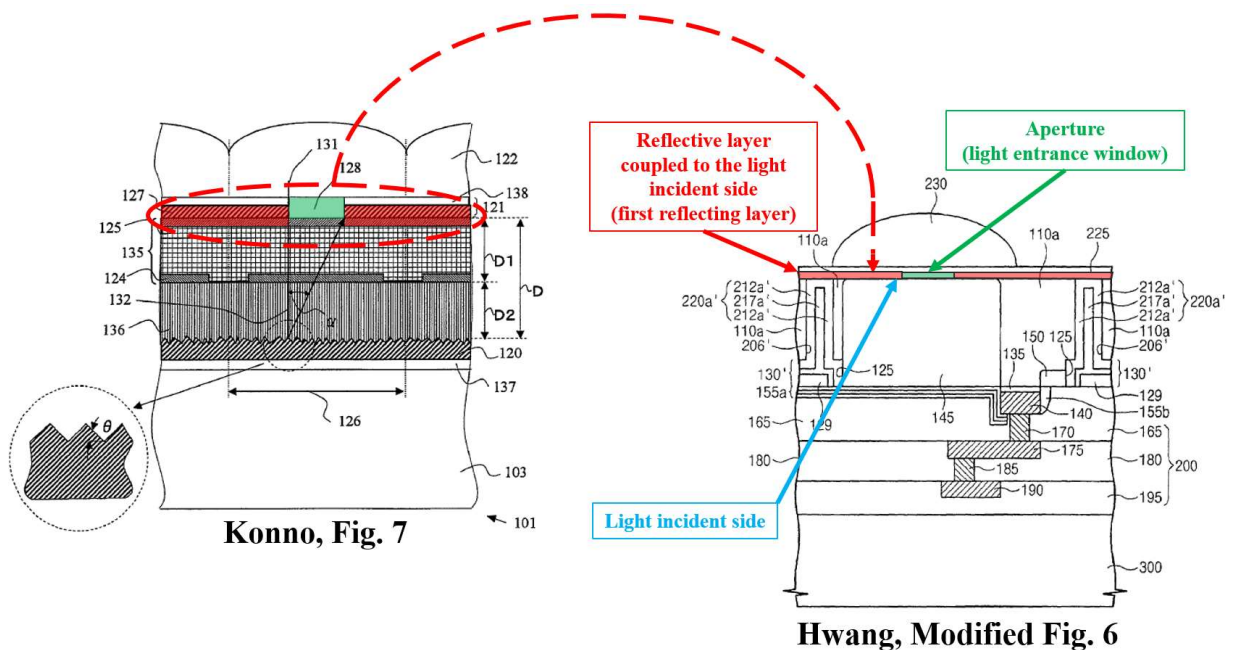


Fig. 7

Konno, Fig. 7 (annotated). Ex-1003, ¶228. Konno explains that “photons which entered from the light entrance window 128 can be effectively confined between the first and second reflection layers 121 and 120 to ... improve detection sensitivity.” Konno, 11:65-12:3.

Therefore, it would have been obvious to use Konno’s first reflective layer 121 and light entrance window 128 in Hwang’s image sensor—i.e., forming them on Hwang’s light incident surface, as shown below—to reduce loss of light reflected from the photodiodes and improve light efficiency. Ex-1003, ¶¶228-231.



Konno, Fig. 7 (annotated); Hwang, Fig. 6 (annotated, modified); Ex-1003, ¶¶231.

As shown above, this modification results in Hwang’s image sensor having a *reflective layer* (the first reflective layer) *coupled to the light incident side* (Hwang’s

“second surface”) *having an aperture* (light entrance window 128) *to allow entry of light into the pixel*. Ex-1003, ¶232

POSITAs would have been motivated to make this modification, as adding Konno’s first reflective layer 121 to Hwang’s image sensor allows for light to be reflected from the first reflective layer back into the Hwang’s semiconductor pattern 110*a*, thus increasing its efficiency. Ex-1003, ¶233. Konno explains that using the first reflective layer 121 allows for “[t]he second reflecting layer 120 and the first reflecting layer 121 [to] have a function of confining photons which entered into the solid-state imaging element [] between the both....” Konno, 8:31-33.

Additionally, POSITAs would reasonably have expected success in implementing Konno’s reflective layer in Hwang’s image sensor. Ex-1003, ¶234. POSITAs would recognize that the first reflective layer 121 and light entrance window 128 could be readily implemented in Hwang’s image sensor. Ex-1003, ¶234. For example, in the manufacturing steps shown for Hwang’s substantially similar embodiments in Figures 13/14 and 16/17, Hwang explains that “[a] color filter 225 is disposed on the second surface of the pixel semiconductor pattern 110*a*.” Hwang, 8:17-18. POSITAs would recognize that Konno’s first reflective layer 121 and light entrance window 128 could be placed between Hwang’s color filter 225 and pixel semiconductor pattern 110*a*, similarly to how in Konno the first reflective

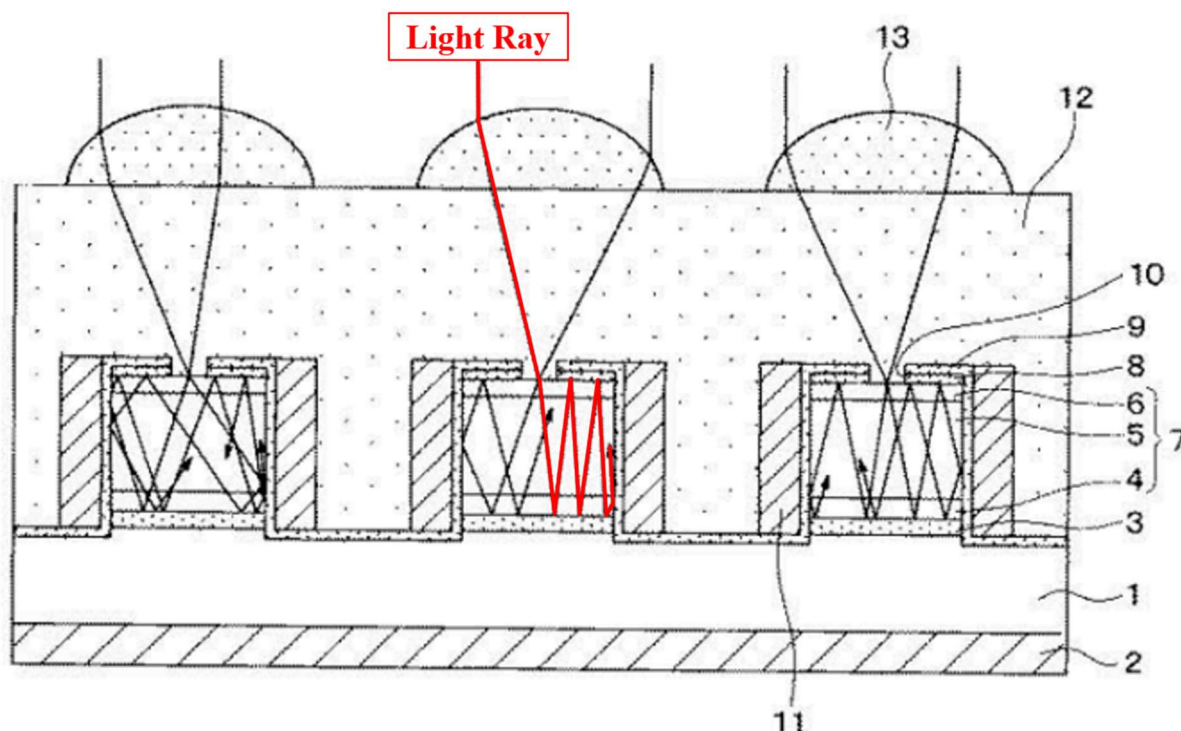
layer 121 and light entrance window 128 are formed above the photoelectric conversion element 135. Ex-1003, ¶234. *See generally* Konno, 8:18-30, Figs. 3-4.

- f. 19[f]: “wherein the reflective layer is operable to reflect at least a portion of light impinging thereupon from inside the pixel back into the pixel back into the pixel.”**

This limitation would have been obvious based on Hwang in view of Konno. Ex-1003, ¶¶235-237.

As discussed for claim 19[e] above, it would have been obvious in view of Konno to add Konno’s first reflective layer 121 (i.e., a *reflective layer coupled to the light incident side*) in Hwang’s image sensor, thereby forming a *reflective layer that is operable to reflect at least a portion of light impinging thereupon from inside the pixel back into the pixel back into the pixel*. Ex-1003, ¶236. As explained for claims 19[b] and 19[c] above, Hwang’s image sensor as modified by Konno includes both a second reflecting layer 120 and a peripheral reflecting layer 220a’. As explained for claim 20 below, the purpose of its backside and peripheral reflecting layers is to reflect light back into the pixel. *See* Ex-1003, ¶¶236-237.

POSITAs would recognize that Hwang’s image sensor is operable to reflect at least a portion of light multiple times off of the first reflective layer 121 (e.g., back into the pixel back into the pixel) because it includes reflective backside, peripheral, and frontside surfaces. *See* Ex-1003, ¶¶236-237. Such reflection was well-known in the art, as shown for example in the below figure from Yamada (Ex-1029):



Yamada, Fig. 1 (annotated) (showing light ray reflected by first reflective film 3, second reflective film 8, and third reflective film 11). Ex-1003, ¶237.

4. **Claim 20: “The device of claim 19, wherein at least one of the backside light trapping material and the peripheral light trapping material reflects light incident thereon back into the pixel.”**

This limitation is obvious based on Hwang in view of Konno. Ex-1003, ¶¶238-241.

First, Hwang teaches or suggests that *the peripheral light trapping material reflects light incident thereon back into the pixel*. Ex-1003, ¶239. That is, light is “reflected by ... the sidewall multi-layered reflection layer 220 [220a’ in Figure 6]”

(*peripheral light trapping material*) and is therefore “incident again on the photodiode 145...” Hwang, 10:28-35.

Second, Hwang, as modified by Konno, includes a *backside light trapping material* (i.e., second reflecting layer 120 as incorporated from Konno) that *reflects light incident thereon back into the pixel*. Ex-1003, ¶240. Hwang discloses that “external light incident on the second surface [the light incident surface] of the photodiode 145 is reflected by the first boundary surface and at least one second boundary surface within the base multi-layered reflection layer 155*a*.” Hwang, 9:6-14. External light would similarly be reflected back into the pixel after modifying Hwang’s image sensor to include Konno’s second reflecting layer 120. Ex-1003, ¶240. *E.g.*, Konno, 13:66-14:3 (“This makes it possible to reflect photons which entered from the light entrance window 128 to the first reflecting layer 121, and therefore the amount of photons to be detected again by the photoelectric conversion film 125 can be increased.”).

5. Claim 21: “The device of claim 19, wherein said peripheral light trapping material has a refractive index of less than about 2.1.”

Hwang teaches or suggests this limitation. Ex-1003, ¶¶242-243.

Hwang discloses that the *peripheral light trapping material* includes a material having *a refractive index of less than about 2.1*. Ex-1003, ¶243. Hwang discloses that “sidewall multi-layered reflection layer 220*a*’ includes a first sidewall

reflection layer 212a' and a second sidewall reflection layer 217a'." Hwang, 11:64-12:12. Hwang explains that "[t]he first sidewall reflection layer 210 [212a' in Figure 6] can be a silicon oxide layer or a layer of air (with a refractive index of 1)." Hwang, 10:2-5. As Hwang explains, silicon oxide has a refractive index of approximately 1.46. Hwang, 9:28-30.¹¹ In such a structure, the peripheral light trapping material would include a material (i.e., silicon dioxide) with *a refractive index of less than about 2.1*.

6. Claim 22: "The device of claim 19, wherein said peripheral light trapping material includes a member selected from the group consisting of an oxide, a nitride, oxynitrides, a gas, at least a partial vacuum, and combinations thereof."

Hwang teaches or suggests this limitation. Ex-1003, ¶244. Hwang's peripheral light trapping material contains first sidewall reflection layer 212a' that "can be silicon oxide." Hwang, 10:2-5. *Supra*, §VII.E.5 (claim 21).

¹¹ POSITAs would understand Hwang's "silicon oxide" to mean specifically "silicon dioxide" (SiO₂), as Hwang discloses it has "a refractive index of approximately 1.46." Hwang, 9:28-29. Ex-1003, n.11; Ex-1017, 181 ("SiO₂ ($\bar{n} \approx 1.46$)").

7. **Claim 23:** “The device of claim 22, wherein said peripheral light trapping material is selected from the group consisting of silicon oxide, silicon nitride, silicon dioxide, and combinations thereof.”

Hwang teaches or suggests this limitation. Ex-1003, ¶245. Hwang’s peripheral light trapping material contains first sidewall reflection layer 212a’ that “can be silicon oxide.” Hwang, 10:2-5. *Supra*, §VII.E.5 (claim 21).

8. **Claim 26:** The device of claim 19, wherein the peripheral sidewall extends completely around the pixel periphery.

Hwang teaches or suggests this limitation. Ex-1003, ¶246. Hwang’s “sidewall multi-layered reflection layer 220 [220a’ in Figure 6] encloses the side walls of the pixel semiconductor patterns 110a.” Hwang, 6:15-17. *Supra* §VII.E.3 (claim 19[a]). Accordingly, as illustrated below, the *peripheral sidewall* where pixel 110a contacts sidewall reflection layer 220 [220a’ in Figure 6] *extends completely around the pixel periphery*.

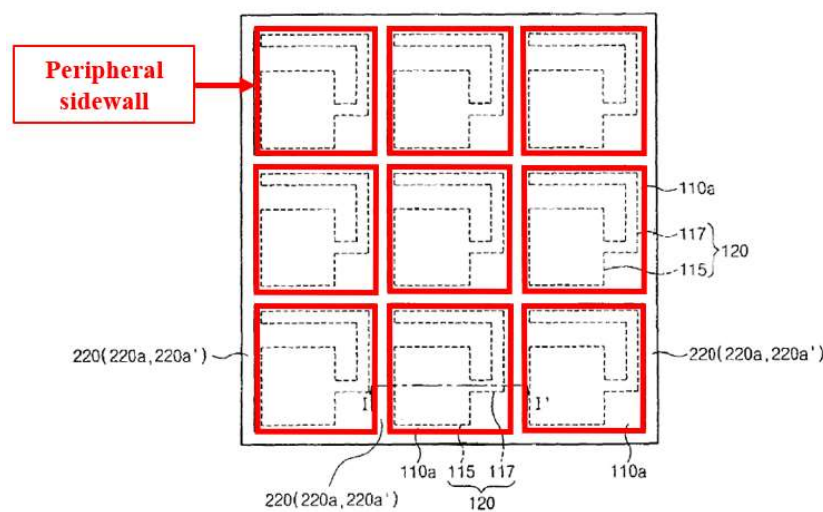


Fig. 1

Hwang, Fig. 1 (annotated); Ex-1003, ¶246.

9. **Claim 27: “The device of claim 19, wherein the peripheral sidewall extends from the light incident surface to the backside surface.”**

Hwang teaches or suggests this limitation. Ex-1003, ¶247. As illustrated below, the *peripheral sidewall* where pixel semiconductor pattern 110a contacts sidewall multi-layered reflection layer 220a' extends fully *from the light incident surface to the backside surface*.

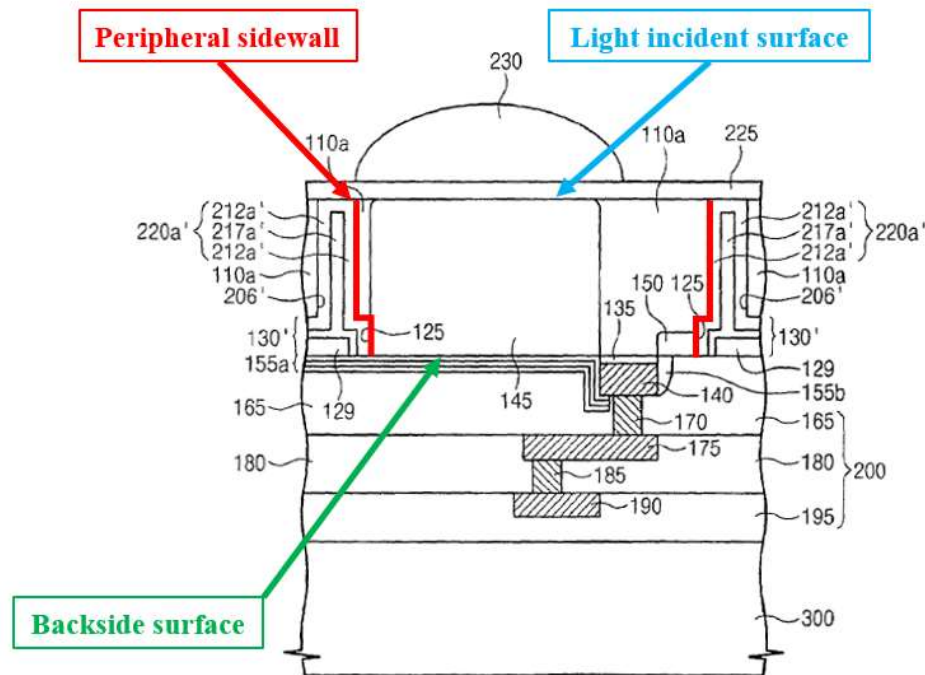


Fig. 6

Hwang, Fig. 6 (annotated); Ex-1003, ¶247; *supra*, §VII.E.3 (claim 19[a]).

10. Claim 28: “The device of claim 19, wherein said aperture has an effective surface area of less than about 90% of total area of the incident light surface.”

This limitation would have been obvious based on Hwang in view of Konno. See Ex-1003, ¶¶248-251.

As discussed for claim 19[e] above, it would have been obvious in view of Konno to use Konno’s first reflective layer 121 and light entrance window 128 (i.e., its *aperture*) in Hwang’s image sensor. In such a structure, Hwang’s image sensor would have an *aperture having an effective surface area of less than about 90% of total area of the incident light surface*. See Ex-1003, ¶¶248-251. Konno discloses that “when the width 126 of pixel is 100 μm , it [i.e., the width of the *aperture*] is 20 μm .” Konno, 8:66-9:3; *see supra*, §VII.A.6 (claim 28); Ex-1003, ¶249.

Indeed, having an aperture with an *effective surface area of less than about 90% of total area of the incident light surface* was well-known and would have been obvious here. See Ex-1003, ¶¶250. Other similar image sensors balanced the competing considerations of increasing the size of the aperture to allow more light to be collected, but keeping the aperture small enough to prevent internal light from escaping, and designed apertures with an *effective surface area of less than about 90% of total area of the incident light surface*. Ex-1003, ¶250. For example, Ex-1016 (“Kim”) discloses photodiodes that contain an aperture (i.e., opening 107) formed of reflective films 106 that reflects light back into the photodiodes, and

discloses that “openings 107 can occupy between 70 to 90% of the uppermost surface area of photodiodes 102,” i.e., the *incident light surface*. Kim, [0015]; *see also id.*, [0018] (“[l]ight 105 reflected from photodiodes 102 can return to photodiodes 102 after being reflected by reflected films 106”). Ex-1003, ¶250.

Nevertheless, designing the aperture to be less than about 90% of the incident light surface total surface area would be nothing more than a design choice, as evidenced by the ’599 patent’s failure to identify any particular benefit of doing so. *See* ’599 patent, 12:9-14; Ex-1003, ¶251.

11. Claim 29: “The device of claim 19, further comprising a lens functionally coupled to the aperture and operable to focus incident light through the aperture and into the pixel.”

This limitation is obvious based on Hwang in view of Konno. Ex-1003, ¶¶252-256.

Konno’s solid-state imaging element includes a microlens 122 *functionally coupled to the aperture and operable to focus incident light through the aperture and into the pixel*. Ex-1003, ¶¶253-256. As illustrated below, “photons 132 received by [Konno’s] solid-state imaging element 110 are concentrated by the microlens 122, enter into the photoelectric conversion element 135 from the light entrance window 128...” Konno, 9:58-61.

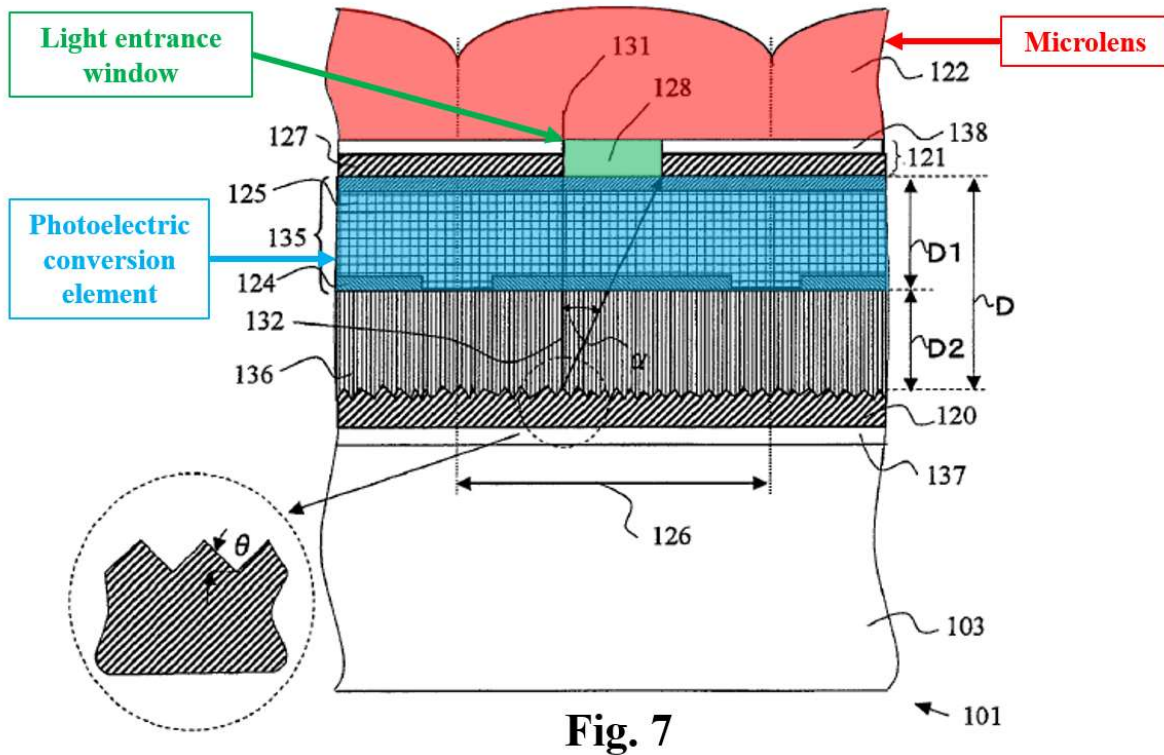


Fig. 7

Id., Fig. 7 (annotated); *see also id.*, 9:4-9 (“microlens 122 ... leads [photons] to the light entrance window 128”); Ex-1003, ¶253.

Using such a lens in Hwang’s image sensor would have been obvious. Ex-1003, ¶254. Indeed, Hwang’s image sensor already includes a “micro lens 230,” which “[e]xternal light passes through” before being “incident on the second surface [i.e., the *light incident surface*].” Hwang, 8:20-22; Ex-1003, ¶254. When incorporating Konno’s first reflecting layer 121 and light entrance window 128 into Hwang’s image sensor, it would be obvious that such a lens should be configured to concentrate the light through the window (as taught in Konno), to ensure that the light enters the pixel. Ex-1003, ¶254-255. That is, it would be obvious to use a lens

that is *functionally coupled to the aperture and operable to focus incident light through the aperture and into the pixel*. Ex-1003, ¶254-255.

POSITAs would reasonably expect success in using such a lens in Hwang’s image sensor, as Hwang already includes a microlens, and configuring a lens to direct light in a desired manner is straightforward and commonplace when designing light sensors. Ex-1003, ¶256.

12. Claim 30: “The device of claim 19, wherein at least one of the backside light trapping material and the peripheral light trapping material is a metal layer.”

This limitation is obvious based on Hwang in view of Konno. Ex-1003, ¶¶257-259.

As explained in claim 19[b] above, it would have been obvious in view of Konno to use Konno’s second reflecting layer 120 in Hwang’s image sensor. Ex-1003, ¶258. Konno explains that the “[t]he second reflecting layer 120 ... can be formed by forming a thin film of a metal such as aluminum and silver by deposition or the like.” Konno, 8:31-38; *see also* Konno, 13:57-59 (explaining that only the “shape” of the second reflecting layer 120 differs between the first and second embodiments).

13. Claim 31: “The device of claim 19, wherein said textured region comprises a textured film layer.”

This limitation would have been obvious based on Hwang in view of Konno. *See* Ex-1003, ¶¶260-261.

As discussed for claim 19[d] above, it would have been obvious to incorporate Konno's textured transparent layer 136, which constitutes a *textured film layer*, into Hwang's image sensor. Ex-1003, ¶261. As such, Hwang's image sensor would have a *textured region [that] comprises a textured film layer* (transparent layer 136). See Ex-1003, ¶261.

14. Claim 32: “The device of claim 31, wherein said textured film layer comprises any of silicon dioxide, silicon nitride, amorphous silicon, polysilicon, a metal and combinations thereof.”

This limitation would have been obvious based on Hwang in view of Konno. See Ex-1003, ¶¶262-264.

As discussed for claim 19[d], Konno discloses that its transparent layer 136 can be “formed from a material which transmits photons, for example, glass” and it would have been obvious to use SiO₂, i.e., glass, as a textured film layer in Hwang's image sensor, as modified by Konno. Konno, 9:35-37; Ex-1003, ¶263.

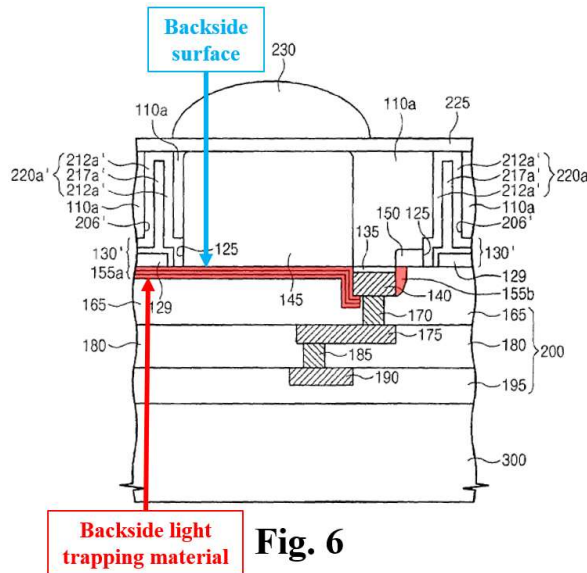
15. Claim 34: “The device of claim 19, wherein the backside light trapping material substantially covers the backside surface.”

This limitation would have been obvious based on Hwang in view of Konno. See Ex-1003, ¶¶265-271.

As explained above for claim 19[b], Hwang's image sensor, as modified by Konno includes a *backside light trapping material* (Konno's second reflecting layer 120). Ex-1003, ¶266. It would be obvious to have the backside light trapping

material *substantially cover[] the backside surface*. As explained for claim 19[b] above, both Hwang's base multi-layered reflection layer 155*a* and Konno's second reflecting layer serve to reflect light back into the pixel. Ex-1003, ¶266. POSITAs would have been motivated to make the backside light trapping material cover as much area as possible in order to increase the amount of light reflected back into the pixel, thus increasing the sensitivity of the sensor. Ex-1003, ¶267.

As shown below, Hwang depicts the base multi-layered reflection layer covering substantially all of the backside surface of the pixel semiconductor material 110*a*, while Konno depicts second reflecting 120 covering the entire backside. Ex-1003, ¶¶267-269; Konno, Fig. 7. Hwang teaches extending the multi-layered reflection layer to cover as much of the backside as possible to improve the sensitivity of the image sensor. Ex-1003, ¶¶267-269. For example, Hwang's gate spacer 155*b* "can include the same material as the base multi-layered reflection layer 155*a*," Hwang, 7:53-55, and Hwang's base multi-layered reflection layer 155*a* can even be "extended to cover a portion of the second surface of the gate electrode 140." *Id.*, 7:45-51. POSITAs would be motivated to ensure that Konno's second reflecting layer 120 covers at least as much of the backside as Hwang's base multi-layered reflection layer 155*a* to achieve the same results.



Hwang, Fig. 6 (annotated); Ex-1003, ¶¶270-271.

- 16. Claim 36:** “The device of claim 19, wherein said peripheral sidewall extends through the pixel substantially from the light incident surface to the backside surface.”

Hwang teaches or suggests this limitation. As explained above for claim 27, the *peripheral sidewall* where the pixel semiconductor pattern 110a contacts the sidewall multi-layered reflection layer 220a' *extends through the pixel substantially from the light incident surface to the backside surface*, as illustrated below.

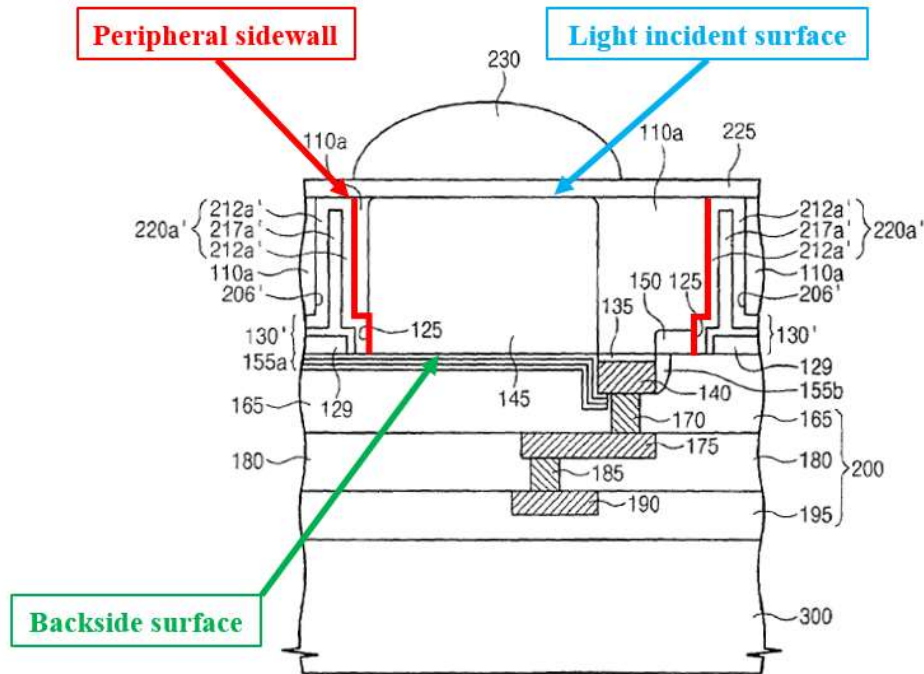


Fig. 6

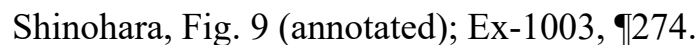
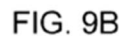
Hwang, Fig. 6 (annotated); Ex-1003, ¶272.

F. Ground 6: Claim 33 Is Obvious Based on Hwang, Konno, and Shinohara

- 1. Claim 33: “The device of claim 19, wherein the peripheral light trapping material comprises any of aluminum oxide and hafnium oxide.”**

This limitation would have been obvious based on Hwang in view of Konno and Shinohara. Ex-1003, ¶¶273-277.

Shinohara discloses a *peripheral light trapping material that comprises any of aluminum oxide or hafnium oxide*. Ex-1003, ¶274. Specifically, Shinohara describes “an element isolation region 68 for isolating pixels” which is formed with



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suppressed.” *Id.* Shinohara discloses examples of negative fixed charge materials such as “hafnium dioxide (HfO₂)” or “dialuminum trioxide (Al₂O₃).” Shinohara, [0091]. *See also* ’599 Patent, 9:53-59 (using “aluminum oxide” and “Al₂O₃” interchangeably); Ex-1003, ¶275.

POSITAs would be motivated to use Shinohara’s isolation region 68—including either of hafnium oxide or aluminum oxide—in place of Hwang’s sidewall multi-layered reflection layer 220a’ to limit dark current. Ex-1003, ¶276. POSITAs would expect success in doing so because Shinohara’s isolation region 68 serves the same purpose as Hwang’s sidewall multi-layered reflection layer 220a’. *See* Ex-1003, ¶276; Shinohara, [0094].

G. Ground 7: Claims 1-14, 16, 18, and 24-25 Are Obvious Based on Hwang, Konno, and Mori

1. Claim 1

a. Limitations 1[pre]-[a], [d]-[e]

Limitations 1[pre]-[a], [d]-[e] are identical to limitations 19[pre]-[a], [e]-[f], respectively. As discussed in Ground 5, Hwang in view of Konno teaches or suggests these limitations. *Supra*, §§ VII.E.3, Ex-1003, ¶¶278-279, 294-295.

b. 1[b]: “a backside light trapping material at least partially covering the backside surface;”

As discussed above in Ground 5, claim 19[b], Hwang’s image sensor includes a *backside light trapping material* (i.e., base multi-layered reflection layer 155a) *at least partially covering the backside surface*. Ex-1003, ¶¶280-284.

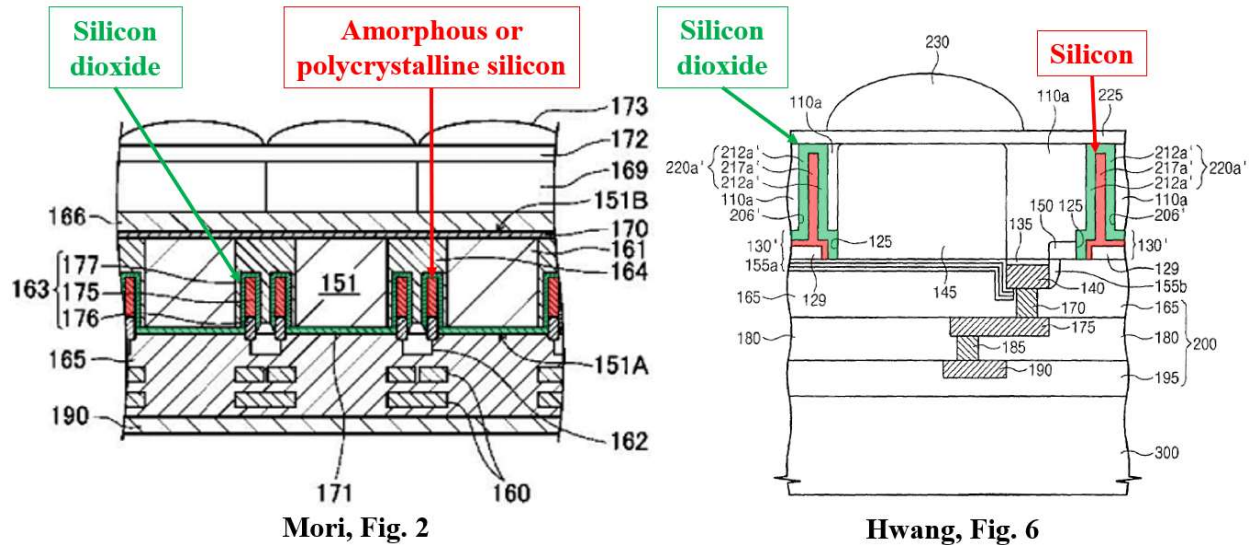
Additionally, this limitation would have been obvious based on Hwang in view of Konno, for the reasons discussed in Ground 5 for claim 19[b] and [d]. Ex-1003, ¶284.

c. 1[c]: “a peripheral light trapping material substantially covering the peripheral sidewall, wherein said peripheral light trapping material is doped with a dopant to create a surface field; and”

This limitation would be obvious based on Hwang in view of Mori.

As explained for Ground 5, claim 19[c] above, Hwang’s image sensor includes a *peripheral light trapping material* (sidewall multi-layered reflection layer 220a’) *substantially covering the peripheral sidewall*. Ex-1003, ¶¶285-293. As shown below, Hwang’s sidewall multi-layered reflection layer 220a’ includes a first sidewall reflection layer 212a’, which can be silicon oxide, and a second sidewall reflection layer 217a’, which can be silicon. *See* Ex-1003, ¶286; Hwang, 11:64-12:12, 10:2-5.

Mori discloses a similar multi-layer partition disposed between adjacent pixels of an image sensor and comprising a layer of silicon (silicon layer 175) sandwiched between layers of silicon dioxide (side SiO₂ film 177), as shown in Mori’s Figure 2. That is, both references utilize a similar silicon/silicon dioxide film disposed at the pixel sidewalls:



Mori, Fig. 2 (annotated); Hwang, Fig. 6 (annotated); Ex-1003, ¶287.

Mori explains the advantages of doping the silicon dioxide layer (Mori's SiO₂ layer 177) with p-type impurities in order to mitigate dark current stemming from crystal defects—i.e., to “prevent charges generated when dark due to crystal defects on the partition groove 174 from flowing into the photoelectric conversion unit 161.” Mori, [0036]; *see also* Ex-1003, ¶288.

Doping Mori's silicon dioxide layer with p-type impurities would lead to an excess of positive charges, creating an electric field at the surface of the layer, i.e., *a surface field*. Ex-1003, ¶¶288-290. Accordingly, Mori teaches that Mori's side SiO₂ film *is doped with a dopant to create a surface field* as set forth in this limitation. Ex-1003, ¶¶288-290. The '599 patent does not explain how doping the peripheral light trapping material operates to create a surface field—its only disclosure relating to such doping is that:

[I]t can also be beneficial to dope the sidewalls to create a surface field that will improve electrical isolation between the pixels. In one aspect, it can also be beneficial to dope the low refractive index material of the Bragg-type reflectors to increase such electrical isolation.

'599 patent, 10:14-18. That is, the '599 patent teaches that doping in the same manner as in Mori increases electrical isolation via a surface field. Ex-1003, ¶289. Thus, Mori's doped SiO₂ film 177 along the side of its pixel (photoelectric conversion unit 161) would constitute a *peripheral light trapping material doped with a dopant to create a surface field* as contemplated by the limited disclosure of the '599 patent. Ex-1003, ¶289.

Based on Mori's teaching, it is obvious to similarly dope Hwang's silicon dioxide layers in the same manner as Mori's SiO₂ film such that Hwang's *peripheral light trapping material is doped with a dopant to create a surface field*. Ex-1003, ¶291. Like Mori's side SiO₂ film 177, Hwang's silicon oxide layer 212a' adjoins the side of Hwang's pixel (pixel semiconductor pattern 110a). Ex-1003, ¶291. POSITAs would recognize that doping Hwang's silicon oxide layer 212a' with p-type impurities would similarly mitigate dark current stemming from crystal defects in Hwang's sensor. Ex-1003, ¶291.

POSITAs would expect success in making this modification, given that Hwang and Mori have the same arrangement of a silicon/silicon dioxide film at the sidewall. Ex-1003, ¶292. Moreover, this doping could be readily implemented in

Hwang's image sensor, e.g., in the manufacturing steps shown in Hwang's figures 20/21 after applying layer 212a' in grooves 206'. Ex-1003, ¶292.

2. Claim 2: “The device of claim 1, wherein at least one of the backside light trapping material and the peripheral light trapping material reflects light incident thereon back into the pixel.”

First, this limitation is obvious based on Hwang alone, which teaches or suggests *the peripheral light trapping material reflects light incident thereon back into the pixel*, for the reasons discussed for Ground 5, claim 20 above. Ex-1003, ¶239.

Second, this limitation is also obvious based on Hwang in view of Konno, which suggests *the backside light trapping material reflects light incident thereon back into the pixel*, for the reasons discussed for Ground 5, claim 20 above. Ex-1003, ¶240.

3. Claims 3-5, 7-14, 16, 18

These claims are obvious based on Hwang in view of Konno and Mori. Ex-1003, ¶¶297-299, 303-312. The additional limitations of claims 3-5, 7-14, 16, and 18 are identical to those of claims 21-23, 26-30, 19[d], 31-32, 34, 36, and 19[d], respectively (*i.e.*, claim 3 corresponds to claim 21, claim 4 corresponds to claim 22, claim 5 corresponds to claim 23, claim 7 corresponds to claim 26, claim 8 corresponds to claim 27, claim 9 corresponds to claim 28, claim 10 corresponds to claim 29, claim 11 corresponds to claim 30, claim 12 corresponds to claim 19[d], claim 13 corresponds to claim 31, claim 14 corresponds to claim 32, claim 16

corresponds to claim 34, and claim 18 corresponds to claim 36). Hwang in view of Konno teaches or suggest these limitations for the reasons discussed for Ground 5 in Sections §§VII.E.3, VII.E.5-16.

4. Claim 6: “The device of claim 1, wherein the dopant is boron or antimony.”

This limitation would have been obvious based on Hwang in view of Mori. Ex-1003, ¶¶300-302.

It would have been obvious in view of Mori to dope Hwang’s silicon oxide layer (the *low refractive index material*) with p-type impurities—i.e., a p-type dopant. *Supra*, §VII.G.1 (claim 1[c]); Ex-1003, ¶¶301. It further would be obvious to use boron as the p-type dopant, as boron is one of the most commonly used p-type dopants for Si-based systems. *Id. E.g.*, Ex-1018, 27-28 (explaining silicon is commonly doped with Column-III-dopants (e.g., boron)). POSITAs would recognize that using boron as a p-type dopant for silicon-based systems is a known technique that would have yielded predictable results, particularly in light of boron’s similar use as a p-type dopant in other similar light trapping devices. Ex-1003, ¶130. *E.g.*, Ex-1019, [0011] (“silicon substrate doped with a P-type dopant such as boron”). Additionally, using boron would have been obvious to try, as POSITAs would had have a limited number of types of p-type dopants from which to choose. Ex-1003, ¶130.

5. Claim 24-25

These claims are obvious based on Hwang in view of Konno and Mori. Ex-1003, ¶¶313-314. The additional limitations of claims 24-25 are identical to those of claims 1[c] and 6, respectively (*i.e.*, claim 1[c] corresponds to claim 24, and claim 6 corresponds to claim 25). Hwang in view of Konno further in view of Mori teaches or suggest these limitations for the reasons discussed above in this Ground 7, in Sections §§VII.G.1, VII.G.4.

H. Ground 8: Claim 15 Is Obvious Based on Hwang, Konno, Mori, and Shinohara

1. Claim 15: “The device of claim 1, wherein the peripheral light trapping material comprises any of aluminum oxide and hafnium oxide.”

This limitation would have been obvious based on Hwang in view of Konno, Mori, and Shinohara. Ex-1003, ¶¶315-319.

First, base claim 1 is obvious based on Hwang, Konno, and Mori as discussed for Ground 7 above—*i.e.*, it would have been obvious in view of Mori to dope the SiO₂ films in Hwang’s *peripheral light trapping material*.

Second, as discussed for Ground 6 above, Shinohara discloses a *peripheral light trapping material that comprises any of aluminum oxide or hafnium oxide* and explains that such a peripheral light trapping material would help suppress the generation of dark current. *Supra*, §VII.F.1 (claim 33), Ex-1003 ¶¶315-317.

POSITAs would be motivated to use either Shinohara's hafnium oxide or aluminum oxide in Hwang's sidewall multi-layered reflection layer 220a' to reduce dark current. Ex-1003, ¶318. POSITAs would have had an expectation of success in substituting Shinohara's hafnium oxide or aluminum oxide in place of the silicon used as the second sidewall reflection layer 217a' in the Si/SiO₂ layers used in Hwang's sidewall multi-layered reflection layer 220a'. Ex-1003, ¶318. *E.g.*, Suzunaga, [0067] ("[t]he film having a high refractive index is not necessarily limited to a semiconductor material, but may be for example, any one of ... Al₂O₃ ... and the like as depicted in Table 1, and may be combined with a film having a low refractive index, such as SiO₂..."). As discussed above, Shinohara surrounds its negative fixed charge material with a p-type semiconductor layer 43. *See* Ex-1003, ¶318. And as discussed above, Mori's doping process similarly results in a more heavily doped p-type region in the corresponding location. *See* Ex-1003, ¶318. Accordingly, POSITAs would recognize that the modification is structurally compatible. Ex-1003, ¶318.

VIII. DISCRETIONARY DENIAL IS INAPPROPRIATE

The Board should not exercise its discretion to deny institution under 35 U.S.C. §314(a). No other petitions have been filed against the '599 patent, thus the *General Plastic* factors for serial petitions do not weigh against institution. The existence of a parallel ITC proceeding should not be a factor for consideration in determining

whether the Board may exercise its discretion to deny institution. Katherine Vidal, *Memorandum—Interim Procedure for Discretionary Denials in AIA Post-Grant Proceedings with Parallel District Court Litigation*, USPTO (June 21, 2022) at 6-7, https://www.uspto.gov/sites/default/files/documents/interim_proc_discretionary_denials_aia_parallel_district_court_litigation_memo_20220621.pdf. The parallel district court case has been stayed. Discretionary denial is further inappropriate because this petition presents compelling evidence of unpatentability. Accordingly, the *Fintiv* factors should not be applied to deny institution of this proceeding.

IX. CONCLUSION

Petitioner respectfully requests *inter partes* review and cancellation of the Challenged Claims of the '599 patent.

Date: November 29, 2024

Respectfully submitted,

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Petition for *Inter Partes* Review of U.S. Pat. No. 9,905,599

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Claims Appendix

1[pre]. A light trapping device, comprising:

1[a] at least one light sensitive pixel having a light incident surface, a backside surface opposite the light incident surface, and a peripheral sidewall extending at least partially around the pixel periphery;

1[b] a backside light trapping material at least partially covering the backside surface;

1[c] a peripheral light trapping material substantially covering the peripheral sidewall, wherein said peripheral light trapping material is doped with a dopant to create a surface field; and

1[d] a reflective layer coupled to the light incident side and having an aperture to allow entry of light into the pixel;

1[e] wherein the reflective layer is operable to reflect at least a portion of light impinging thereupon from inside the pixel back into the pixel back into the pixel.

2. The device of claim 1, wherein at least one of the backside light trapping material and the peripheral light trapping material reflects light incident thereon back into the pixel.

3. The device of claim 1, wherein said peripheral light trapping material has a refractive index of less than about 2.1.

4. The device of claim 1, wherein said peripheral light trapping material includes a member selected from the group consisting of an oxide, a nitride, oxynitrides, a gas, at least a partial vacuum, and combinations thereof.

5. The device of claim 4, wherein said peripheral light trapping material is selected from the group consisting of silicon oxide, silicon nitride, silicon dioxide, and combinations thereof.

6. The device of claim 1, wherein the dopant is boron or antimony.

7. The device of claim 1, wherein the peripheral sidewall extends completely around the pixel periphery.

8. The device of claim 1, wherein the peripheral sidewall extends from the light incident surface to the backside surface.
9. The device of claim 1, wherein said aperture has an effective surface area of less than about 90% of total area of the incident light surface.
10. The device of claim 1, further comprising a lens functionally coupled to the aperture and operable to focus incident light through the aperture and into the pixel.
11. The device of claim 1, wherein at least one of the backside light trapping material and the peripheral light trapping material is a metal layer.
12. The device of claim 1, further comprising a textured region positioned to interact with light incident thereon to increase quantum efficiency of the device.
13. The device of claim 12, wherein said textured region comprises a textured film layer.
14. The device of claim 13, wherein said textured film layer comprises any of silicon dioxide, silicon nitride, amorphous silicon, polysilicon, a metal and combinations thereof.
15. The device of claim 1, wherein the peripheral light trapping material comprises any of aluminum oxide and hafnium oxide.
16. The device of claim 1, wherein the backside light trapping material substantially covers the backside surface.
17. The device of claim 1, wherein the backside light trapping material completely covers the backside surface.
18. The device of claim 1, wherein said peripheral sidewall extends through the pixel substantially from the light incident surface to the backside surface.
- 19[pre]. A light trapping device, comprising:
 - 19[a] at least one light sensitive pixel having a light incident surface, a backside surface opposite the light incident surface, and a peripheral sidewall extending at least partially around the pixel periphery;

19[b] a backside light trapping material at least partially covering the backside surface;

19[c] a peripheral light trapping material substantially covering the peripheral sidewall;

19[d] a textured region positioned to interact with light incident thereon to increase quantum efficiency of the device; and

19[e] a reflective layer coupled to the light incident side and having an aperture to allow entry of light into the pixel;

19[f] wherein the reflective layer is operable to reflect at least a portion of light impinging thereupon from inside the pixel back into the pixel back into the pixel.

20. The device of claim 19, wherein at least one of the backside light trapping material and the peripheral light trapping material reflects light incident thereon back into the pixel.

21. The device of claim 19, wherein said peripheral light trapping material has a refractive index of less than about 2.1.

22. The device of claim 19, wherein said peripheral light trapping material includes a member selected from the group consisting of an oxide, a nitride, oxynitrides, a gas, at least a partial vacuum, and combinations thereof.

23. The device of claim 22, wherein said peripheral light trapping material is selected from the group consisting of silicon oxide, silicon nitride, silicon dioxide, and combinations thereof.

24. The device of claim 19, wherein said peripheral light trapping material is doped with a dopant to create a surface field.

25. The device of claim 24, wherein the dopant is boron or antimony.

26. The device of claim 19, wherein the peripheral sidewall extends completely around the pixel periphery.

27. The device of claim 19, wherein the peripheral sidewall extends from the light incident surface to the backside surface.

- 28.** The device of claim 19, wherein said aperture has an effective surface area of less than about 90% of total area of the incident light surface.
- 29.** The device of claim 19, further comprising a lens functionally coupled to the aperture and operable to focus incident light through the aperture and into the pixel.
- 30.** The device of claim 19, wherein at least one of the backside light trapping material and the peripheral light trapping material is a metal layer.
- 31.** The device of claim 19, wherein said textured region comprises a textured film layer.
- 32.** The device of claim 31, wherein said textured film layer comprises any of silicon dioxide, silicon nitride, amorphous silicon, polysilicon, a metal and combinations thereof.
- 33.** The device of claim 19, wherein the peripheral light trapping material comprises any of aluminum oxide and hafnium oxide.
- 34.** The device of claim 19, wherein the backside light trapping material substantially covers the backside surface.
- 35.** The device of claim 19, wherein the backside light trapping material completely covers the backside surface.
- 36.** The device of claim 19, wherein said peripheral sidewall extends through the pixel substantially from the light incident surface to the backside surface.

CERTIFICATION OF WORD COUNT

I certify that the foregoing complies with the type-volume limitation of 37 C.F.R. § 42.24 and contains 13,380 words based on the word count indicated by the word-processing system used to prepare the paper, and excluding those portions exempted by § 42.24(a).

Date: November 29, 2024

/ Dave A. Garr /

Dave A. Garr (Reg. No. 74,932)

CERTIFICATE OF SERVICE

Pursuant to 37 C.F.R. §§ 42.6 and 42.105, I hereby certify that the foregoing Petition for *Inter Partes* Review of U.S. Patent No. 9,905,599 under U.S.C. §§ 311–319 and 37 C.F.R. § 42.100 *et seq.*, together with its supporting exhibits, and Power of Attorney was served by Federal Express for Saturday delivery, a means at least as fast and reliable as Priority Mail Express®, on the following correspondence address of record for patent owner:

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