UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SAMSUNG ELECTRONICS CO., LTD., SAMSUNG ELECTRONICS AMERICA, INC., SAMSUNG SEMICONDUCTOR, INC., and SAMSUNG AUSTIN SEMICONDUCTOR LLC,
Petitioners,

v.

W&WSENS DEVICES INC.,
Patent Owner.

Case IPR2025-00994
U.S. Patent No. 11,621,360

PATENT OWNER'S PRELIMINARY RESPONSE

TABLE OF CONTENTS

Page

TABLE OF AUTHORITIES

Page(s)

Cases

Other Authorities

PATENT OWNER'S EXHIBIT LIST

Exhibit	Description
2001	Messages between W&Wsens and Samsung (April 25, 2019 through April 26, 2019)
2002	Messages between W&Wsens and Samsung (April 27-28, 2019, August 14, 2019, February 20, 2020)
2003	Messages between W&Wsens and Samsung (April 27, 2019, August 14-15, 2019, February 20, 2020)
2004	Messages between W&Wsens and Samsung (April 24-25, 2019, May 14, 2019, August 14, 2019, March 3, 2020)
2005	W&Wsens Devices Inc. presentation – Thin Silicon Photosensors for The Next Generation
2006	Excerpts from the file history of U.S. Patent No. 10,348,240
2007	Excerpts from the file history of U.S Patent No. 10,587,095
2008	Excerpts from Plaintiff W&Wsens Devices Inc.'s First Supplemental Objections and Responses to Defendants' First Set of Interrogatories (Nos. 1 and 3), *W&Wsens Devices, Inc. v. Samsung Elecs. Co.*, No. 24-cv-00854-JRG, E.D. Tex., served April 3, 2025
2009	Excerpts from Plaintiff W&Wsens Devices Inc.'s Objections and Responses to Defendants' First Set of Interrogatories (Nos. 1- 3), *W&Wsens Devices, Inc. v. Samsung Elecs. Co.*, No. 24-cv-00854-JRG, E.D. Tex., served March 20, 2025
2010	Photon-trapping microstructures enable high-speed high-efficiency silicon photodiodes, Nature Photonics 11, 301-308 (2017)
2011	U.S. Patent Application Publication No. 2011/0309331 ("Yu-331")
2012	Second Amended Docket Control Order, *W&Wsens Devices, Inc. v. Samsung Elecs. Co.*, No. 24-cv-00854-JRG, Dkt. No. 54 (E.D. Tex. April 22, 2025)

Exhibit	Description
2013	Order, *Resonant Sys., Inc. v. Sony Grp. Corp.*, No. 2:22-cv-00424-JRG, Dkt. No. 84 (E.D. Tex. July 9, 2024)
2014	Order, *Gen. Access Sols., Ltd. v. Cellco P'ship*, No. 2:22-cv-00394-JRG, Dkt. No. 225 (E.D. Tex. May 22, 2024)
2015	Order, *Cal. Inst. of Tech. v. Samsung Elecs. Co.*, No. 21-cv-00446-JRG, Dkt. No. 108 (E.D. Tex. Jan. 20, 2023)
2016	Excerpt from U.S. District Court – National Judicial Caseload Profile Federal for the Eastern District of Texas
2017	Excerpts from Defendants' Supplemental Invalidity Contentions cover pleading, *W&Wsens Devices, Inc. v. Samsung Elecs. Co.*, No. 24-cv-00854-JRG, E.D. Tex., served May 30, 2025
2018	U.S. Patent No. 10,622,498
2019	U.S. Patent No. 9,530,905
2020	Excerpts from file history of U.S. Patent Application No. 17/532,831
2021	U.S. Patent Application Publication No. 2020/0006416 ("Baba")
2022	TechInsight – The state of the art of CMOS Image Sensors, by Ziad Shukri, presented at IISW 2021
2023	PV Education Webpage – Optical Properties of Silicon, available at https://www.pveducation.org/pvcdrom/materials/optical-properties-of-silicon#
2024	Tech Times Webpage – Three types of photodiodes and their structure and operating principles, available at https://techtimes.dexerials.jp/en/photonics/three-types-of-photodiodes/
2025	U.S. Patent No. 11,309,444
2026	Excerpts from file history of U.S. Patent No. 11,309,444

Exhibit	Description
2027	U.S. Patent No. 12,243,948
2028	Excerpts from file history of U.S. Patent No. 12,243,948
2029	Excerpts from "Electrical Engineering Dictionary," by Phillip. A. Laplante, CRC Press LLC 2000
2030	PatDocs Machine Translation of JP3423279B2 to Hiramoto
2031	Wikipedia webpage, "Beer-Lambert law" available at https://en.wikipedia.org/wiki/Beer%E2%80%93Lambert_law
2032	"Understanding the Limits of the Bouguer-Beer-Lambert Law," by T. Mayerhöfer, et al., Spectroscopyonline, available at https://www.spectroscopyonline.com/view/understanding-the-limits-of-the-bouguer-beer-lambert-law, dated 2023-2024
2033	JP3423279B2 to Hiramoto

I. INTRODUCTION

The Board should deny institution of this Petition because the asserted references do not disclose a photodetector device having an "array of pillars" and "in-pillars holes with solid dielectric." These microstructures play a critical role, "increas[ing] photon absorption . . . by at least 1.1 times at selected visible and infrared wavelength ranges . . . compared to a like device lacking [the] in-pillar holes," a claimed property that is also absent from the asserted references.

Silicon photodetectors have many advantages, including high carrier mobility, mature manufacturing processes, and high quantum efficiencies for photoelectric conversion over most of the visible light range. However, because silicon is relatively transparent to red and infrared light, traditional silicon-based photodetectors struggled to achieve acceptable photoconversion efficiency, especially in dim settings. U.S. Patent No. 11,621,360 (Ex. 1001, "the '360 Patent") at 1:62-64. One solution to this problem is to increase the thickness of the photodetector, but this solution comes at the cost of decreased bandwidth in telecommunications applications and confounding manufacturing challenges as pixel dimensions continue to shrink. *Id.* at 1:64-66, 2:6-8. To increase the quantum efficiency of silicon photodetectors, W&Wsens invented microstructured pillars and

holes in thin silicon photodetectors, which dramatically improved their sensitivity in low-light situations.[1]

Kuboi, the primary reference cited against the Challenged Claims 1, 3, 5, and 6 in Ground 1, does not disclose an "array of pillars" or "in-pillar holes" because it takes an altogether different approach to this problem. Rather than introducing microstructures to enhance the efficiency of a silicon-based photodetector, Kuboi proposes a hybrid photodetector that replaces silicon with ***organic films*** that perform the photoconversion. Although Samsung likens these organic films to the "microstructures" disclosed and claimed in the '360 Patent, they are nothing of the sort. Kuboi's organic film features do not increase photon absorption in a silicon-based photodetector, like the microstructured pillars and holes of the '360 Patent do, Kuboi's organic films themselves perform the photodetection. The other asserted references also fail to disclose these structures and, therefore, cannot render obvious the Challenged Claims. Thus, institution should be denied.

Although there are a variety of reasons why the '360 Patent is valid over Kuboi, Yu, and Shinohara, this Preliminary Response focuses on only limited

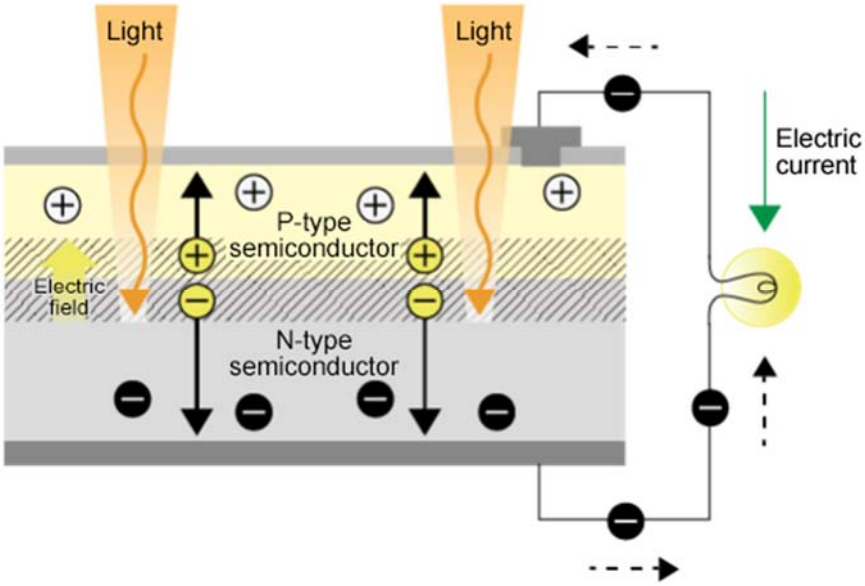
[1] "[Q]uantum efficiency η is defined as the number of photo-generated electron–hole pairs, which contribute to the photocurrent, divided by the number of the incident photons." Ex. 1070 at 25.

reasons why *inter partes* review should not be instituted. *See Travelocity.com L.P. v. Cronos Techs., LLC*, No. CBM2014-00082, Paper 12 at 10 (P.T.A.B. Oct. 16, 2014) ("[N]othing may be gleaned from the Patent Owner's challenge or failure to challenge the grounds of unpatentability for any particular reason.").

II. OVERVIEW

A. There Was a Long-Felt Need to Increase the Sensitivity of Thin-Silicon Photodetectors

There was a long-felt need to increase the effective absorption coefficient of thinner silicon to shrink pixels. *See* '360 Patent at 8:4-22, 13:40-48. Each pixel in an active-pixel sensor (APS), like a CMOS (Complementary Metal-Oxide-Semiconductor) or CCD (Charge-Coupled Device) sensor, has an array of photodetectors and one or more active transistors. The photodetectors convert light into electricity that can be stored as a signal and read by a computer. These signals measure the amount of light in a scene and, in combination, can be used to create an image. The cells of CMOS sensors are generally made from semiconducting silicon.



Ex. 2024 at 4 (showing schematic of photodiode structure).

To improve device performance, CMOS sensor designers are increasing pixel count and shrinking individual pixel size so that more pixels fit on the sensor and resolution rises. As the distance between adjacent pixels—pixel pitch—decreases, chip designers have been increasing the active silicon thickness of the photodiode region to preserve light absorption and maintain image quality.

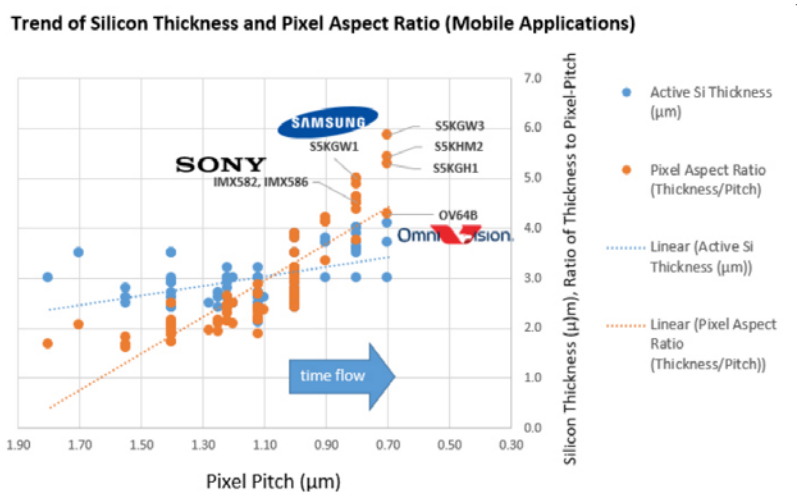
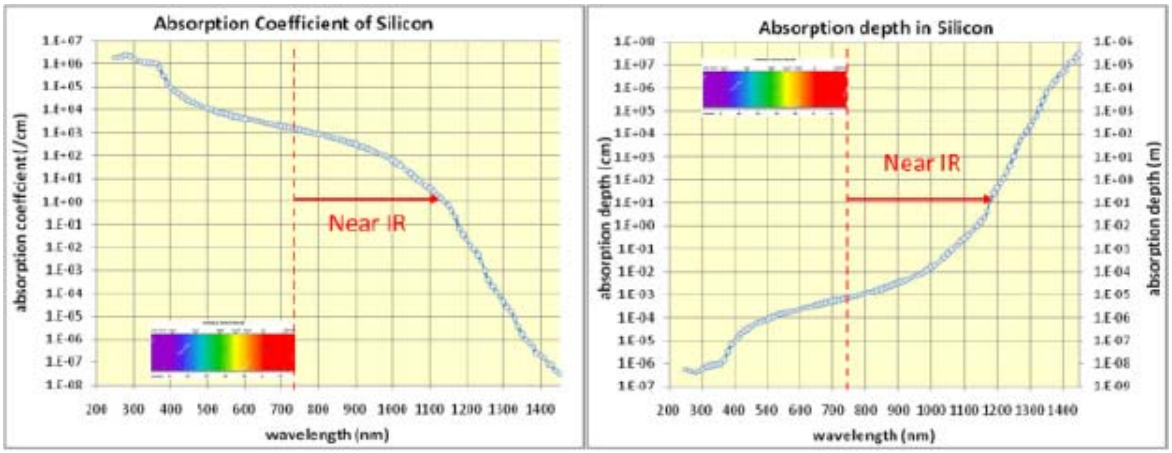


Figure 3 Trend of silicon thickness to pixel pitch ratio.

Ex. 2022 at 8, Fig. 3 (2021 International Image Sensor Workshop by TechInsights) (showing the trend of decreasing pixel pitch and active Si thickness over time).

Prior to W&Wsens' inventions, these trends had created significant challenges in ensuring sufficient light sensitivity and absorption, particularly when pixel dimensions shrunk to 1µm and below. Specifically, long-wavelength light (red to infrared) corresponds to silicon's indirect bandgap, which necessitates a relatively thick silicon layer to achieve acceptable sensitivity and absorption. '360 Patent at 1:64-2:8. For example, for wavelengths longer than 730nm, a thickness of at least 10µm of silicon would be necessary to absorb more than 64% of the incident light:



Ex. 2023 at 2-3 (annotations added) (illustrating silicon's decreasing ability to absorb longer wavelength light).

Fabricating silicon devices with such thickness while maintaining the smaller lateral dimensions of the pixels used in higher resolution CMOS sensors in the 1µm scale led to difficulties, including lower yield and increased costs for the CMOS sensors. Further reduction in pixel size requires a thinner absorption region, but

thinning this region reduces detection efficiency, especially for light with wavelengths in the red to infrared part of the spectrum. Materials other than silicon, such as indium gallium arsenide (InGaAs), are relatively expensive and have high multiplication noise when compared with silicon. '360 Patent at 2:19-21; Ex. 1070 at 7 ("Silicon photodectectors [sic] and receiver OEICs, therefore, are the only choice when high volumes are needed and the price has to be low as, for instance, in consumer electronics.").

Thus, there was a long-felt need to increase the effective absorption coefficient of thinner silicon to shrink pixels while increasing photosensitivity. '360 Patent at 1:51-2:21, 8:4-22.

B. The '360 Patent Uses Microstructures to Increase the Sensitivity of Thin-Silicon Photodetectors

To overcome the limitations of conventional silicon CMOS sensors, W&Wsens' inventions use microstructures in the surface of light-sensitive silicon photodetectors of CMOS sensors. These microstructures, such as pillars and holes, improve the silicon's photosensitivity without the need for a thicker silicon absorption layer, which results in telecommunications bandwidths over 10 Gb/s for 850 nm wavelength light and photodetector quantum efficiencies exceeding 90%. '360 Patent, Abstract, 9:66-10:9, 10:47-54, 11:32-37, 15:14-23.

This result is counterintuitive because the presence of holes reduces the amount of photosensitive silicon material available to absorb incident light, which

would have been expected to reduce light absorption. Yet the '360 Patent's photodetector device ultimately enhances the effective absorption length of the thin silicon because light interacts with the absorbing silicon layers for a longer length of time, which is equivalent to using a thick silicon layer. *Id.* at 8:4-22, 8:57-67. To capitalize on this invention, the '360 Patent claims "a photodetector device," such as the "high-speed high efficiency microstructured photodiode 520" of Fig. 5B, which has "a laterally extending array of pillars" and "deliberately formed in-pillar holes with solid dielectric," an example of which is depicted in Fig. 49 reproduced below:

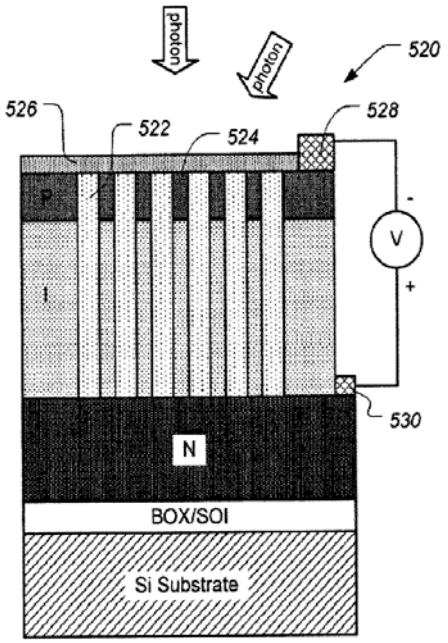


FIG. 5B

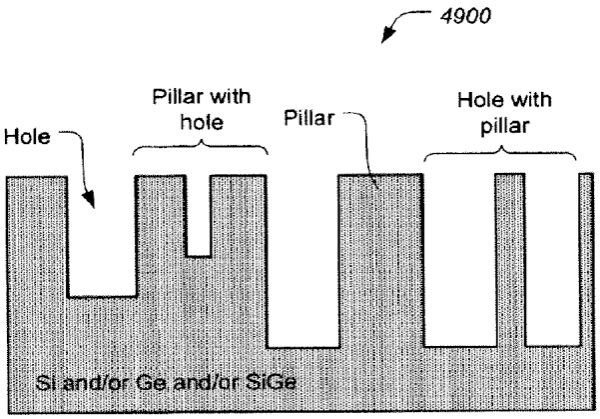


FIG. 49

'360 Patent, Fig. 5B; *see id.* at 55:8-13 (Claim 1), 15:48-50, 15:64-16:48 (explaining embodiment in Fig. 5B), 55:33-34, Fig. 49 (depicting an example "Pillar with hole"); *see also id.* at 49:40-50:21.

This novel structure and arrangement of the "pillars, in-pillar holes, and solid dielectric between . . . sidewalls of adjacent pillars of [the] array of pillars" result in a marked increase in photon absorption compared to other photodetectors lacking these in-pillar holes. *Id.* at 55:47-53 (Claims reciting an "increase [in] photon absorption of said device of incident light by at least 1.1 times at selected visible and infrared wavelength ranges of said incident light compared to a like device lacking said one or more in-pillar holes"); *id.* at 12:36-42.

C. The Examiner Expressly Found the Prior Art Lacked "In-Pillar Holes" During Examinations of the '360 Patent and its Parent

The Examiner found that the prior art lacked "in-pillar holes" during prosecution of the '360 Patent and its parent, the '444 Patent.[2] Specifically, in the '360 Patent's Reasons for Allowance, the Examiner stated that the prior art of record "failed to anticipate or render obvious: a photodetector device formed in or on a

[2] The '360 Patent is a divisional application of U.S. Patent Application No. 17/532,831, filed on November 22, 2021, which issued as U.S. Patent No. 11,309,444 ("the '444 Patent") on April 19, 2022. '360 Patent, Cover (60); Ex. 2025, Cover; Ex. 1003 at 283 (Filing Receipt).

semiconductor substrate and provided with ***deliberately formed in-pillar holes comprising a laterally extending array of pillars with specific structures and characteristics***, *inter alia,* as found in claim [1]." Ex. 1003 at 105-106 (emphasis added).

The examination of the '360 Patent's parent divisional (the '444 Patent) is also informative for why the Petition's challenge is cumulative over the prior art cited during examination. The '444 Patent's examination is relevant because the claims of the '444 Patent recite similar novel features as those recited in the '360 Patent, including "laterally extending array of pillars," and "in-pillar holes." Ex. 2025 at 55:9-10, 55:17-19. The Examiner for the '444 Patent explained in the Reasons for Allowance that the prior art does not teach a photodiode having in-pillar holes filled with dielectric or the claimed pillar pitch and dimensions:

> [T]he prior art discloses a P-I-N diode device for converting light photons into electrons but fails to disclose the specific characteristic recited in the claims of the instant invention e.g. the combination of claimed features ***in conjunction with the dielectric filled "in-pillar holes",*** the particularly claimed pillar pitch and pillar dimensions.

Ex. 2026 at 10 (emphasis added). As an example of his consideration of the prior art of record, the Examiner listed Hsu et al. (U.S. Patent No. 7,525,170) as its

Relevant Prior Art, and explained how Hsu "show[ed] P-I-N diode pillars, but lacks many of the further claimed features, including the 'in-pillar holes'":

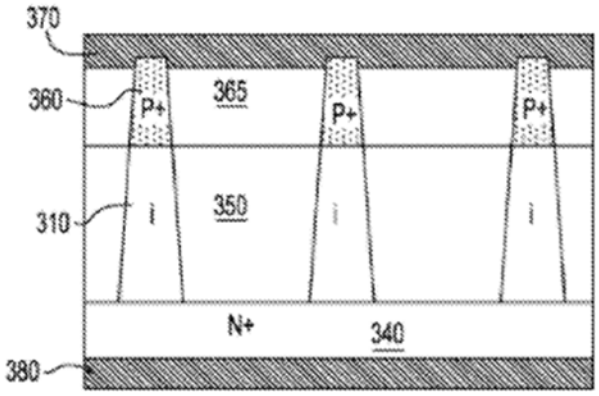
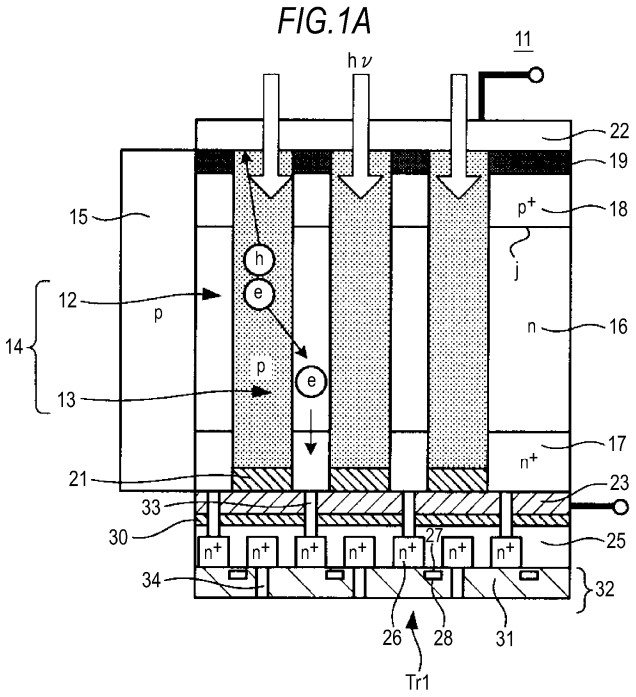


FIG. 5H

Id. at 4 (citing Hsu, Fig. 5H). Thus, both the '360 Patent and its parent divisional '444 Patent were distinguished over the prior art for the Claims' specific recitations of "array of pillars" and "in-pillar holes."

D. Kuboi Does Not Disclose a Microstructure-Enhanced Photodetector Device

Kuboi (Ex. 1004) does not disclose a photodetector device enhanced by microstructures, such as pillars and holes, as is required by the Challenged Claims. Kuboi is instead directed to a "solid-state imaging device" that includes photodetectors with a "hybrid photoelectric conversion portion 14" having "organic material layers 13" embedded in a silicon "semiconductor layer 12." Kuboi at [0001], [0055].

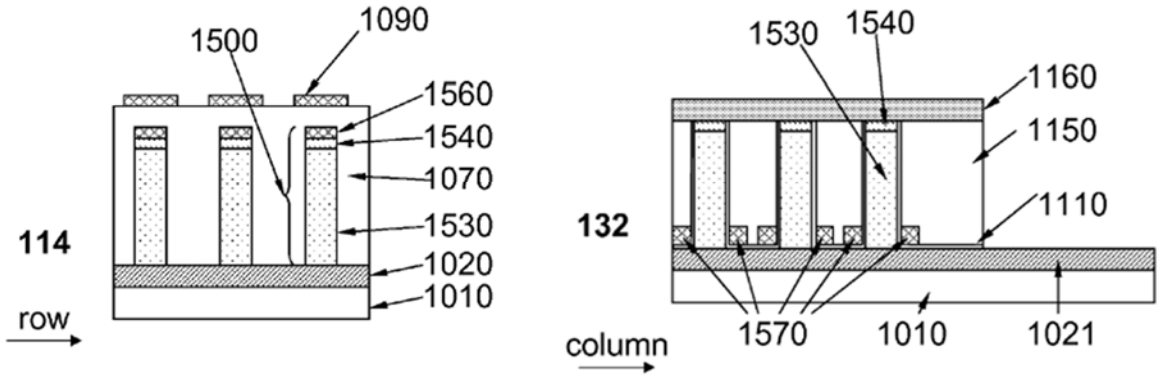


Id., Fig. 1A (showing Kuboi's hybrid structure).

Unlike the photon-absorbing, silicon-based image sensors claimed by the '360 Patent, Kuboi's imaging device is configured so that "[t]he organic material layer 13 is [the] region where photoelectric conversion is performed," rather than its silicon semiconductor layer 12. *Id.* at [0057]. Accordingly, for reasons described in greater detail below, Kuboi does not disclose a microstructure enhanced photodetector device, because it does not utilize any types of microstructures, such as an "array of pillars" or "in-pillar holes," to enhance its imaging device.

E. Yu Describes Nanopillars But Not In-Pillar Holes

Yu (Ex. 1050) does not disclose "in-pillar holes." It is limited to an image sensor with "pixels" that include "at least one nanopillar." Yu at Abstract, [0048].



Yu, Fig. 1, Steps 114 and 132 (showing an image sensor with nanopillars 1500).

The Examiner already considered Yu's teachings during prosecution of the '360 Patent because a cumulative reference, U.S. Patent Publication No. 2011/0309331 to Yu ("Yu-331", Ex. 2011), was cited and considered by the Examiner. Ex. 1003 at 227 (Form-892); Ex. 2011 at [0001] (incorporating Yu); *see* Paper 10 at 17-18 (PO's Request for Discretionary Denial).

The Office has also already highlighted the differences between Yu/Yu-331 and the '360 Patent's family of patents. Specifically, the Office expressly considered Yu and Yu-331 during examination of a related W&Wsens patent, U.S. Patent No. 12,243,948 (Ex. 2027, "'948 Patent").[3] Ex. 2028 ('948 Patent File History) at 13-14, 24, 28-29 (Yu "20120153124" listed repeatedly in examiner's search history); *id.* at 34, 37 (Yu-331 marked as considered). The '948 Patent's examination is

[3] The '948 Patent is the subject to pending post-grant review petition PGR2025-00082, filed by Petitioners.

relevant because the claims of the '948 Patent recite similar novel features as those recited in the '360 Patent, including "array of pillars," "one or more holes," and an "increase[] by a factor of at least 1.1 the absorption of the light." Ex. 2027 at 55:39-42, 55:48-50, 55:64-67. During the '948 Patent's examination, the Examiner explained that the '948 Patent was patentable over Yu/Yu-331 because Yu/Yu-331 did not disclose the claimed microstructures:

> [T]he prior art of [Yu-331] discloses in Fig. 5 . . . pillar shaped photodetector devices, but fails to disclose the specific characteristic recited in the claims of the instant invention, e.g. the combination of claimed features of an ***array of pillars*** with particular material composition and NP junction sensitive to visible and infrared wavelengths, ***one or more holes*** that are fabricated as recesses at or under the light receiving surface of at least some of the pillars, wherein at least some of the holes are elongated along the respective light receiving surfaces, side isolation, solid dielectric forming base dielectric, electrical contacts and ***the presence of the holes increase absorption by a specific amount***.

Ex. 2028 ('948 Patent File History) at 6 (emphasis added).

As such, the examinations of the '360 Patent's family of patents confirm that Yu and Yu-331 fail to disclose "in-pillar holes" that increase the light absorption properties of the claimed photodetector device.

F. Shinohara Does Not Cure the Deficiencies in the Primary References Kuboi and Yu

Shinohara (Ex. 1005) discloses an imaging device having a "backside illuminated structure" including "an element isolation region isolating the pixels." Shinohara, Abstract. Shinohara is relied upon by the Petition for allegedly disclosing "a solid dielectric insulating film" and a "monolithic integration of the array of pillars (or pixels) with electronic circuits that include active elements for signal processing and transmission." Pet. at 16, 19, 26-30 (limitation [1b.1]), 43-47 (limitation [1f]), 66-69 (limitation [1i]); *id*. at 76, 99 (limitation [1i]). However, Samsung does not contend that Shinohara teaches any of the microstructure claim limitations of the Challenged Claims that are missing from Kuboi and Yu.

III. SAMSUNG'S CHALLENGE AND ASSERTED REFERENCES

The Petition presents the following grounds:

Ground	Claims	Basis	References
1	1, 3, and 5-6	§ 103	Kuboi and Shinohara
2	1 and 8-9	§ 103	Yu
3	1 and 8-9	§ 103	Yu and Shinohara

Pet. at 8.

IV. LEVEL OF ORDINARY SKILL IN THE ART

For purposes of this Preliminary Response, W&Wsens adopts Samsung's definition of a person of ordinary skill in the art: "A person of ordinary skill in the art ("POSITA") would have had at least a master's degree in electrical engineering or a similar field and at least two years of experience working with semiconductor systems and semiconductor devices . . . Additional relevant work experience can compensate for less education, and vice versa." *Id*. at 8.

V. THE CHALLENGED CLAIMS ARE PATENTABLE

A. Kuboi Does Not Disclose Microstructure "Pillars" or "In-Pillar Holes" (Ground 1)

Ground 1 fails because Kuboi does not disclose "pillars" or "in-pillar holes," which the '360 Patent describes as microstructures that "effectively increase the effective absorption length resulting in a greater absorption of the photons." '360 Patent at Abstract, 7:63-8:33, 8:57-67. The express language of the Challenged Claims requires that the photodetector include both an "array of pillars" and "deliberately formed in-pillar holes with solid dielectric therein." *Id.* at 55:9-13, 55:33-34 (Claim 1). Kuboi does not disclose either.

1. Samsung Has Not Met Its Burden to Identify Pillars That Enhance Photon Absorption in Kuboi

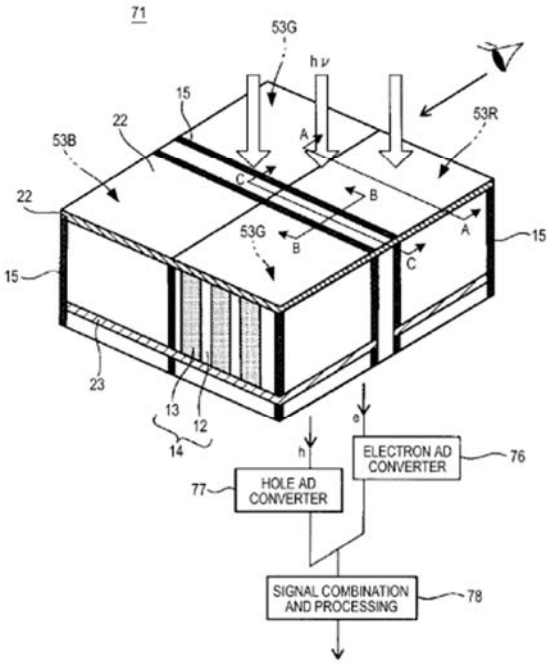
The Board should deny institution because Samsung has not met its burden to identify pillars that "increase photon absorption . . . of incident light" in the Kuboi reference. '360 Patent, Claim 1; 37 C.F.R. § 42.104(b)(4). The "red, blue, . . . and

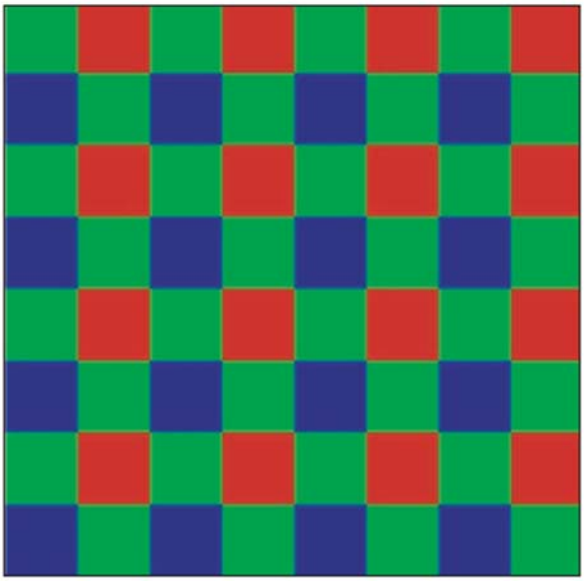
green pixels" of Kuboi's imaging device are not "pillars," as the term is understood in the context of the '360 Patent, because they are not microstructures that "increase photon absorption of said device of incident light . . . compared to a like device lacking said one or more in-pillar holes." *See* Pet. at 24 (contending that "each pixel constitutes a pillar"); '360 Patent, Claim 1.

As claimed, "pillars" and "in-pillar holes" are structures that enhance the operation of silicon-based photodetectors by "increas[ing] photon absorption . . . of incident light." '360 Patent at Claim 1; *see also id.* at 7:63-8:33, 8:57-67. The claims are, thus, fully consistent with the specification, which describes pillars and holes as microstructures that enhance the efficiency of photodetectors compared to like devices without microstructures. *See id.* at Abstract ("microstructures, ***such as pillars and/or holes***") (emphasis added); *id.* at 8:52-56 (defining "microstructures" and "microstructured"); *id*. at 11:52-12:5 (describing microstructure that "enhance bulk absorption coefficient in photo sensitive devices"); *id.* at 49:40-59 (describing the pillars and in-pillar holes as configured "to optimize enhancement of the absorption coefficient, light trapping" and other effects). Thus, the claimed "pillars" and "in-pillar holes" are structures of the photodetector that enhance the photo absorption properties of the device.

Rather than disclosing photon-absorption enhancing pillars, Kuboi discloses an array of ***pixels*** organized into the well-known "Bayer arrangement":

FIG.13



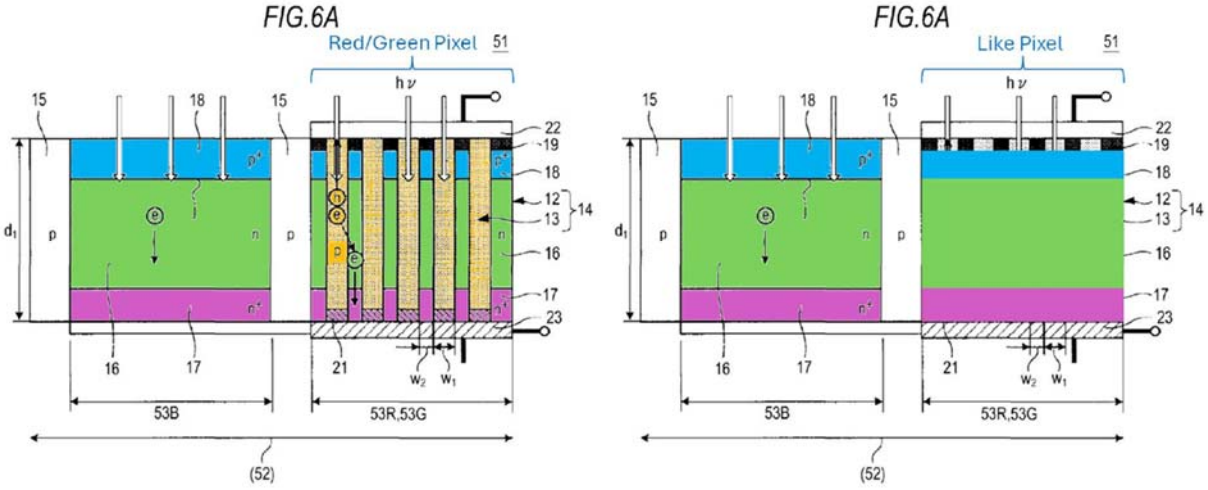


2. The color filter array Bayer pattern.

Kuboi, ¶ [0181] ("[A] group of red, blue, green, and green pixels corresponding to the Bayer arrangement are arranged in a two-dimensional array as shown in FIG. 13."); *id.* at Fig. 13; Ex. 1012 at 2 (2005 article illustrating and discussing the Bayer pattern).

Such pixel arrays represent the baseline technology that W&Wsens' technology improved upon and do not include any "pillars" that "increase photon absorption," as claimed. '360 Patent, Claim 1. Indeed, in focusing solely on Kuboi's organic films (the alleged "holes") increase photon absorption, Samsung ignores that the claims require the "***pillars***, in-pillar holes, ***and*** solid dielectric" all to "increase photon absorption." *See* Pet. at 51-63. Accordingly, when comparing Kuboi's

device to hypothetical "like" devices, Samsung points to no difference in the alleged "pillars" that accounts for increased photon absorption:

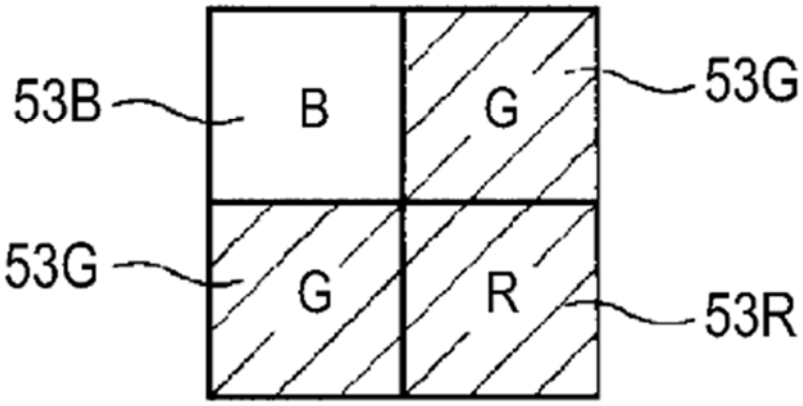


Id. at 53. Samsung has, therefore, failed to "specify where each element of the claim is found in the prior art patents or printed publications relied upon" because it does not allege that the alleged pillars (*i.e.* Kuboi's pixels) play any role in increasing photon absorption when compared to "a like device lacking said one or more in-pillar holes," as claimed. 37 C.F.R. § 42.104(b)(4); '360 Patent, Claim 1.

2. Kuboi Does Not Disclose Pillars or In-Pillar Holes

Petitioner's failure to identify any "pillars" that "increase photon absorption" is consistent with Kuboi's failure to disclose such pillars. Kuboi discloses an imaging device with "a pixel region 52 in which a group of pixels made up of a blue (B) pixel 53B, a red (R) pixel 53R, a green (G) pixel 53G." Kuboi [0090], Figs. 6A/6B.

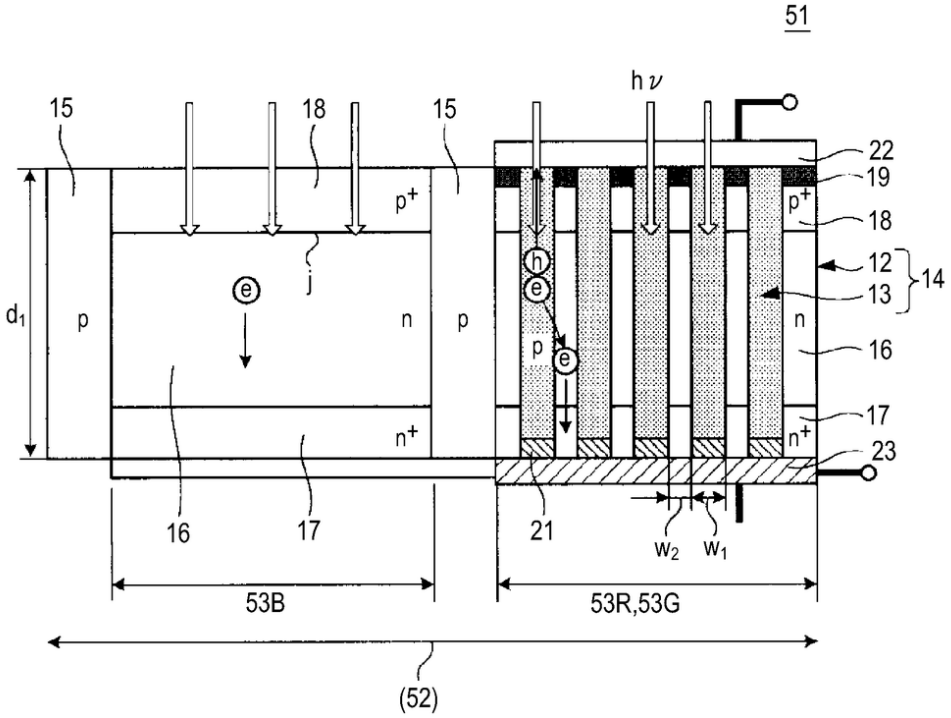
FIG.6B



Kuboi, Fig. 6B.

These pixels do not form an "array of pillars" and do not have "in-pillar holes," as recited in the Challenged Claims. The blue pixel 53B in this array performs conventional silicon-based photoelectric conversion, and the red and green pixels 53R and 53G have the "hybrid photoelectric conversion portion[s]" with organic layers. Kuboi, [0090] ("[B]lue pixel 53B is formed by a photoelectric conversion portion which is formed of a photodiode PD formed in a silicon semiconductor region, and the red pixel 53R, the green pixel 53G, and the green pixel 53G are formed by the hybrid photoelectric conversion portion 14 shown in FIGS. 1A and 1B."). These two pixel types are shown side by side in Fig. 6A.

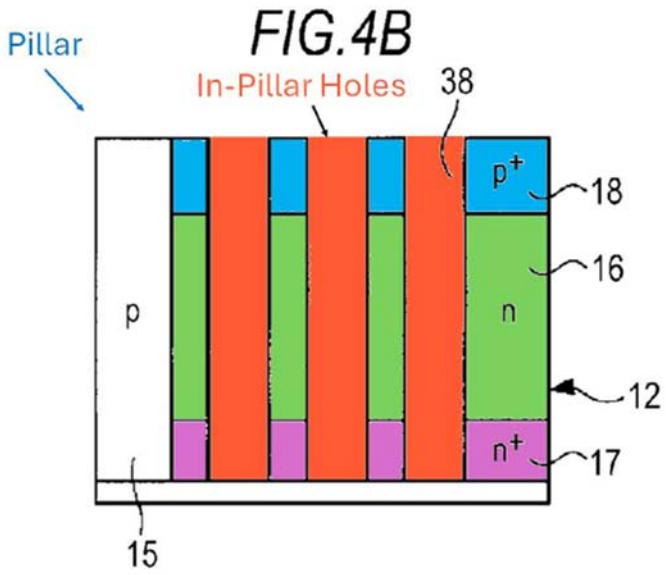
FIG.6A



Kuboi, Fig. 6A.

Both types of pixels in Kuboi fail to satisfy the "array of pillars" required by the claims. Kuboi's blue pixel 53B does not constitute a "pillar" because it contains ***no*** structures that improve or increase photon absorption. Rather, the blue pixel *is* the entire photoelectric conversion portion. Kuboi, [0090] ("[A] photoelectric conversion portion which is formed of a photodiode PD formed in a silicon semiconductor region."). Kuboi's red and green pixels are not "pillars" for the same reason that the blue pixel is not a "pillar": the pixel itself is not a structure that increases photon absorption.

Because Kuboi fails to disclose an array of pillars, it also does not disclose "in-pillar holes," as claimed. Pet. at 37 (citing Kuboi, [0072], [0013]-[0014], [0067], [0095]).



Id. at 37-38 (citing Kuboi, Fig. 4B (annotated)) (alleging that "holes 38" of Kuboi constitute "in-pillar holes"). As noted above, the blue pixel 53B does not include any structures that increase photon absorption, which is consistent with the Petition's failure to allege that Kuboi's blue pixel 53B includes "in-pillar holes." *Id*. at 37-39 (limiting discussion of in-pillar holes to only the pixel with organic hybrid photoconversion). Kuboi's red and green pixels also do not disclose in-pillar holes at least because the alleged holes are not formed in a pillar.

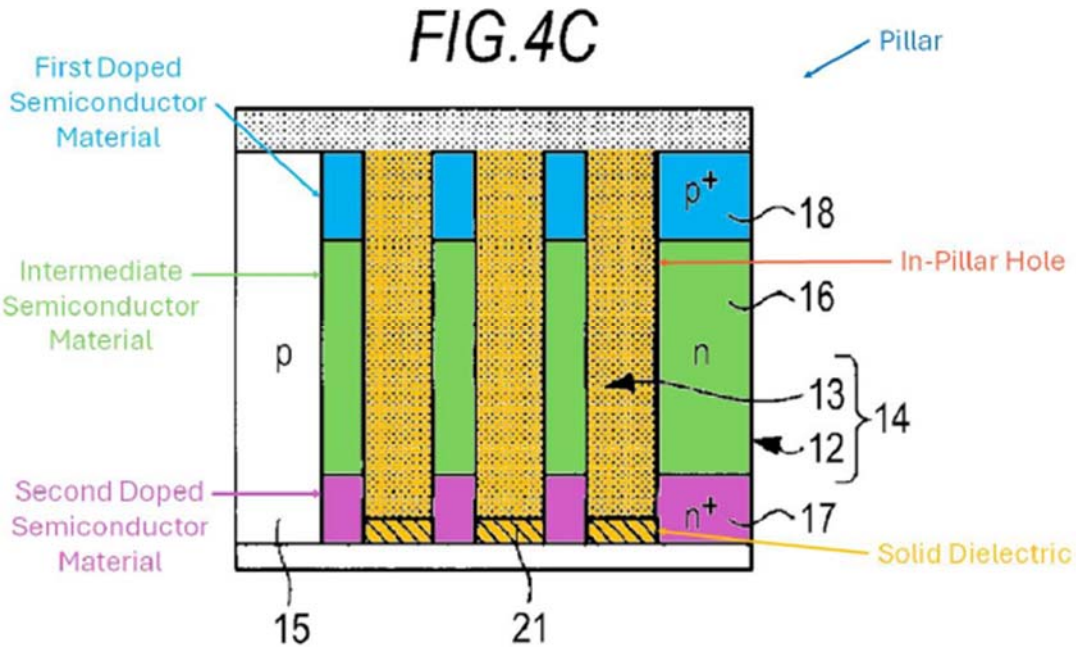
Moreover, as discussed in detail below, Kuboi's red and green pixels operate according to an entirely different principle than Kuboi's blue pixel 53B and the invention claimed in the '360 Patent. *See infra* § V.C. Rather than Kuboi's alleged

holes "increase[ing] photon absorption in the device," as claimed, Kuboi relies on an entirely different material system with a device that performs photoelectric conversion using organic layers while blocking light from entering the silicon-based semiconductor layers with a light shielding film 19. Kuboi, [0091].

The Board should, therefore, deny institution because Kuboi does not disclose an "array of pillars" or "in-pillar holes," as recited in each of the Challenged Claims.

B. Kuboi Does Not Disclose Holes with Solid Dielectric Therein (Ground 1)

Kuboi also fails to disclose "in-pillar holes with solid dielectric therein" because Kuboi's holes 38 are not filled with solid dielectric. The Petition cites to an "electron blocking film 21," as the purported dielectric. Pet. at 38-39 (quoting Kuboi, [0073]).



Id. at 39 (citing Kuboi, Fig. 4C (annotated)).

But as Samsung admits, this element is only "formed on the bottom portions of the vertical holes 38" and does not fill the entire hole 38. Pet. at 38. So, to claim that the holes are "entirely fill[ed]" with dielectric, Samsung takes the untenable position that Kuboi's ***organic semiconductor materials*** ("perylene-based compounds, phthalocyanine compounds, quinacridone compounds, porphyrin compounds, merocyanine compounds") are dielectric materials. *Id*. at 39 (quoting Kuboi at [0058])). They are not.

The term "dielectric material" is well-understood in the art to mean an ***insulator*** that can be polarized in an electric field:

> **dielectric** (1) a medium that exhibits negligible or no electrical conductivity and thus acts as a good electrical insulator. (2) a medium characterized by zero conductivity, unity relative permeability, and a relative permittivity greater than one. Also known as an insulator.

Ex. 2029 at 3 (Electrical Engineering Dictionary); *see also id*. at 4 ("**dielectric medium** medium that is polarizable but relatively nonconducting"). Samsung's own extrinsic evidence confirms this. *See* Ex. 1063 at 20 ("Dielectric layers such as silicon dioxide and silicon nitride are used for insulation between conducting layers, ..."). Dielectric materials, like all insulators, are not suitable for photoconversion because they lack the necessary band structure to create signal charges when

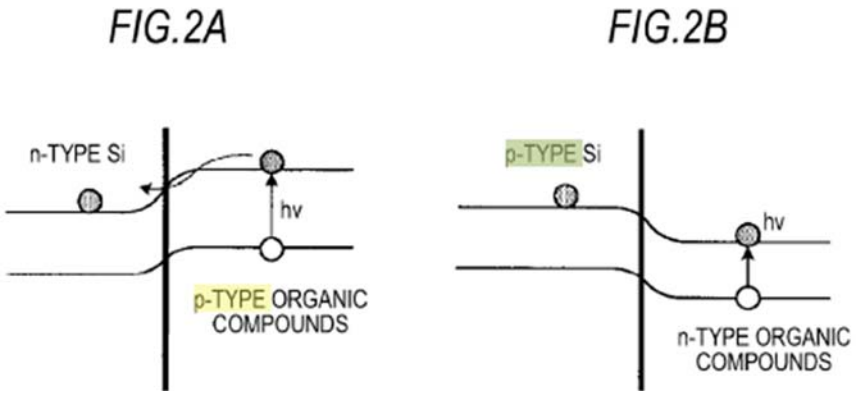
illuminated. Ex. 1070 at 22-25 (discussing optical absorption and photogeneration in ***semiconductor materials***).

References cited in Kuboi's background further establish that organic photoconversion films are ***semiconductors***, not dielectric materials. *See, e.g.*, Kuboi, [0005] (citing Ex. 2030 (JP Patent 3423279), "Hiramoto"). Kuboi cites Hiramoto as disclosing a "method of effectively extracting electrons generated by photoelectric conversion using an organic film made of two kinds of organic materials." Kuboi, [0005]. Accordingly, Kuboi states that its organic layers may include "***perylene***-based compounds, ***phthalocyanine*** compounds," (Kuboi, [0058]), and Hiramoto discloses that those layers are semiconducting. Ex. 2030 at 6 ("A preferable example of the ***organic semiconductor layer*** is a co-evaporated thin film of a ***phthalocyanine*** pigment and a ***perylene*** pigment."); *see also id.* at 5 ("[A]n organic ***semiconductor*** thin-film solar cell having a structure in which co-deposited thin films of two kinds of organic semiconductors are sandwiched between electrodes.") (emphases added); Ex. 2033. Therefore, Kuboi's organic films are semiconductors, not dielectrics.

In view of the foregoing, the Board should reject Dr. Lebby's claim that a "POSITA would have understood that phthalocyanine, perylene-based, and porphyrin compounds are solid dielectrics" as plainly erroneous and as contradicted by the cited reference itself. Pet. at 39 (citing Lebby Decl., ¶¶ 158-159). Dr. Lebby's

opinion is based on the plainly incorrect notion that any material with a "dielectric constant" or "dielectric properties" is a dielectric material. Ex. 1002, ¶ 159. The term "dielectric constant" merely refers to "an electric property of an insulator or semi-conducting material, which describes how differently electric fields will behave inside of the material as compared to air." Ex. 2029 at 3-4 (Electrical Engineering Dictionary) (definition of "dielectric constant"). Notably, Dr. Lebby did not make this mistake when opining that "silicon oxide and silicon nitride films are dielectric materials." Lebby Decl., ¶ 120. In that part of his opinion, Dr. Lebby acknowledges that these materials are dielectric materials because they are insulators. *Id*.

As shown below, Kuboi confirms that its organic films are semiconducting by characterizing them as p-type or n-type materials and explaining that they carry signal charges. *See, e.g.*, Kuboi, ¶¶ [0055], [0056], [0085]. By definition, organic semiconductors that are doped to be p-type or n-type and that carry signal charges are not dielectric materials because they are not insulators. Ex. 2029 at 3 (Electrical Engineering Dictionary) (definition of "dielectric").



Kuboi, Figs. 2A and 2B (annotated); *see also, e.g., id.* at [0057] ("In this example, since signal charges are electrons, the organic photoelectric conversion film 13 is formed of a p-type organic material."); [0058] ("As the p-type organic material, organic compounds which have a desired absorption band and satisfy an energy band structure shown in FIG. 2A described later are used."); [0085] ("The organic photoelectric conversion film 13 is formed by an n-type organic material. As the n-type organic material, organic materials such as, for example, naphthalene-based compounds, perylene-based compounds, and C60 can be used.").

For these reasons, Kuboi fails to disclose the claimed "one or more deliberately formed in-pillar holes with solid dielectric therein."

C. Kuboi Does Not Disclose a "Photodetector Device [that] is Configured to Respond to Light Photons Incident on Said Array of Pillars by Photo-Generated Charge Carriers" (Ground 1)

Kuboi does not disclose a "photodetector device [that] is configured to ***respond to light photons incident on [the] array of pillars*** by photo-generated charge carriers therein." '360 Patent at 55:36-39 (emphasis added). The claimed

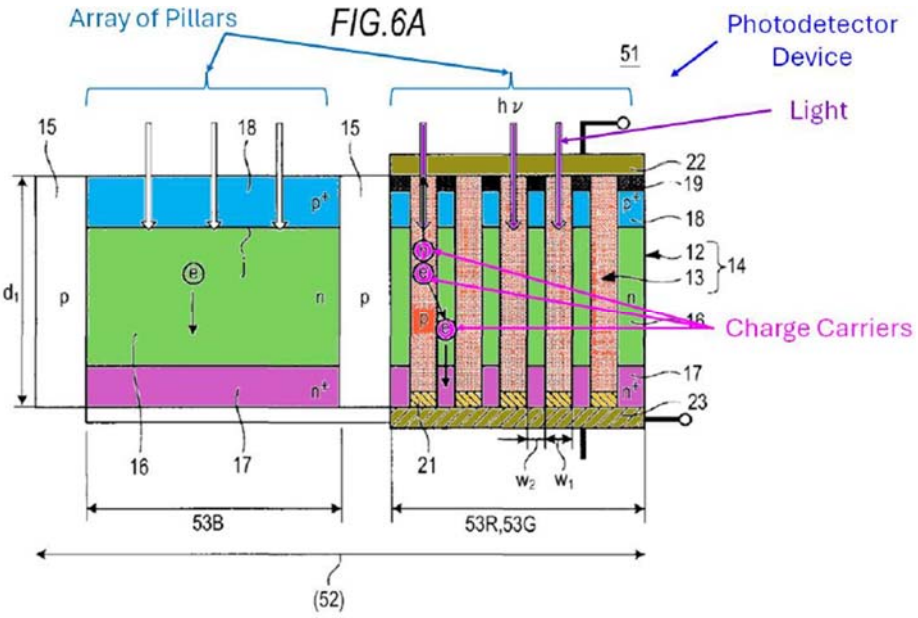
array of pillars must be formed from at least silicon. *Id.* at 55:30-32 ("each of the first and second doped semiconductor materials and said intermediate semiconductor material ***comprises Si***") (emphasis added). Accordingly, the Challenged Claims all require a silicon-based photodetector device that has photosensitive semiconductor materials designed to absorb photons and generate electrical output ("photo-generated charger carriers.")

Kuboi itself distinguishes solid-state imaging devices "having a silicon based photodiode," such as those claimed by the '360 Patent, and those "in which an organic material layer is used as the photoelectric conversion portion." Kuboi at [0002]-[0004]. The '360 Patent claims the former, and Kuboi is limited to the latter. Specifically, rather than use microstructures to enhance photon absorption in the silicon-based semiconductor layers of the photodetector, Kuboi proposes a "hybrid" photodetector, where electron-hole pairs are generated in organic material layers ***instead of*** the silicon-based semiconductor layers.

> The hybrid photoelectric conversion portion is configured so that charges generated in the organic material layers through photoelectric conversion move inside the semiconductor layer so as to be guided to a charge accumulation region.

Kuboi at [0011]. Thus, Kuboi distinguishes its organic material layers, which generate charges, from the semiconductor layer, which guides the charges to the

accumulation region. This arrangement is illustrated in Samsung's annotated Kuboi Fig. 6A, where light is incident only on "organic material layers 13":



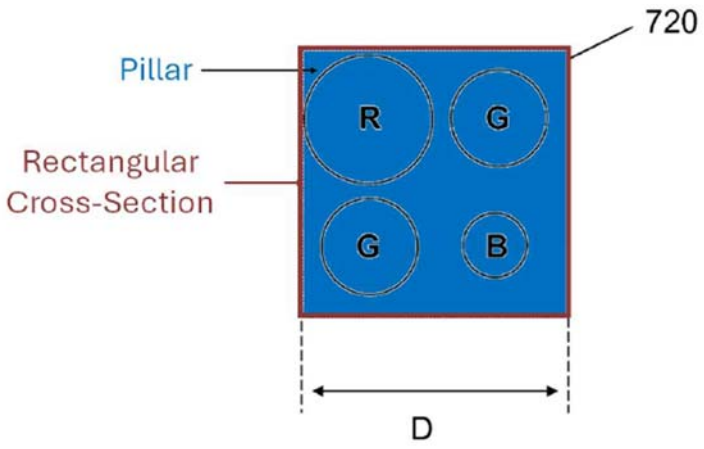
Pet. at 42 (citing Kuboi, Fig. 6A (annotated)). Kuboi goes so far as to use a "light shielding film 19" on the surface "so that light hv does not enter the semiconductor layer 12," further confirming that Kuboi's semiconductor layer does not act as an absorption layer that "respond[s] to light photons incident on said array of pillars by photo-generated charge carriers therein." Kuboi at [0059], [0064] ("The light hv does not enter the semiconductor layer 12 due to the light shielding film 19."); '360 Patent at 55:37-39 (Claim 1).

Kuboi's imaging device does not, therefore, respond to light photons incident on the alleged array of pillars by photo-generated charge carriers. Pet. at 41-42. Instead, Kuboi's "photoelectric conversion films 13" (the alleged microstructures) are the elements that themselves perform photoelectric conversion. Kuboi at [0057]

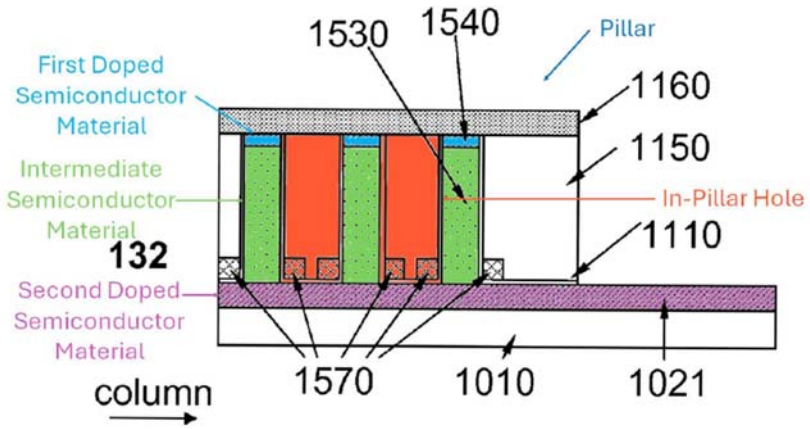
(organic material layers 13 are "where photoelectric conversion is performed"); *id.* at [0012] ("hybrid photoelectric conversion portion in which photoelectric conversion is performed in the organic material layer"); *id.* at [0014] ("Photoelectric conversion is performed in the organic material layer of the hybrid photoelectric conversion portion , . . ."); *see also id.* at [0076], [0080], [0082], [0107]. As such, organic material layers 13 are the active part of Kuboi's photodetector, not the alleged array of pillars of semiconductor material, and the alleged pillars are not "configured" to create "photo-generated charge carriers" from light "incident on [the] array of pillars."

D. Yu Does Not Disclose "In-Pillar Holes" (Grounds 2-3)

Yu, like the other primary reference Kuboi, fails to disclose "one or more deliberately formed in-pillar holes with solid dielectric therein," as required by the Challenged Claims. While Yu describes "nanopillars," the Petition makes clear that it does not map these nanopillars to the claimed "array of pillars." Pet. at 80 ("A POSITA would have understood that Yu's 'nanopillars' are not the claimed pillars."). Rather, the Petition alleges that Yu's entire "pixel" constitutes a "pillar." *Id.* ("Rather, Yu's pixel is the claimed pillar . . . .").



Id. (citing Yu, Fig. 7B (annotated)).



Id. at 88 (citing Yu, Fig. 1, step 132 (annotated)).

For the reasons discussed above, Yu's entire pixel cannot be a "pillar" because an entire pixel is not a microstructure within a photodetector that improves its photon absorption. *See* Section V.A, *supra*. Accordingly, Yu fails to disclose an array of pillars and in-pillar holes and cannot render obvious the Challenged Claims.

E. The Asserted References Do Not Disclose Microstructures that "Increase Photo Absorption" by "At Least 1.1 Times" (Grounds 1-3)

All of the Challenged Claims require "pillars, in-pillar holes, and solid dielectric between at least portions of sidewalls of adjacent pillars of [the] array of pillars increase photon absorption of [the] device of incident light by at least 1.1 times at selected visible and infrared wavelength ranges of [the] incident light compared to a like device lacking [the] one or more in-pillar holes." '360 Patent at 55:47-53 (limitation [1h]). None of the asserted references disclose such structures.

Samsung does not argue that Kuboi or Yu inherently or expressly discloses that the presence of its alleged "in-pillar holes" increases photo absorption by at least 1.1 times at selected visible and infrared wavelength ranges, as the Challenged Claims require. Pet. at 51-52, 93. Instead, Samsung relies on thirty pages of expert testimony to try to fill in claim limitation [1h], which is missing from the asserted references, Kuboi, Shinohara, and Yu. *Id*. at 51-63 (Ground 1, citing Lebby Decl., ¶¶ 187-213); *see also id*. at 93-99 (Grounds 2-3, citing Lebby Decl., ¶¶ 280-291). Dr. Lebby offers convoluted calculations that are extrinsic to the references and at odds with the record evidence for at least two reasons.

First, Samsung uses a facially flawed methodology to attempt to calculate a hypothetical amount of photo absorption for Kuboi's and Yu's pixels based on the Lambert-Beer Law and a series of assumptions stemming from their pixel

dimensions. Lebby Decl. ¶¶ 192-198, 282-285. Samsung posits that "[a] POSITA would have understood that the amount of light absorbed, P_{abs}, by a material of thickness 'd' can be determined using the Lambert-Beer formula: $I_0 (1- e^{-\alpha d})$." Pet. at 51-52. However, a POSITA would understand that the value "d" in the Lambert-Beer expression refers to the "path length" or the distance that the amount of light travels. Ex. 2031 at 1.

Dr. Lebby's analysis is flawed because he incorrectly assumes that the distance "d" is simply the depth of Kuboi's holes (1.4 μm). Lebby Decl., ¶ 188. A POSITA would understand that the light may reflect or scatter as it travels through the non-homogenous materials of Kuboi's hybrid photoelectric portion, and that the distance "d" traveled by the light may be more than simply the thickness of the material. *See* Ex. 2032 at 4 ("Understanding the Limits of Bouger-Beer-Lambert Law") (discussing how, in contrast to a "microhomogenous" material, light "is reflected, leading to scattering" when traveling through a material with "microstructure[s]"). As a result, a POSITA would understand that simply plugging in the material thickness into the Lambert-Beer expression would not accurately determine the light absorption of Kuboi's hybrid photoelectric conversion portion. Ex. 2032 at 4 (discussing an example microstructure polymer where "***simply determining the absorbance and dividing it by the thickness will not lead to the same result*** as [the Lambert-Beer formula] would imply" because of "scattering"

and "reflected" when light "entering and leaving [a] pore") (emphasis added); *see also* '360 Patent at 8:23-51 (describing "resonance/scattering/near field effects of microstructures").

Samsung's use of the Beer-Lambert Law is, therefore, invalid because it fails to account for the light scattering and reflection effects in the photodetectors that are the subject of the '360 Patent and the structures in Kuboi and Yu. Other than Dr. Lebby's facially erroneous application of the Beer-Lambert Law, Samsung offers no support for its contention that Kuboi or Yu have structures that increase light absorption as required. Even if Samsung were to try to correct Dr. Lebby's analysis, Kuboi and Yu do not disclose any findings about its light absorption or how its elements affect the light path length.

Second, Samsung cites an external reference Han (Ex. 1051) for its discussion of the alleged "impact of nanoholes on the ultimate efficiency associated with photo absorption." Pet. at 61-62 (citing Ex. 1051, Fig. 4). Han's Fig. 4 is "a graphical plot of the calculated ultimate efficiency as a function of the thickness of the nanohole array, the nanorod array, and the homogeneous c-Si film (a) with and (b) without a Si_3N_4 antireflection (AR) coating." Ex. 1051 at 7. But Han's graphs do not concern the efficiency of "in-pillar holes" because Han does not disclose or suggest the use of "in-pillar holes." Samsung offers no explanation for how Han's discussion of the efficiency of its "nanohole arrays" applies to the efficiency of Kuboi's very different

hybrid photoelectric conversion portion and organic photoelectric conversion film. Pet. at 62-63.

Therefore, Samsung fails to show that any of its asserted references disclose the claimed improvement in light absorption.

VI. CONCLUSION

For all of these reasons, W&Wsens requests that the Board deny institution of *inter partes* review of the Challenged Claims of the '360 Patent.

Respectfully submitted,

Date: October 8, 2025

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CERTIFICATE OF COMPLIANCE WITH 37 C.F.R. § 42.24

The undersigned hereby certifies that the portions of the foregoing **PATENT OWNER'S PRELIMINARY RESPONSE** has 5,778 words in compliance with the 14,000 word limit set forth in 37 C.F.R. § 42.24. This word count was prepared using the Microsoft Word word-processing system used to prepare this paper.

Dated: October 8, 2025

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CERTIFICATE OF SERVICE

The undersigned certifies, in accordance with 37 C.F.R. § 42.6(e), and pursuant to agreement by the parties that filing with the Board through the Patent Trial and Appeal Case Tracking System (P-TACTS) constitutes electronic service, that service was made on Petitioners as detailed below.

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Documents served	PATENT OWNER'S PRELIMINARY RESPONSE
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