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(54) Title: BACKSIDE ILLUMINATED GLOBAL SHUTTER CMOS IMAGE SENSOR

(57) Abstract: A system and method are provided for photonic isolation of storage nodes, with at least one storage node disposed on a substrate paired with a backside illuminated photonic sensor and configured to receive data collected by the sensor until read; at least one trench disposed in the substrate, the trench being aligned with the storage node; and a photonic block, disposed in the trench, proximate to the storage node and blocking photons to at least a portion of the storage node.

BACKSIDE ILLUMINATED GLOBAL SHUTTER CMOS IMAGE SENSOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Patent Application No. 15/342,253, filed on November 3, 2016, which is herein incorporated by reference in its entirety.

FIELD

[0001] The invention relates to CMOS Image Sensors, and, more particularly, to global shutter equipped backside illuminated image sensors.

BACKGROUND

[0002] Global shutter operation is carried out in a solid-state image sensor by having a means of simultaneously beginning and ending signal charge integration. The goal is to be able to electronically shutter the exposure, removing the need for a mechanical shutter. The problem is that after the end of signal charge integration the charge needs to be protected until it is sequentially read from both photo-carriers generated by subsequent light and from photons entering the volume of the storage node so they do not produce local photon-carriers. The first problem has solutions related to the doping of the structure around the storage node so that it only collects charge from a shallow layer on the device side of the image sensor silicon. The second problem is handled on front-side illuminated devices, as illustrated in **Fig. 1**, by using a conformal or close fitting metal layer **2** (e.g., Tungsten), that optically blocks photons from physically entering the storage node **3**. This works because the collection volume of the storage node **3** is close to the front side. For back-side illumination, as illustrated in **Fig. 2** the photons hit a back surface of the silicon **5** which is located a distance from the storage node volume **3** that is comparable to the pixel dimension and the storage

node geometry. A metal layer **4** created on the back surface of the silicon is ineffective in preventing subsequent photons from entering the storage node volume due to diffraction and the spread in chief ray angle acting over the distance between the metal layer and the storage node volume (i.e., the nominal thickness of the Si).

[0003] What is needed, therefore, are techniques for effectively shielding a storage node in a backside illuminated sensor.

SUMMARY

[0004] One embodiment of the present disclosure provides a system for photonic isolation of storage nodes, the system comprising: at least one storage node disposed on a substrate paired with a backside illuminated photonic sensor and configured to receive data collected by the sensor until read; at least one trench disposed in the substrate, the trench being aligned with the storage node; a photonic block, disposed in the trench, proximate to the storage node and blocking photons to at least a portion of the storage node.

[0005] Another embodiment provides such a system wherein the trench is straight walled.

[0006] A further embodiment provides such a system wherein the trench has a broad area disposed proximate to the storage node.

[0007] Yet another embodiment provides such a system wherein the trench has a shaft narrower than the broad area, the shaft connecting the broad area to the surface of the substrate opposite to the storage node.

[0008] A yet further embodiment provides such a system wherein the trench extends from a surface of the substrate opposite to the storage node to a doping gradient disposed around the storage node.

[0009] Still another embodiment provides such a system wherein at least a portion of the trench is filled with an optically opaque material.

[0010] A still further embodiment provides such a system wherein the optically opaque material is a metal.

[0011] Even another embodiment provides such a system wherein the optically opaque material is an organic material filled with nanoparticles.

[0012] An even further embodiment provides such a system wherein the opaque material is an organic material filled with an antireflective optical stack.

[0013] A still even another embodiment provides such a system wherein at least a portion of the trench is filled with a photo-absorptive material.

[0014] A still even further embodiment provides such a system wherein a remainder of the trench is left empty.

[0015] One embodiment provides a method for photonic blocking of at least a portion of a backside illuminated sensor, the method comprising: disposing a trench extending from a first surface of a substrate upon which the sensor is disposed, to a doping gradient disposed proximate to the sensor; providing a bottom of the trench having a geometry substantially coincident with the shape of the portion; and filling at least the bottom of the trench with an optically opaque material.

[0016] Another embodiment provides such a method wherein the optically opaque material is a metal.

[0017] A further embodiment provides such a method wherein the optically opaque material is an organic material filled with nanoparticles.

[0018] Yet another embodiment provides such a method wherein the optically opaque material is an organic material filled with an antireflective optical stack.

[0019] A yet further embodiment provides such a method wherein the trench is straight walled.

[0020] Still another embodiment provides such a method wherein the trench has a shaft narrower than the bottom, the shaft connecting the bottom to the surface of the substrate opposite to the storage node.

[0021] A still further embodiment provides such a method wherein walls of the trench are angled.

[0022] One embodiment provides a camera, the camera comprising at least one backside illuminated sensor wherein a photonic block is disposed proximate to the storage node at a first end of a trench disposed in a substrate upon which the sensor is built.

[0023] The features and advantages described herein are not all-inclusive and, in particular, many additional features and advantages will be apparent to one of ordinary skill in the art in view of the drawings, specification, and claims. Moreover, it should be noted that the language used in the specification has been principally selected for readability and instructional purposes, and not to limit the scope of the inventive subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Figure 1 is a block diagram illustrating a known front illuminated sensor.

[0025] Figure 2 is a block diagram illustrating a known backside illuminated sensor with a photonic block disposed on a backside of the substrate.

[0026] Figure 3 is a block diagram illustrating backside illuminated sensor configured according to one embodiment.

[0027] Figure 4 is a block diagram illustrating an array backside illuminated sensors having global shutter function and configured according to one embodiment.

[0028] Figure 5 is a flowchart illustrating a method for isolating a storage node configured according to one embodiment.

[0029] Figure 6 is a block diagram illustrating a camera comprising a backside illuminated sensor configured according to one embodiment of the disclosure.

DETAILED DESCRIPTION

[0030] As illustrated in Fig. 3 and Fig. 4, one embodiment **10** provides a CMOS Image Sensor **20** that employs backside illumination (BSI) on a substrate **12**. In such an embodiment, optical block **26** disposed in an intra-pixel trench **14** are disposed through the substrate **12.** The trench **14** extends into the substrate **12.** The trench 14 and is positioned within a pixel. The trench **14** is positioned so that one end is disposed proximate to a storage node **22** of the pixel, with a layer of doped region **24** disposed between the trench and the storage node. In some embodiments substantially all of the depth of the substrate **12** may be penetrated by the optical block **26** so that the deepest point is disposed proximate to the portion of the device which is sought to be protected, while in others the trench **14** only extends to an depth to block photons entering through the substrate **12** from reaching the storage node **22,** without interfering with the processing of charge.

[0031] One embodiment provides an optical block **26** physically close to the storage node **22** by etching a trench **14** from the back surface **30** of the silicon substrate and filling the bottom of the trench **14** with an optical block **26** material. In one example the optical block **26** material is an optically opaque or absorptive material such as metal, such as Tungsten, organics that may be filled with nanoparticles or an antireflective optical stack structure. Absorptive materials of the optical block **26** may include but are not limited to polysilicon and similar materials. In those parts of the trench 14 not occupied by the block **26**, the trench **14** may be empty or filled.

[0032] The trench **14** could be of various shapes, as illustrated in Fig. 4, for instance straight-walled **36**, widening away **34** from the block **26** or t-shaped**32**. In the T-shaped trench **32** embodiment, a broad feature **28** near the storage node **22** is provided to accommodate the block **26**. The trench **14** including the broad feature **28** should be deep enough to reach the doping gradient **24** that protects the storage node **22** from photo-carrier collection.

[0033] Trenches **14** may be made through the plasma or chemical etching or combinations of the same or such other techniques as would be understood by those skilled in the art to allow for controlled removal of substrate **12** material in alignment with the storage node **22**. In one embodiment, etches are completed after the completion of the structures disposed on the substrate **12**, while one skilled in the art would foresee that trenches **14** extended prior to completion of the structures would also be within the scope of this disclosure.

[0034] In embodiments, the photonic isolation of storage nodes **22** is provided by a system comprising at least one storage node **22** disposed on a substrate **12** paired with a backside illuminated photonic sensor **20** and configured to receive data collected by the sensor **20** until read. At least one trench **14** is disposed in the substrate **12** of such embodiments, the trench **14** being aligned with the storage node **22**. Such embodiments may also include a photonic block disposed in the trench **14**, proximate to the storage node **22**, whereby photons are block from reaching at least a portion of the storage node **22**.

[0035] In embodiments, the trench **14** may be straight walled.

[0036] In embodiments, the trench **14** has a broad area **28** disposed proximate to the storage node **22**.

[0037] In embodiments, the trench **14** has a shaft narrower than the broad area, the shaft connecting the broad area to the surface of the substrate **12** opposite to the storage node **22**.

[0038] In embodiments, the trench **14** extends from a surface of the substrate **12** opposite to the storage node **22** to a doping gradient **24** disposed around the storage node **22**.

[0039] In embodiments, the trench **14** may be filled with an optically opaque material **26**, which may be a metal, an organic material filled with nanoparticles, or an organic material filled with an antireflective optical stack. Alternatively, at least a portion of the trench **14** may be filled with a photo-absorptive material **26**. In embodiments where the trench **14** is filled, such filling may be partial, with a remainder of the trench **14** left empty.

[0040] In embodiments a method, as illustrated in Fig. 5, for photonic blocking of at least a portion of a backside illuminated sensor involving disposing a trench extending from a first surface of a substrate upon which the sensor is disposed to a doping gradient disposed proximate to the sensor **40**, providing a bottom of the trench having a geometry substantially coincident with the shape of the portion **42**, and filling at least the bottom of the trench with an optically opaque material is provided **44**. In such embodiments, metal, an organic material filled with nanoparticles, or an organic material filled with an antireflective optical stack may serve as the optically opaque material.

[0041] Regarding the trench **14**, in embodiments, the trench **14** is straight walled. In other embodiments, the trench **14** has a shaft portion that is narrower than the bottom, the shaft connecting the bottom to the surface of the substrate **12** opposite to the storage node **22**. In other cases, the walls of the trench **14** are angled.

[0042] In an exemplary embodiment, as shown in Figure 6, a camera **50** is provided comprising a lens **52** and at least one backside illuminated sensor **10** wherein a photonic block as described in the disclosure which is disposed proximate to the storage node at a first end of a trench disposed in a substrate upon which the sensor is built.

[0043] The foregoing description of the embodiments of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of this disclosure. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

CLAIMS

What is claimed is:

1. A system for photonic isolation of storage nodes for an imaging sensor within a pixel, the system comprising:

At least one storage node disposed on a substrate paired with a backside illuminated photonic sensor within said pixel and configured to receive data collected by said sensor until read;

At least one trench disposed in said substrate, said trench being aligned with said storage node;

A photonic block, disposed in said trench, proximate to said storage node and blocking photons to at least a portion of said storage node.

2. The system of claim 1 wherein said trench is straight walled.

3. The system of claim 1 wherein said trench has a broad area disposed proximate to said storage node.

4. The system of claim 3 wherein said trench has a shaft narrower than said broad area, said shaft connecting said broad area to the surface of the substrate opposite to said storage node.

5. The system of claim 1 wherein said trench extends from a surface of the substrate opposite to said storage node to a doping gradient disposed around said storage node.

6. The system of claim 1 wherein at least a portion of said trench is filled with an optically opaque material.

7. The system of claim 6 wherein said optically opaque material is a metal.

8. The system of claim 6 wherein said optically opaque material is an organic material filled with nanoparticles.

9. The system of claim 6 wherein said opaque material is an organic material filled with an antireflective optical stack.

10. The system of claim 1 wherein at least a portion of said trench is filled with a photo-absorptive material.

11. The system of claim 6 wherein a remainder of said trench is left empty.

12. The system of claim 10 wherein a remainder of said trench is left empty.

13. A method for photonic blocking of at least a portion of a backside illuminated sensor, said method comprising:

Disposing a trench extending from a first surface of a substrate upon which said sensor is disposed, to a doping gradient disposed proximate to said sensor;

Providing a bottom of said trench having a geometry substantially coincident with the shape of said portion; and

Filling at least said bottom of said trench with an optically opaque material.

14. The method of claim 13 wherein said optically opaque material is a metal.

15. The method of claim 13 wherein said optically opaque material is an organic material filled with nanoparticles.

16. The method of claim 13 wherein said optically opaque material is an organic material filled with an antireflective optical stack.

17. The method of claim 13 wherein said trench is straight walled.

18. The method of claim 10 wherein said trench has a shaft narrower than said bottom, said shaft connecting said bottom to the surface of the substrate opposite to said storage node.

19. The method of claim 10 wherein walls of said trench are angled.

20. A camera, said camera comprising at least one backside illuminated sensor wherein a photonic block is disposed proximate to said storage node at a first end of a trench disposed in a substrate upon which said sensor is built.

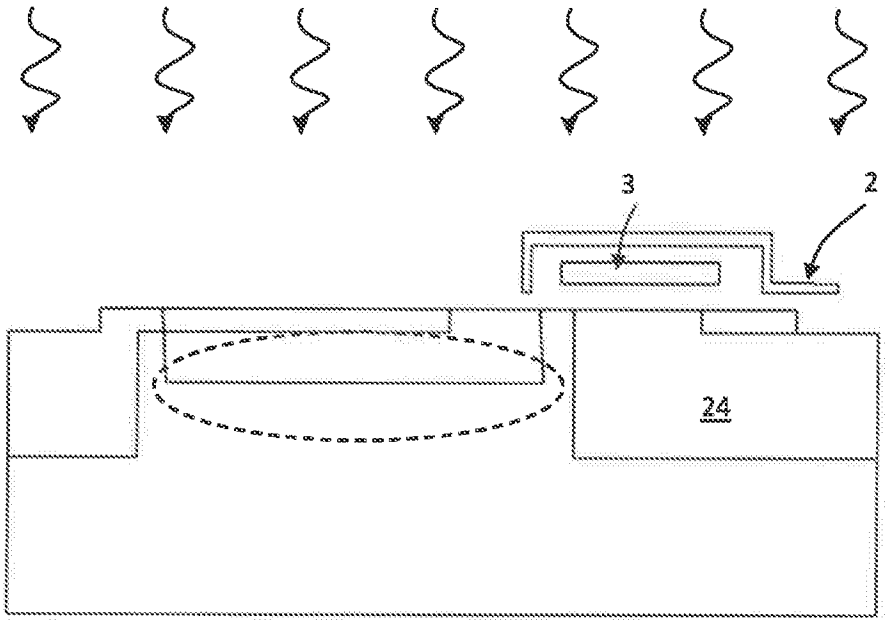

Fig. 1 (Prior Art)

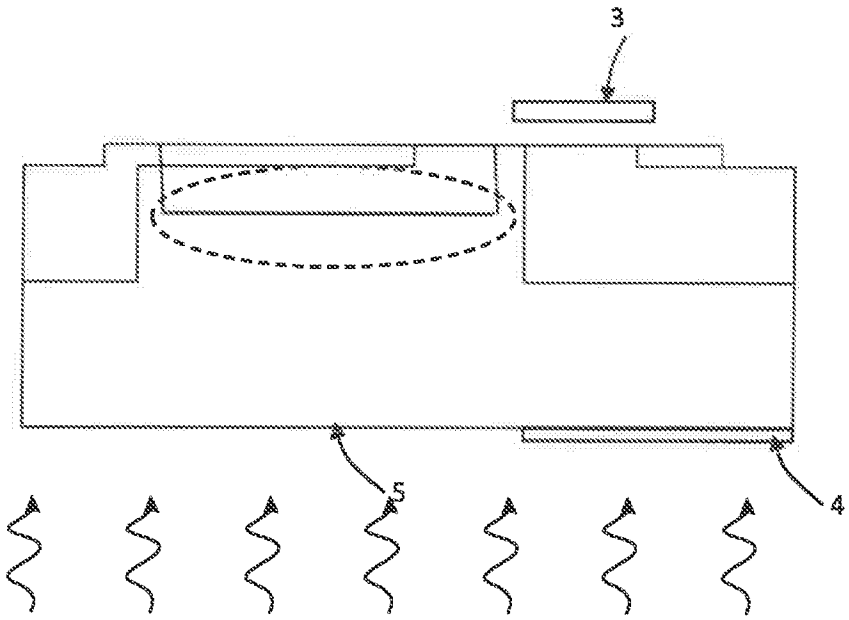

Fig. 2 (Prior Art)

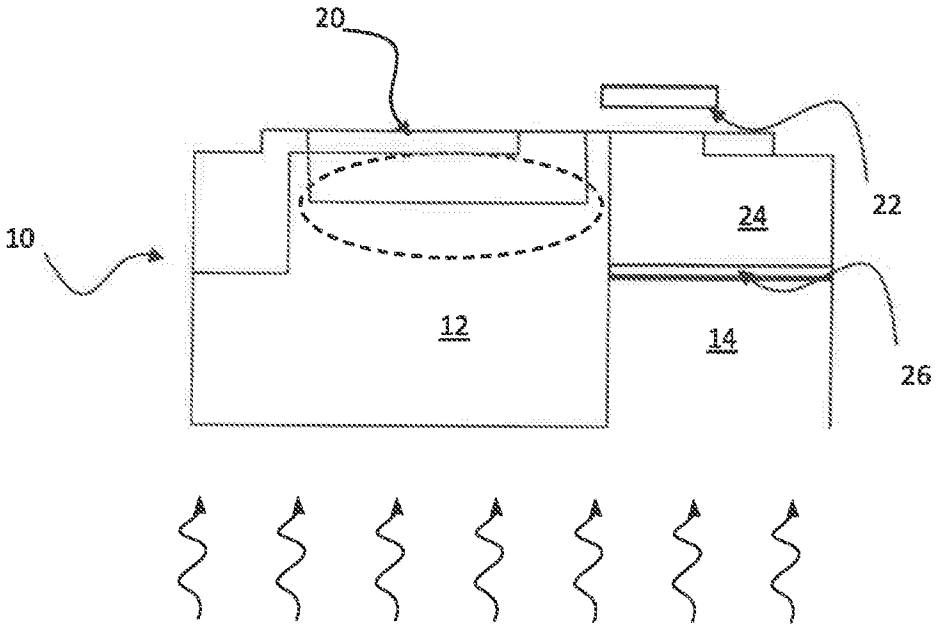
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Fig. 3

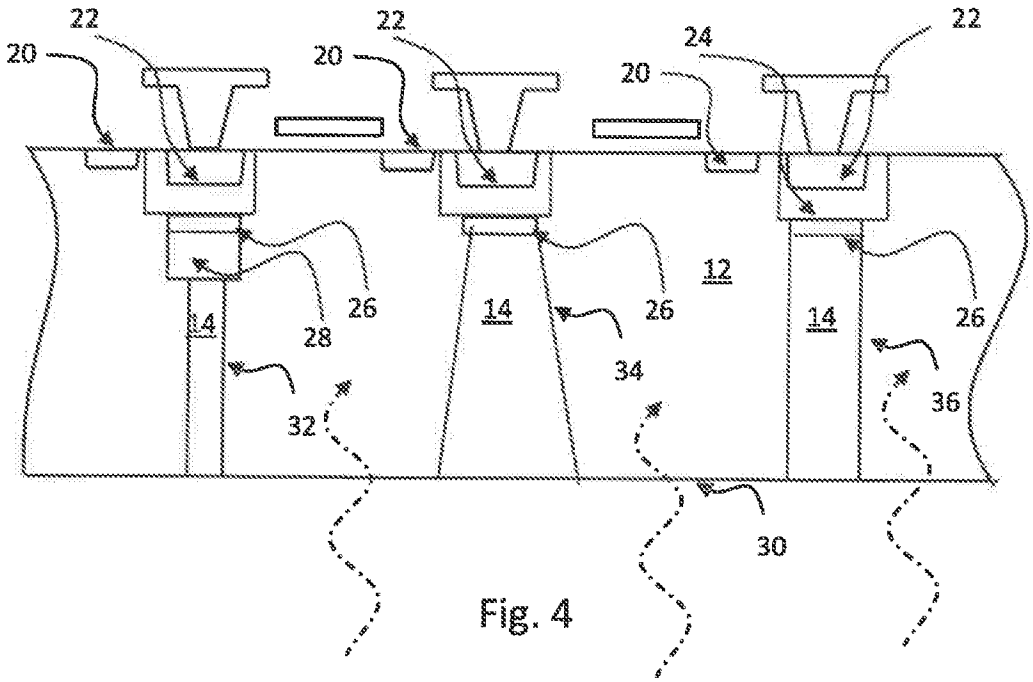
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Fig. 4

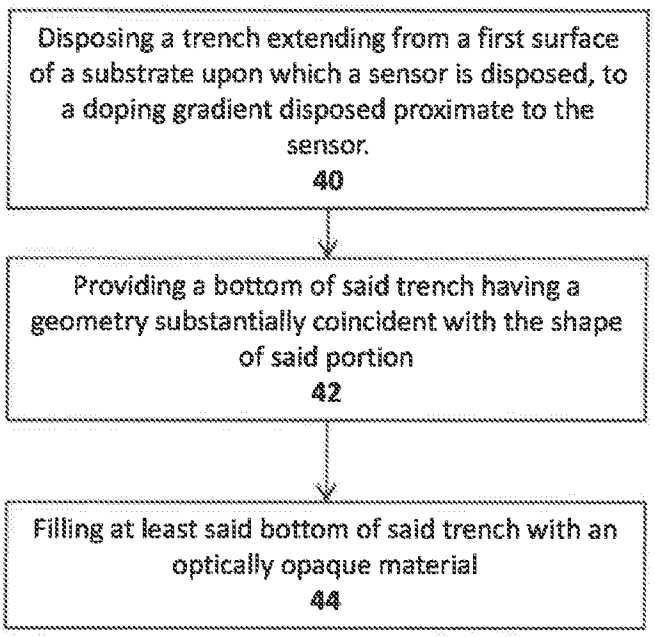
Disposing a trench extending from a first surface of a substrate upon which a sensor is disposed, to a doping gradient disposed proximate to the sensor.
40
Providing a bottom of said trench having a geometry substantially coincident with the shape of said portion
42
Filling at least said bottom of said trench with an optically opaque material
44

Fig. 5

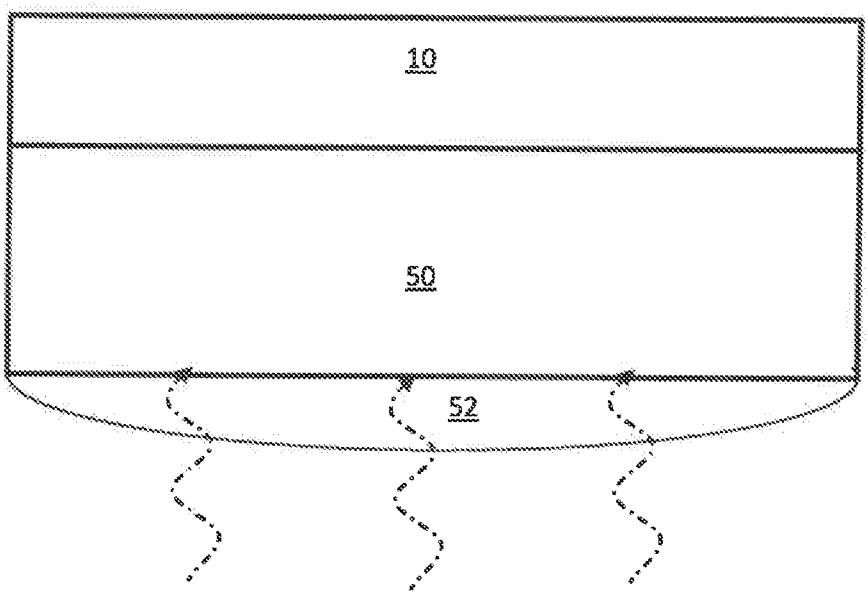

Fig. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US17/59242

A. CLASSIFICATION OF SUBJECT MATTER
IPC: **H01L 27/146**(2006.01);**H04N 5/374**(2011.01)

CPC: H01L 27/14627
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
CPC. : Please See Continuation Sheet

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X, P --- Y, P	US 2017/0005121 A1 (LENCHENKOV et al.) 05 January 2017 (05.01.2017), entire document.	1-4, 6, 10 and 18-20 ---------- 5, 7-9 and 11-17
Y	US 2016/0204150 A1 (OH et al.) 14 July 2016 (14.07.2016), entire document.	5 and 13-17
Y	US 2016/0118438 A1 (LEUNG et al.) 28 April 2016 (28.04.2016), entire document.	7 and 14
Y, P	US 2017/0117309 A1 (CHEN et al.) 27 April 2017 (27.04.2017), entire document.	8, 9, 15 and 16
Y	US 2015/0263054 A1 (CHIEN et al.) 17 September 2015 (17.09.2015), entire document.	11 and 12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 December 2017 (07.12.2017)	
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (571) 273-8300	Authorized officer Harry C. Kim Telephone No. (571) 272-4300

INTERNATIONAL SEARCH REPORT	International application No. PCT/US17/59242

Continuation of B. FIELDS SEARCHED Item 1:
H01L 27/14627, 27/1463, 27/1464, 27/14643, 27/14623, 27/14687, 27/14609, 27/3227; H04N 5/374, 5/378; H01L 25/167; H04L 31/02024, 31/0203, 31/0284, 31/1032, 31/107

Continuation of B. FIELDS SEARCHED Item 3:
EAST: US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB
Search Terms: solid, state, photodiod$4, imager, imaging, pixel$4, ccd, charge, coupl$3, cmos, photo, element$4, electric$4, sensor, imag$3, video, sens$3, pickup, pick, up, captur$3, device, array, apparatus, element, unit, detector, block$3, reflect$3, isolat$3, DTI, trench$1, backside, storage, photodiode, photosensor, photodetector, bae, systems, drop$4, gradient, opaque, tungsten, aluminum, silver, nickel, copper, platinum, polysilicon, poly$1silicon, poly, air, gap, void, unfill$3, air$1gap airgap, extend$3, through, different, shape$1, size$1, structure, organic, nanoparticle$1, nano, particle$1, anti$reflective, antireflect$4, absorp$4