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(71) Applicant *(for all designated States except US)*: **EASTMAN KODAK COMPANY** [US/US]; 343 State Street, Rochester, New York 14650-2201 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **GUIDASH, Robert Michael** [US/US]; 460 Antlers Drive, Rochester, New York 14618 (US). **MCGRATH, Robert Daniel** [US/US]; 32 Old Farm Circle, Pittsford, New York 14534 (US).

(74) Common Representative: **EASTMAN KODAK COMPANY**; 343 State Street, Rochester, New York 14650-2201 (US).

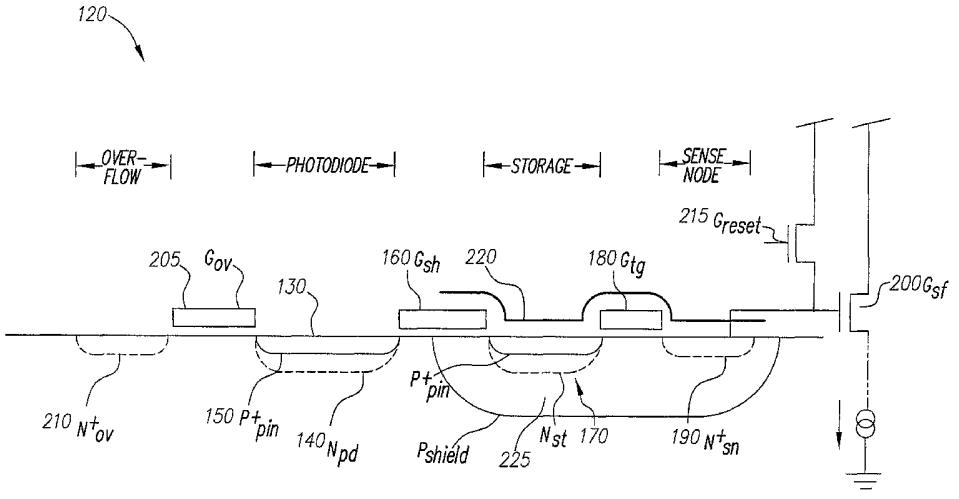
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(54) Title: PINNED-PHOTODIODE PIXEL WITH GLOBAL SHUTTER




(57) Abstract: An image sensor includes a two-dimensional array of pixels having a photodetector for collecting charge in response to incident light; a storage region adjacent the photodetector that receives the charge from the photodetector; a sense node adjacent the storage region that receives the charge from the storage region and converts the charge to a voltage signal; and an input to an amplifier for sensing the voltage signal from the sense node.

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# PINNED-PHOTODIODE PIXEL WITSH GLOBAL SHUTTER

## FIELD OF THE INVENTION

The invention relates generally to the field of image sensors, and in particular to image sensors having global electronic shuttering.

## BACKGROUND OF THE INVENTION

Referring to Fig. 1, currently known and utilized image sensors use a pixel 10 which is a pinned-photodiode-pixel CMOS image sensor. It incorporates a photodiode 20 readout through a transfer gate 30 onto a sense node 40 which can be reset to a reference voltage and which is connected to a readout, for example, the gate of a source follower circuit 50. In addition, the photodiode 20 is connected to an overflow gate 60 to carry off photocurrent generated during the time outside of the shutter window.

The photodiode 20 is made as a pinned photodiode with a shallow p-type pinning layer 70 and a deeper n-type diffusion 80 to create a buried channel with controlled potential, for example 1.5V, for holding charge. This combination of dopings produces a very low dark current and density of dark current point defects. An overflow drain 90 and a reference bias connected to the reset gate are set to a higher voltage, for example 3.3V.

Referring to Figs. 1 and 2, operation involves using either the overflow drain 90 or the transfer gate 30 and the reset gate 100 combination to empty the photodiode 20. The reset gate 100 also is used to reset the sense node 40 to a set bias greater than that of the photodiode 20. The overflow drain 90, the transfer gate 30, and the overflow gate 60 are then turned off on all pixels simultaneously to begin the shutter window and the signal from the incident light is integrated on the photodiode 20. To end the shutter window, the transfer gate 30 is turned on and the signal charge is completely transferred to the sense node 40. The overflow drain 90 is turned on so that any additional charge generated on the photodiode 20 will be drained away. The output is then readout; the reset gate 100 is used to set the sense node 40 back to the reference voltage, and the output is readout again. The signal is the difference between the two readouts.

The prior art has several limitations as follows: (1) the reference readout must be done after the signal readout so that they are from uncorrelated reset operations and temporal noise is added; (2) the signal charge must be held on the sense node from the end of the shutter window until its readout, allowing for the buildup of dark current as background and as bright points during this time.

Consequently, a need exists for overcoming the above-described drawbacks.

## SUMMARY OF THE INVENTION

The present invention is directed to overcoming one or more of the problems set forth above. Briefly summarized, according to one aspect of the present invention, the invention resides in an image sensor comprising a photodetector for collecting charge in response to incident light; a storage region adjacent the photodetector that receives the charge from the photodetector; a sense node adjacent the storage region that receives the charge from the storage region and converts the charge to a voltage signal; and an amplifier for sensing the voltage signal from the sense node.

These and other aspects, objects, features and advantages of the present invention will be more clearly understood and appreciated from a review of the following detailed description of the preferred embodiments and appended claims, and by reference to the accompanying drawings.

**Advantageous Effect Of The Invention**

The present invention has the following advantages of providing global electronic shutter with low dark current storage region and true correlated double sampling for reduced noise.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a side view of a prior art image sensor;

Fig. 2 is a timing diagram for Fig. 1;

Fig. 3 is a top view of an image sensor of the present invention;

Fig. 4 is a side view in cross section of the image sensor of the present invention;

Fig. 5 is a timing diagram for Fig. 4;

Fig. 6 is a side view in cross section of Fig. 4 illustrating an unshared configuration;

Fig. 7 is a side view in cross section of Fig 4 illustrating a shared configuration; and

Fig. 8 is a side view of a digital camera having the image sensor of the present invention for illustrating a typical commercial embodiment to which the ordinary consumer is accustomed.

## DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 3, there is shown the image sensor 110 of the present invention that is arranged in a two-dimensional array of pixels 120. The image sensor 110 also includes readout circuitry 115 for reading out the signals from the pixels 120 and address circuitry 125 for providing timing signals to the pixels 120.

Referring to Fig. 4, there is shown a cross-section of the image sensor of the present invention. The image sensor includes a plurality of pixels 120, only one of which is shown for clarity, each pixel 120 having a first pinned photodiode 130 having a layer 140 for collecting charge generated from incident light and having a pinning layer 150. A shutter gate 160 transfers the charge to a second pinned diode or storage region 170 for storing the transferred charge. A transfer gate 180 transfers the charge to a sense node 190, preferably a floating diffusion, which is adjacent the second pinned diode 170. The sense node 190 converts the charge to a voltage which is sensed by an amplifier 200, preferably a source follower. A doped region or charge shield 225 surrounds the storage region 170 and sense node 190 for substantially shielding the storage region 170 and sense node 190 from photo-generated charge not transferred from the photodetector 130. A reset transistor 215 resets the floating diffusion 190 to a reference voltage. An overflow drain 210 is adjacent the first pinned photodiode 130 for draining excess charge from the first pinned photodiode 130.

The second pinned diode 170 and the floating diffusion 190 are spanned and covered by a lightshield 220 for preventing incident light to be received by the second pinned diode 170 and the floating diffusion 190. The lightshield 220 is preferably substantially 50 to 500 nanometers from a top surface of a semiconductor in the sense node 190.

Referring to Figs. 4 and 5, operation involves using either the overflow gate 205 and overflow drain 210 or the shutter gate 160 and the transfer gate 180 and the reset gate 215 combination to empty the photodiode 130. The reset gate 215 also is used to reset the sense node 190 to a set bias greater than that of the photodiode 130 and, in combination with the shutter gate 160, to empty all charge from the second pinned diode or storage region 170. The shutter gate 160 is turned on and the overflow gate 205, the transfer gate 180 are then turned off on all pixels 120 simultaneously to begin the shutter window and the signal from the incident light generates charge on the photodiode 130 that is integrated on the storage region 170. To end the shutter window, the shutter gate 160 is turned off and the signal charge is held on the storage region 170. The overflow gate 205 is turned on so that any additional charge generated on the photodiode 130 will be drained away. The sense node 190 is reset to a reference voltage by clocking the reset transistor 215 on and off and the output is then readout. Then the transfer gate 180 is turned on so that the signal charge is transferred to the sense node 190 and the output is readout. The signal is the difference between the two readouts.

Fig. 6 is a schematic diagram illustrating the invention of Fig. 4 in which all of the components (overflow drain 210, photodiode 130, shutter gate 160, second pinned diode 170, transfer gate 180, sense node 190, reset transistor 215, and amplifier 200) are within one pixel. Fig. 7 is schematic diagram illustrating the invention of Fig. 4 with the reset transistor 215 and amplifier in 200 physically shared between two pixels 120a and 120b. More specifically, Fig. 7 illustrates electrical sharing of the sense node 190, an amplifier input 200, and a reset transistor 215. It is noted that the sharing of Fig. 7 can be extended beyond two pixels as will be readily apparent to those skilled in the art.

Referring to Fig. 8, there is shown a digital camera 230 for illustrating a typical commercial embodiment of the image sensor 110 of the present invention to which the ordinary consumer is accustomed.

## PARTS LIST

| | |
|---|---|
| 10 | pixel |
| 20 | photodiode |
| 30 | transfer gate |
| 40 | sense node |
| 50 | source follower circuit |
| 60 | overflow gate |
| 70 | p-type pinning layer |
| 80 | n-type diffusion |
| 90 | overflow drain |
| 100 | reset gate |
| 110 | image sensor |
| 115 | readout circuitry |
| 120 | pixels |
| 120a | shared pixel 1 |
| 120b | shared pixel 2 |
| 125 | address circuitry |
| 130 | first pinned photodiode (photodetector) |
| 140 | layer |
| 150 | pinning layer |
| 160 | shutter gate |
| 170 | second pinned diode (storage region) |
| 180 | transfer gate |
| 190 | sense node (floating diffusion) |
| 200 | amplifier |
| 205 | overflow gate |
| 210 | overflow drain |
| 215 | reset transistor (gate) |
| 220 | lightshield |
| 225 | doped region or charge shield |
| 230 | digital camera |

**CLAIMS:**

1. An image sensor comprising:

a two-dimensional array of pixels comprising:

(a) a photodetector for collecting charge in response to incident light;

(b) a storage region adjacent the photodetector that receives the charge from the photodetector; wherein the storage region is optimized for low dark current and low charge generation defects;

(c) a sense node adjacent the storage region that receives the charge from the storage region and converts the charge to a voltage signal; and

(d) an input to an amplifier for sensing the voltage signal from the sense node.

2. The image sensor as in claim 1, wherein each pixel comprises the photodetector and the storage region.

3. The image sensor as in claim 2, wherein the sense node and the input to the amplifier are shared by a subset of pixels.

4. The image sensor as in claim 1 wherein each pixel comprises the photodetector, storage region, sense node and the input to the amplifier.

5. The image sensor as in claim 1 further comprising a doped region surrounding the storage region and sense node for substantially shielding the storage region and sense node from photo-generated charge not transferred from the photodetector.

6. The image sensor as in claim 1, wherein the storage region is a pinned photodiode.

7. The image sensor as in claim 1, wherein the photodetector is a pinned photodiode.

8. The image sensor as in claim 1 further comprising a lightshield spanning a substantial portion or all of the sense node.

9. The image sensor as in claim 8, wherein the lightshield is substantially 50 to 500 nanometers from a top surface of a semiconductor in the sense node.

10. The image sensor as in claim 8, wherein the lightshield spans both the sense node and a substantial portion or all of the storage region.

11. The image sensor as in claim 1 further comprising an overflow drain adjacent the photodetector.

12. A method for operating an image sensor having a two dimensional array of pixels, the method comprising the steps of :

(a) setting a plurality of photodetectors to a reference state in which the photodetectors collect charge in response to incident light;

(b) transferring the charge from the photodetectors to respective storage regions at termination of integration of the photodetectors;

(c) optimizing storage regions for low dark current and low charge generation defects;

(d) transferring the charge from the storage regions to respective sense nodes; and

(e) transferring a voltage signal from the sense nodes to respective amplifiers for readout.

13. The method as in claim 12 further comprising the step of minimizing time charge is held on the sense nodes.

14. A camera comprising:

an image sensor comprising:

a two-dimensional array of pixels comprising:

(a) a photodetector for collecting charge in response to incident light;

(b) a storage region adjacent the photodetector that receives the charge from the photodetector; wherein the storage region is optimized for low dark current and low charge generation defects;

(c) a sense node adjacent the storage region that receives the charge from the storage region and converts the charge to a voltage signal; and

(d) an input to an amplifier for sensing the voltage signal from the sense node.

15. The camera as in claim 14, wherein each pixel comprises the photodetector and the storage region.

16. The camera as in claim 15, wherein the sense node and the input to the amplifier are shared by a subset of pixels.

17. The camera as in claim 14 wherein each pixel comprises the photodetector, storage region, sense node and the input to the amplifier.

18. The camera as in claim 14 further comprising a doped region surrounding the storage region and sense node for substantially shielding the storage region and sense node from photo-generated charge not transferred from the photodetector.

19. The camera as in claim 18, wherein the storage region is a pinned photodiode.

20. The camera as in claim 18, wherein the photodetector is a pinned photodiode.

21. The camera as in claim 14 further comprising a lightshield spanning a substantial portion or all of the sense node.

22. The camera as in claim 21, wherein the lightshield is substantially 50 to 500 nanometers from a top surface of a semiconductor in the sense node.

23. The camera as in claim 21, wherein the lightshield spans both the sense node and a substantial portion or all of the storage region.

24. The camera as in claim 14 further comprising an overflow drain adjacent the photodetector.

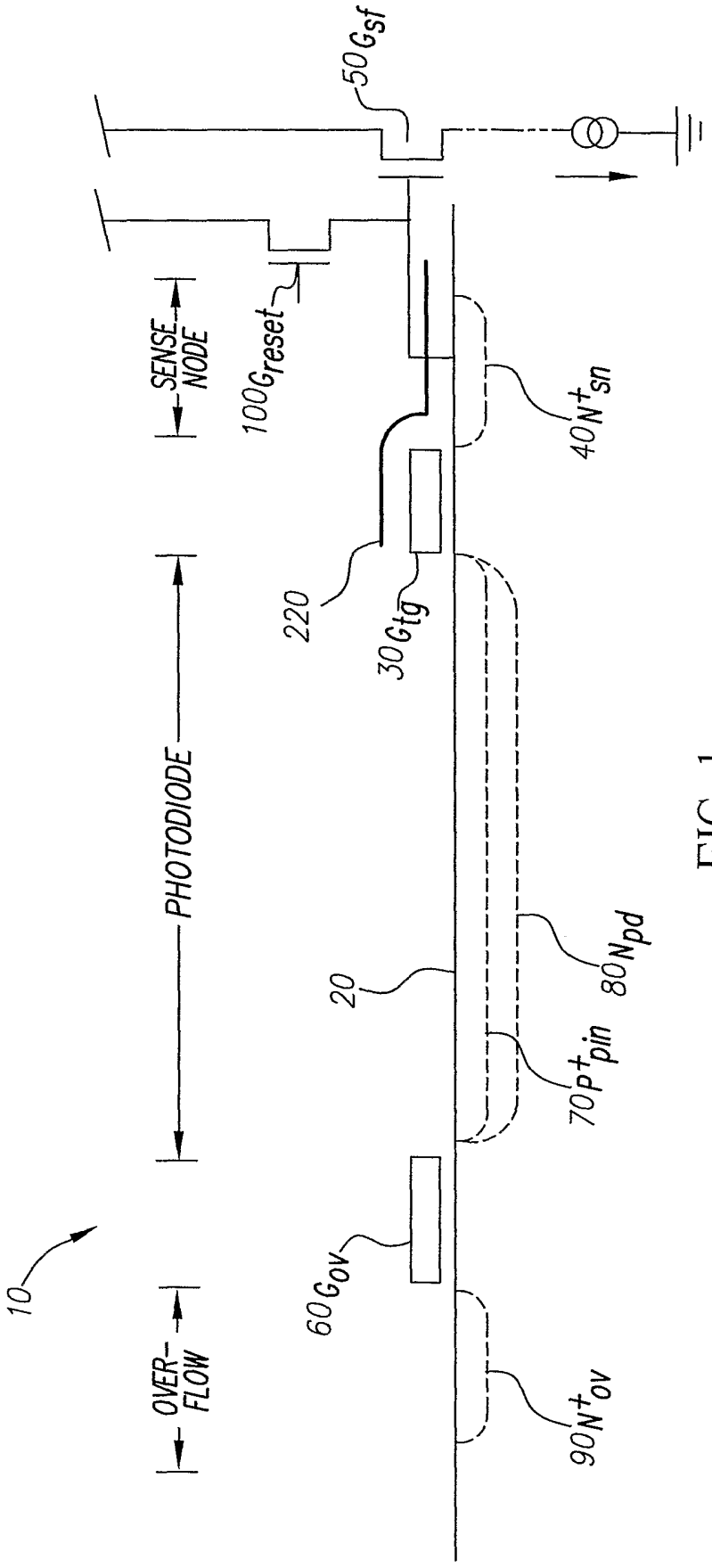



FIG. 1
(Prior Art)

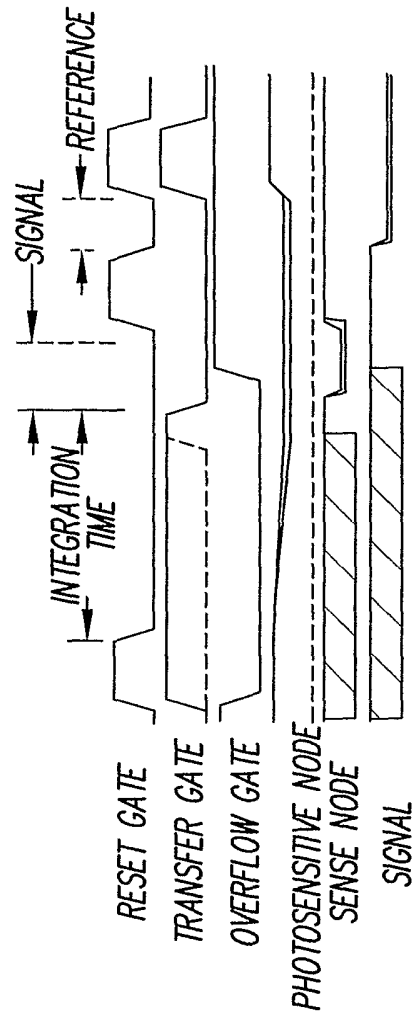



FIG. 2
(Prior Art)

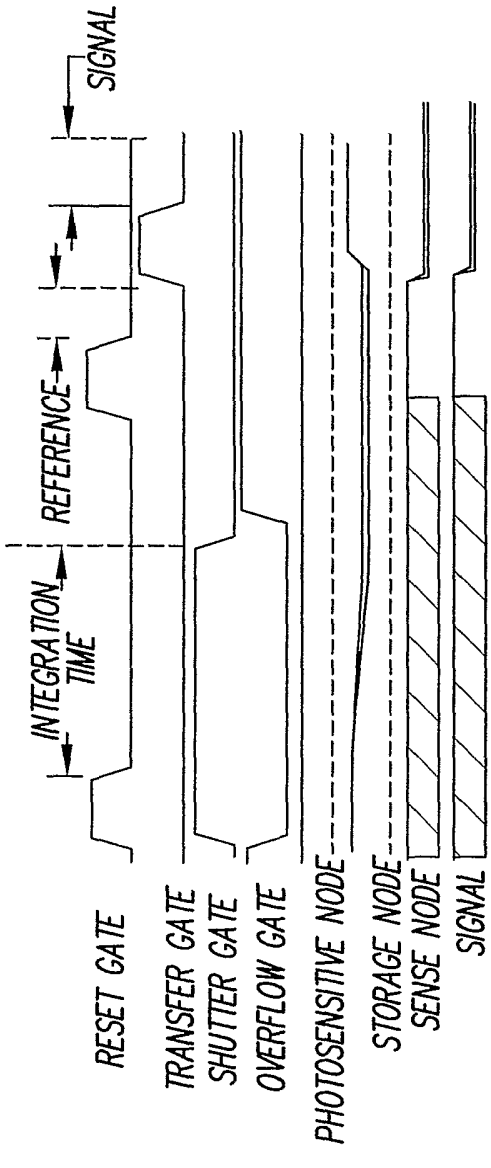



FIG. 5

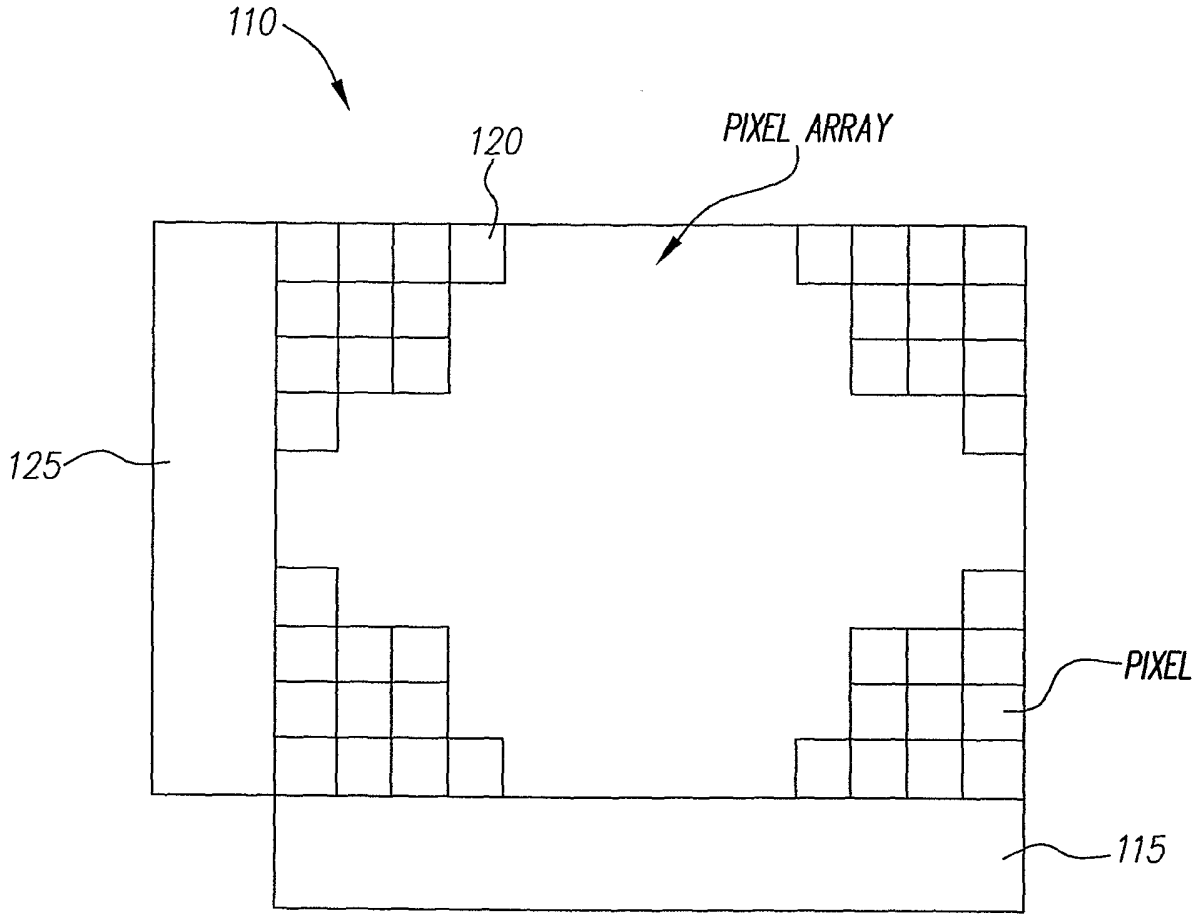



FIG. 3

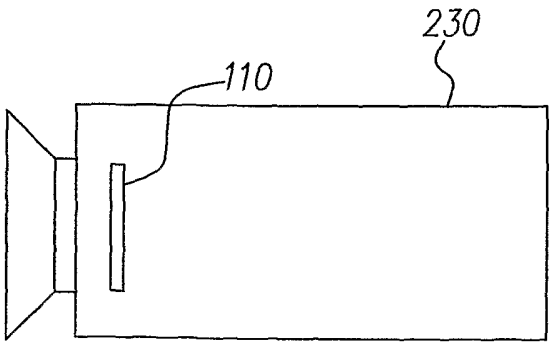



FIG. 8

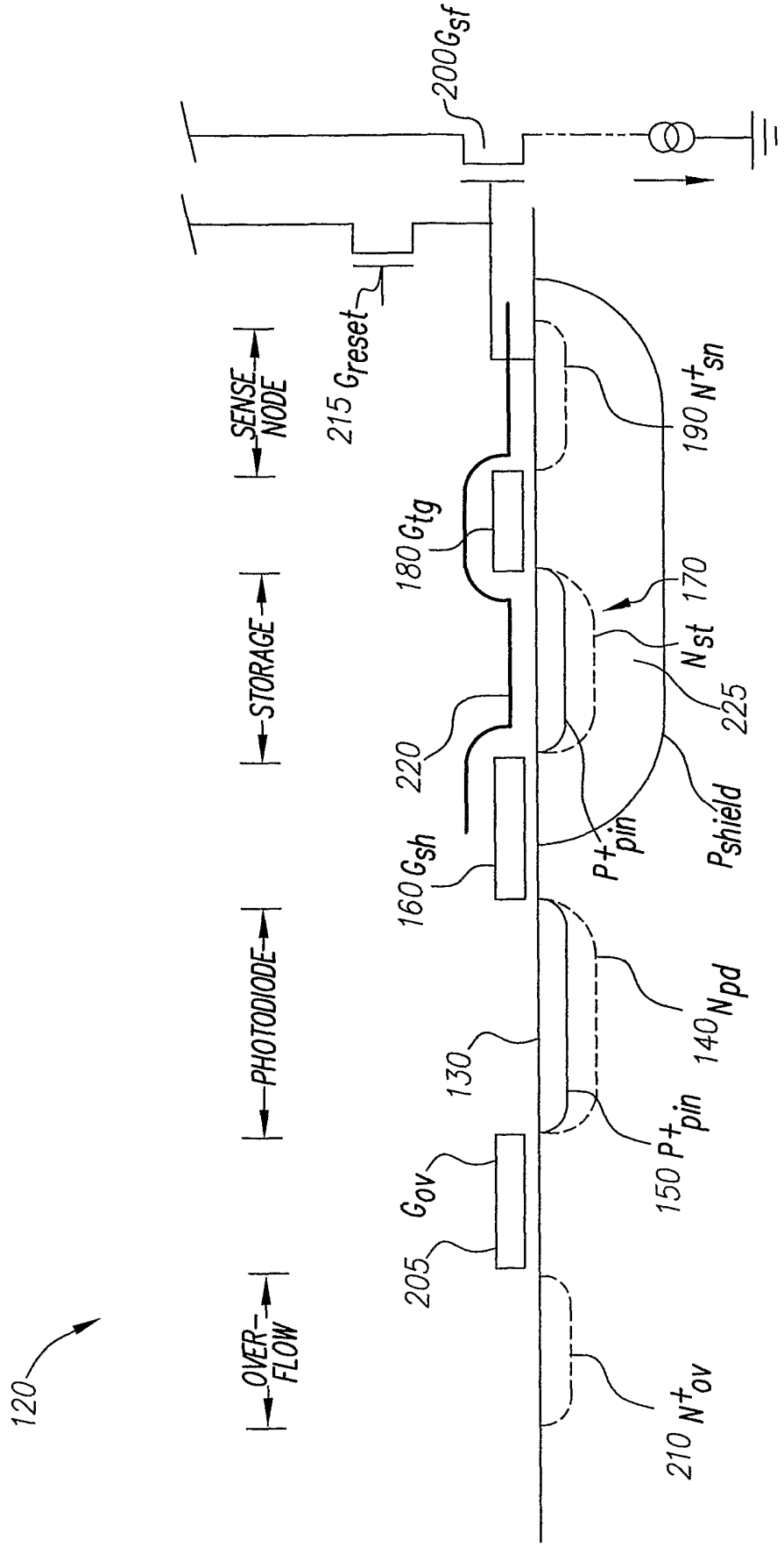

120
OVER-FLOW
PHOTODIODE
STORAGE
SENSE NODE
205 $G_{ov}$
210 $N^+_{ov}$
130
150 $P^+_{pin}$
140 $N_{pd}$
160 $G_{sh}$
220
180 $G_{tg}$
215 $G_{reset}$
200 $G_{sf}$
$P^+_{pin}$
$P_{shield}$
225
$N_{st}$ 170
190 $N^+_{sn}$

FIG. 4

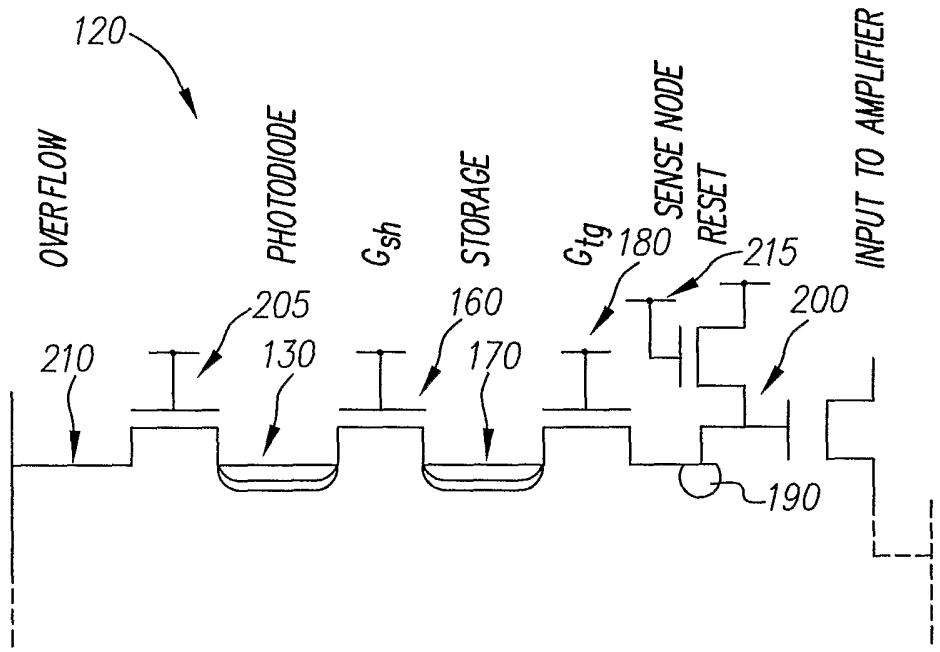

120
OVERFLOW
PHOTODIODE
$G_{sh}$
STORAGE
$G_{tg}$
SENSE NODE
RESET
INPUT TO AMPLIFIER
180
215
205
160
200
210
130
170
190

FIG. 6

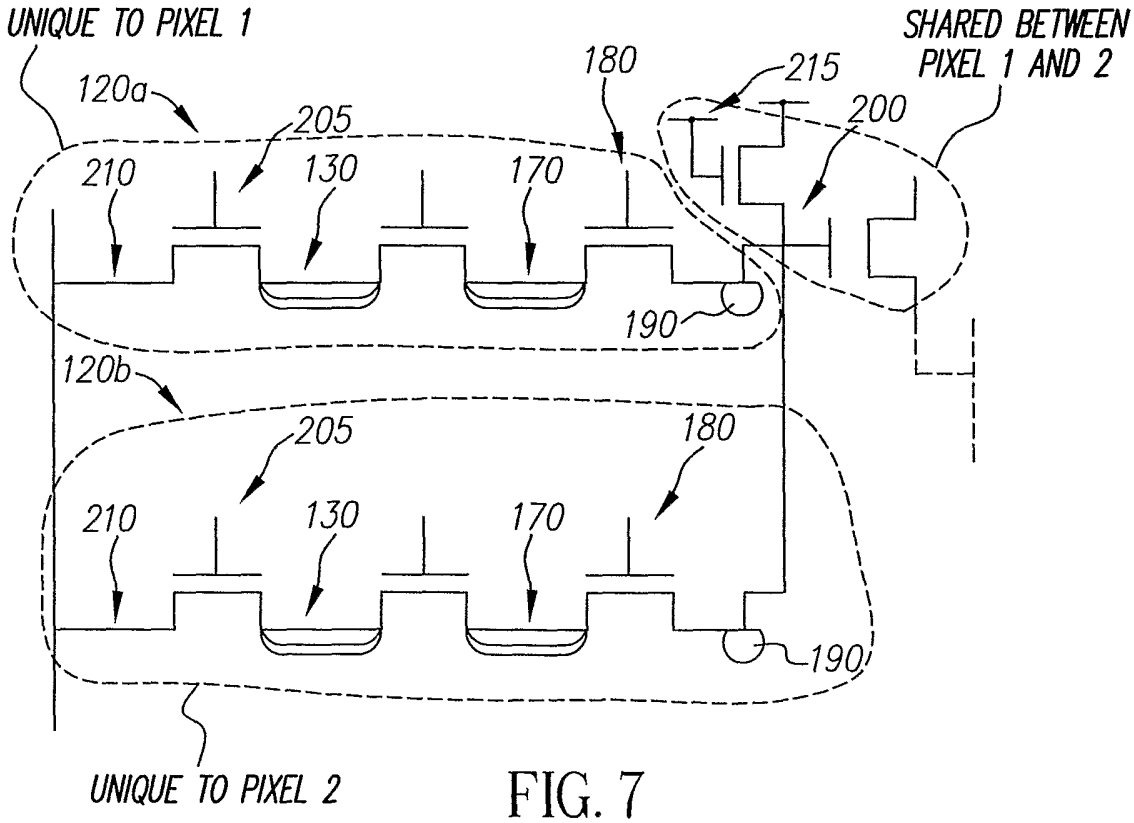

UNIQUE TO PIXEL 1
SHARED BETWEEN PIXEL 1 AND 2
120a
180
215
205
200
210
130
170
190
120b
205
180
210
130
170
190
UNIQUE TO PIXEL 2

FIG. 7

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/020338

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L27/146

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)
H01L

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 practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
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-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 28 September 2006 | 06/10/2006 |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| European Patent Office, P.B. 5818 Patentlaan 2<br>NL – 2280 HV Rijswijk<br>Tel. (+31–70) 340–2040, Tx. 31 651 epo nl,<br>Fax: (+31–70) 340–3016 | Boero, Mauro |

# INTERNATIONAL SEARCH REPORT

International application No
PCT/US2006/020338

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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International application No
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