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Active Pixel Sensor Using a PMOSFET-Type Photodetector with a Transfer Gate for Variable Photosensitivity

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1. Introduction

Recently there has been a great interest in image acquisition systems, i.e., CCDs(charge-coupled devices) and CIS(CMOS image sensors), as the market for digital camera has increased[1]. CCDs have larger gain and better noise characteristic than CIS, but demand high supply voltage and special fabrication processes. On the other hand, CIS can be operated with low supply voltage and fabricated by standard CMOS process. But a photodiode must occupy a larger device area to improve the sensitivity, so that CIS has a lower integration density. By these reasons, there are many on-going researches to improve the sensitivity as well as the fill factor of CIS[2], [3].

Generally, since CIS using a photodiode suffers from noise problem, a noise reduction circuit is necessary. However, CDS(correlated double sampling) is not easily implementable without a frame memory in 3-Tr APS(active pixel sensor). Therefore, in other to improve the image quality, it is essential to use 4-Tr APS. But, the area of 4-Tr APS is larger than 3-Tr APS because of one more transistor that acts as a transfer gate[1].

In this research, a PMOSFET-type photodetector with a transfer gate using 0.35μm 2-poly 4-metal standard CMOS process has been proposed and its optical responses have been measured. In addition, this photodetector has been applied to a voltage-gained CMOS APS.

2. Experiments

Fig. 1 shows a cross-sectional view of a proposed PMOSFET-type photodetector. This structure is like the gate/body tied PMOSFET photodetector[2]. But, the proposed photodetector has another gate that can control the generated photocurrent. Fig. 2 shows the energy band diagram of a proposed PMOSFET-type photodetector with a transfer gate. The operational principle of the photodetector is as follows[2]. A built-in field induced by the n+-poly-silicon gate and n-well separates photo-generated electron-hole pairs. The holes drift toward the channel and are swept to the drain. The electrons, on the other hand, effectively accumulate in the body because of higher potential barrier than the holes. The transfer gate controls the photocurrent flow by controlling the barrier for holes depending on applied bias.

Fig. 3 shows a schematic and a layout of the designed unit pixel for the proposed photodetector. The designed unit pixel consists of 4 NMOSFETs. Among these NMOSFETs, 1 NMOSFET has a function of load MOSFET in the 2D pixel array. The areas of photodetector and unit pixel are 3.8μm×5.7μm and 7.2μm×8.1μm, respectively

3. Results and Discussion

Fig. 4 shows the variation of drain current of the designed photodetector operating in the common drain mode under different illumination. The light source used in the experiment was He-Ne laser(λ=632.8nm). As shown in the figure, incident light power acts as a gate bias, and we can confirm the function of the transfer gate.

Fig. 5 shows the variation of drain current of the designed photodetector operating in the common drain mode with drain voltage under different wave length. The wave lengths used this measurement are 632.8nm(red), 533nm(green), and 473nm(blue). In this figure, we can confirm the photocurrent response at three wave lengths.

Measured waveforms at the integration node and pixel output node of the designed APS, according to incident light power, are shown in Fig. 6. A light source used in this experiment was halogen lamp and the optical power was measured at λ=600nm. It could be confirmed that the stronger light is illuminated, the more charge-up is occurred. It could be confirmed that the generated photocurrent is controlled by using the transfer gate of the proposed photodetector. Thus, the output in proportional to the light power is obtained and a 3-Tr APS with a transfer gate is realized.

4. Conclusions

A new PMOSFET-type photodetector using a transfer gate has been presented. The photodetector has good optical characteristics with photocurrent of several micro-amperes. A CMOS 3-Tr APS using the proposed photodetector has been studied. The sensor exhibits well-defined and highly sensitive characteristics as the incident light power varies. Consequently, this sensor might be applied to a highly-sensitive digital imager.

Acknowledgements

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References

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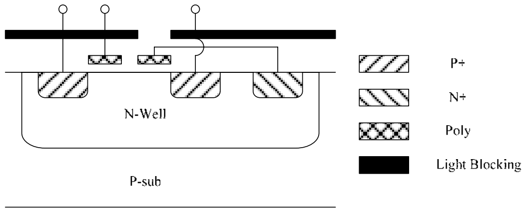
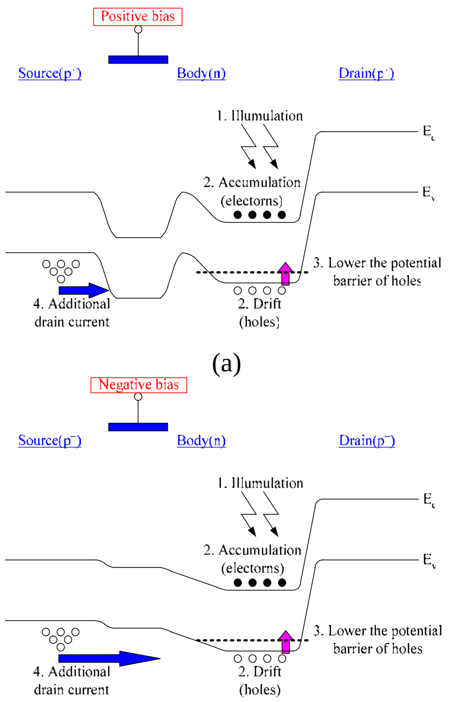
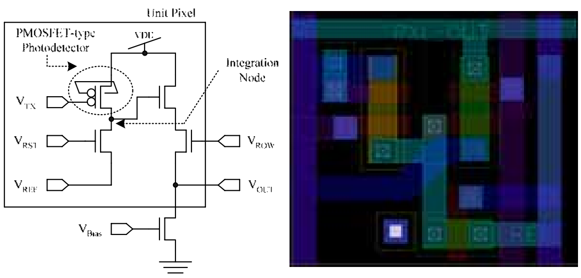


Fig. 1 Cross-sectional view of PMOSFET-type photodetector.



(b)

Fig. 2 Energy band diagram of PMOSFET-type photodetector
(a) the bias of transfer gate is positive
(b) the bias of transfer gate is negative.



(a) (b)

Fig. 3 Designed unit pixel using a PMOSFET-type photodetector
(a) schematic (b) layout.

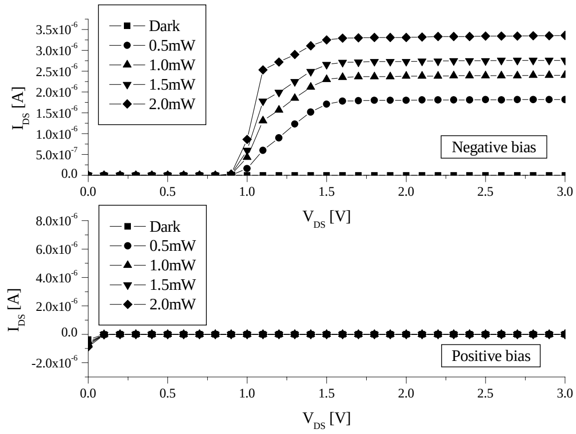


Fig. 4 The optical characteristic of a PMOSFET-type photodetector with a transfer gate (λ= 632.8nm).

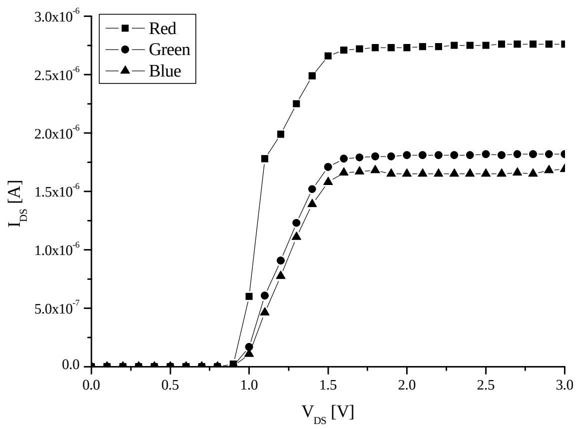


Fig. 5 The optical characteristic of a PMOSFET-type photodetector with a transfer gate (light power = 1.5mW).

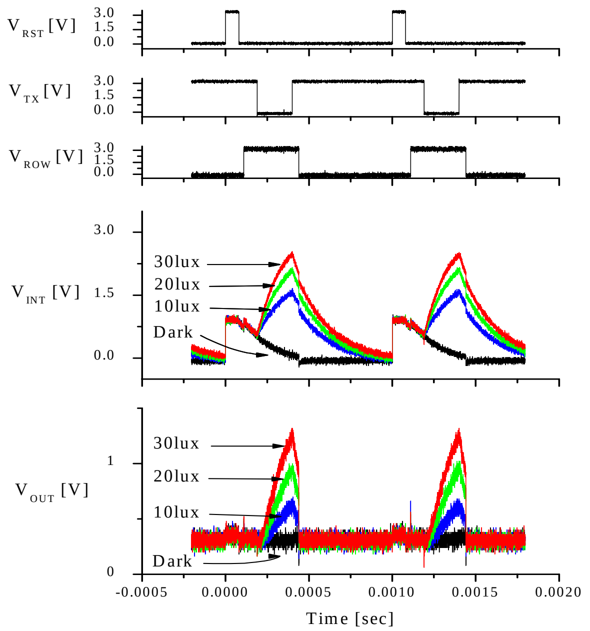


Fig. 6 Waveforms at the integration node and pixel output node of the completed active pixel sensor as the incident light power varies.