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A Wide Dynamic Range CMOS Image Sensor with 200-1100 nm Spectral Sensitivity and High Robustness to Ultraviolet Light Exposure

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Abstract

A 5.6 μm pixel pitch CMOS image sensor using following technologies was fabricated and evaluated. The pixels include the lateral overflow integration capacitor (LOFIC) for high sensitivity and high full well capacity (FWC) and buried channel source follower drivers for low noise. The photodiodes (PDs) are formed by a highly sensitive and highly robust to ultraviolet (UV) light technology.

1. Introduction

In these days, more CMOS image sensor has been widely used not only for consumers but also for scientific instrumentation. In a part of this field, highly sensitive and wide dynamic range (DR) image sensor is strongly required. To achieve it, an improvement of sensitivity especially UV light and an improvement of sensitivity robustness to UV light exposure have been challenged [1-2]. In some of these ways, following technologies have been reported: a LOFIC which achieves wide DR and high SNR simultaneously [3-4], a highly UV light sensitive and highly robust PD [5-6]. In this paper, we demonstrate a CMOS image sensor using these technologies to achieve above all characteristics.

2. Fabricated Structure

Fig. 1 shows the equivalent pixel circuit. The pixel circuit was formed by adding a LOFIC capacitance: C_{LOFIC} and a switch S to normal four transistor type pixel. A high sensitive signal is obtained from floating diffusion (FD), and a high FWC signal from FD + LOFIC. Wide DR signal is made by connecting these two signals [3-4]. In addition, buried channel transistor has been introduced as pixel source follower driver to reduce the SF noise [7].

In the PD, a shorter wavelength light such as UV light is converted to photoelectron at the shallower place in silicon. To have sensitivity to this light, a photo-generated carrier drift layer consisted of thin and steep p^+ layer was uniformly formed on the top surface of in-pixel PD as illustrated in Fig. 2. And both fixed charges and interface states increase due to a strong UV light exposure, and this cause the change of drift field; a sensitivity change and a dark current increase. To suppress these changes, we have made a thin neutral region by forming sufficiently high dopant concentration at the top few nanometer Si surface [5-6]. Additionally to increase sensitivity to NIR light, lower p layer was formed thick and low concentration.

3. Sample chip fabrication and Measurement Results

Fig. 3 shows the chip micrograph. The image sensor chip was fabricated using a 0.18 μm 1P3M CMOS process technology.

Fig. 4 shows the photoelectric conversion characteristic, which has been measured under 5100 K light source. A low dark random noise of 2.1 e^- rms and a wide DR of 98.2 dB were obtained.

Fig. 5 shows the spectral sensitivity of the fabricated CMOS image sensor measured before and after the UV light exposure stress for 1000 min. The super high pressure mercury discharge lamp was employed for this evaluation. The typical UV light intensities are 2.0, 4.4, 8.8 and 17.6 mW/cm^2 for the wavelength of 254, 303, 313 and 365 nm, respectively. For both cases, the high photo sensitivity was obtained for a wide waveband from 200 to 1100 nm. In addition, it was confirmed that there was no sensitivity degradation due to UV light exposure stress.

Fig. 6 shows the captured images. The area was separated into right and left. There are a stuffed doll, a paprika and mountain landscape background picture on the right side, and a stuffed doll, a light bulb and a white paper with a picture drawn by a sun block cream containing UV light absorbent on the right side. During image capturing, an UV light transmission lens: PENTAX B2528UV was employed. As shown in the pictures, the developed CMOS image sensor has a wide DR and wide spectral sensitivity. Table 1 shows the design specifications and performances of the fabricated chip.

4. Conclusions

A 5.6 μm pixel pitch CMOS image sensor with LOFIC, buried channel transistor and buried pinned-PD having the thin and steep p^+ layer of photo-generated electron drift layer was fabricated and evaluated. The fabricated chip simultaneously achieved a wide dynamic range of 98 dB and a wide spectral response to the light waveband from 200 to 1100 nm. Sensitivity degradation did not occur after the strong UV light exposure for 1000 min.

Acknowledgements

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References

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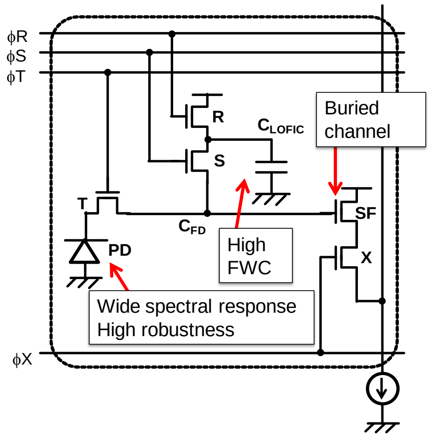


Fig. 1. Equivalent pixel circuit.

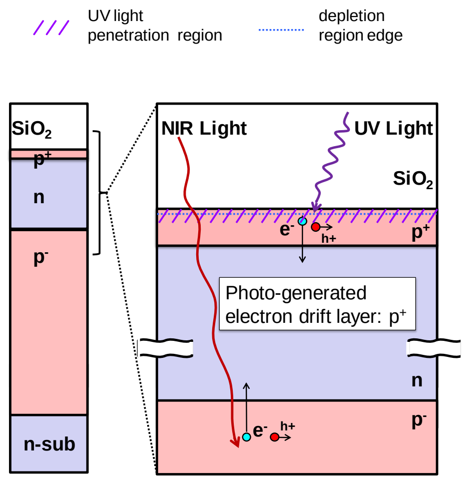


Fig. 2 Cross sectional view of the photodiode.

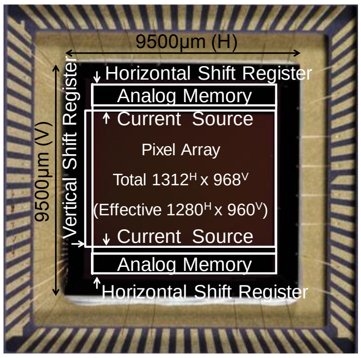


Fig. 3. Chip micrograph.

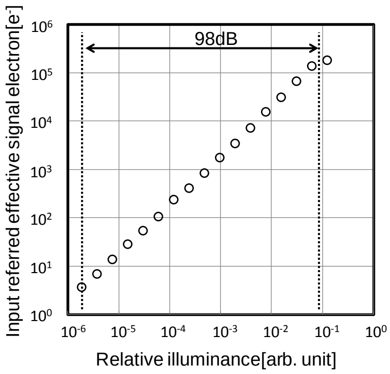


Fig. 4. Photo-electric conversion characteristics under 5100K light source.

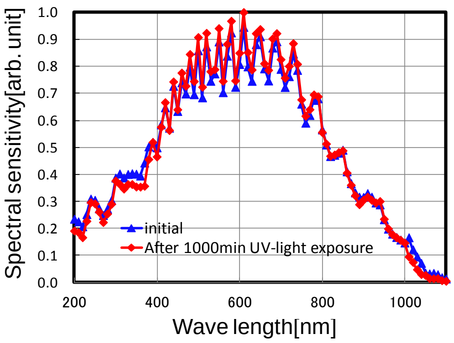


Fig. 5. Spectral sensitivity of the fabricated CMOS image sensor chip measured before and after 1000min UV light exposure stress.

Table 1. Design specifications and performances.

Process technology		0.18 μm 1P3M CMOS with pinned-PD
Supply voltage		3.3V
Die size		$9.5^H \times 9.5^V$ mm²
Pixel size		$5.6^H \times 5.6^V$ μm²
Number of Pixels	Total	$1312^H \times 968^V$
	Effective	$1280^H \times 960^V$
Fill factor		26 %
Dark random noise		2.1 e-
Dynamic Range		98 dB

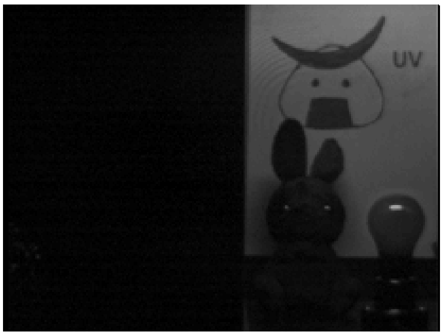
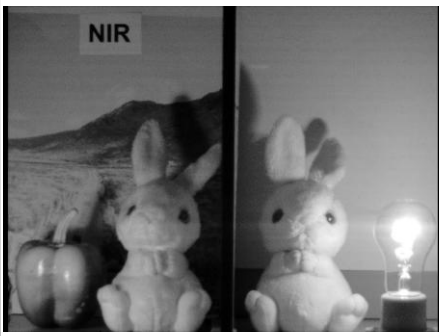
Visible light bulb on the right side and NIR light over 700nm on the left side with IR-cut lens filter.	Around 254 nm UV light with a narrow band UV transmission lens filter.	Visible light bulb on the right side and NIR light over 700nm on the left side without optical filter.
		
(a)	(b)	(c)

Fig. 6. Sample images.