A self-reset CMOS imaging device with high capacitance photodiode

Graduate School of Science and Technology, Nara Institute of Science and Technology[1],
Faculty of Medical Sciences, Kyushu University[2],
°Pakpuwadon Thanet[1], Kiyotaka Sasagawa[1], Mark Christian Guinto[1], Makito Haruta[1],
Hironari Takehara[1], Hiroyuki Tashiro[1,2], and Jun Ohta[1]
E-mail: sasagawa@ms.naist.jp

Introduction

This research aims to develop an image sensor with an extremely high signal-to-noise ratio (SNR) for observing an intrinsic signal in the mouse brain. An integrated self-resetting system has been designed to achieve sufficiently high SNR by overcoming the limitation due to pixel saturation [1,2]. In the previous study, we succeeded in developing the self-resetting system and confirmed that it could detect the intrinsic signal. However, it had an additional noise from the self-resetting system. The requirement of the effective SNR for the adequate image is approximately 70 dB. This time we present the technique to overcome those problems

In this study, we designed a pixel with high capacitance to reduce the number of self-resetting. It means that the unstable self-resetting stage can be reduced. As a result, this new version self-resetting image sensor reaches such high sufficient SNR and has more stable operation within the same optimized size.

Image sensor

The photograph and specifications of the proposed CMOS image sensor are shown in Fig 1. The pixel circuit of the chip is the same as our previous work except for the photodiode. The photodiode type is P+/N-well/P-sub in which provides more pixel capacitance. The evaluation result is shown in Fig. 2. At low light intensity, the present chip shows lower SNR due to low photoconversion gain by the larger capacitance. However, in the photon shot noise limited region, the SNR level is similar, and the SNR curve is less fluctuated due to the smaller number of self-resetting.

Imaging demonstration

To demonstrate the intrinsic signal imaging, we do the physical stimulation of the mouse whisker and set-up the imaging device at the brain surface. The target area on the brain surface is the barrel cortex. The barrel cortex is a region of the somatosensory cortex that corresponds to the mouse whisker. Fig. 3(A) shows the observed area of the mouse brain. The images in Fig.3(B) and (C) were taken along with the stimulation at the exact time. The additional noise from the self-resetting operation in Fig. 3(B) can be significantly improved with the post process as shown in Fig. 3(C).

Conclusions

We developed a self-reset image sensor with P+/N-well/P-sub as a photodiodes structure. The resetting number has been reduced since the saturation level shifted up due to the large pixel capacitance. The SNR reaches over 70 dB with improved stability.

Technology	TSMC 0.35 μm 2-poly 4-metal std, CMOS process
Chip size	2.7 × 2.1 mm
Pixel size	15 × 15 μm²
Photodiodes	P+/N-well/P-sub
Fill factor	30 %
Pixel number	128 × 128
Operating voltage	3.3 V
Pixel type	3-Tr active pixel sensor with 4-Tr Schmitt trigger inverter for self-resetting

Fig. 1 Photograph and specifications of the fabricated CMOS image sensor.

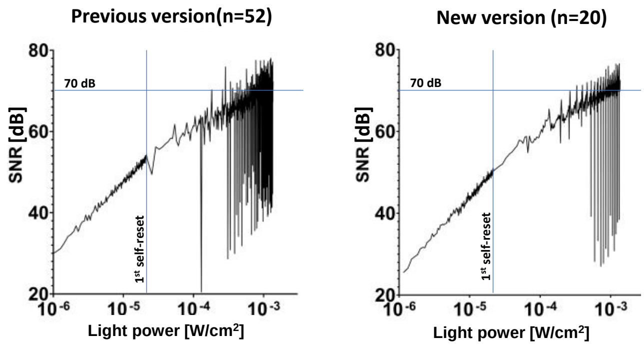
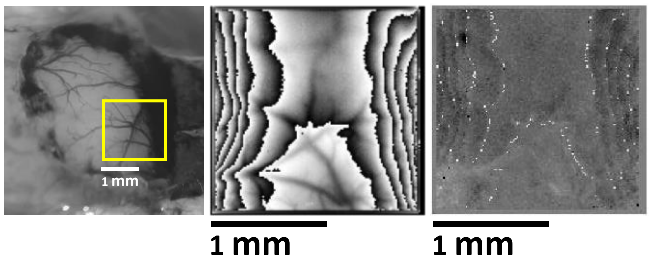


Fig. 2 The evaluation results show that the imager with the new pixel designed has SNR over 70 dB with more stability compare to the previous work. n is the maximum number of self-resetting in the measurement.



(A) (B) (C)

Fig.3 The images from the In-vivo experiment (A) the image location on the mouse brain. (B) A raw image shows the resetting boundary, which is an additional noise from the resetting system. (C) Difference image from the reference frame.

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