R4 2.8μm-Pixel Image Sensor νMaicovicon™

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1. Introduction

In recent years, imaging equipments with image sensors such as mobile cameras, video cameras and digital still cameras have been widespread. The growth of camera market for mobile use is remarkable. In this market, low power consumption and multifunction of image sensors are strongly demanded, while keeping high image quality and high-resolution.

Image sensor is mainly divided into two types, a CCD image sensor (CCD) and a CMOS image sensor (CIS). A CCD is good for high image quality, however it has difficulties in low power consumption and multifunction for a mobile camera. On the other hand, a CIS is good for low power consumption and multifunction, however it has problems of low image quality. We have developed a new image sensor (νMaicovicon™) which has many features such as small pixel size, high image quality equivalent to a CCD, low power consumption and multifunction like a CIS.

2. Technology of νMaicovicon™

Pixel circuits and pixel structures of the conventional CIS and νMaicovicon™ are shown in Figure 1.

A CIS generally needs 4 transistors per pixel, and has a difficulty in realizing small pixel size .We have developed νMaicovicon™ with 3 transistor pixel structure. The pixel in νMaicovicon™ is selected by controlling the potential of Floating Diffusion (FD).The FD potential is controlled by changing pixel drain(DRN) voltage through the reset transistor. FD driving pixel is described to reference [1] in detail. So the selection transistor and the select control line can be eliminated. We have designed 2.8μm square pixel fabricated by using 0.18μm technology and 30% photodiode fill factor has been achieved.

Very low dark current has been realized based on a simple NMOS single channel process and by using buried photodiode structure similar to CCDs. The simplicity of the NMOS process enables us to optimize the process for reducing the dark current. The thermal budget for fabrication process is restricted for PMOS transistor characteristics. The simple NMOS process allows us to use the thermal budget for releasing the damage and the stress in the process, which cause in leakage current. It brings also the advantage of short turn-around time.

3. Readout Circuits

νMaicovicon™ also has the various functions and the low power consumption like CISs. Readout circuits are designed using NMOS dynamic circuit architecture in order to achieve the low power consumptions. Many functions such as vertical image flip and skip readout are also realized.

Figure 4-a shows the normal scan shift register circuit of NMOS dynamic circuit. The signal of the shift register is transmitted from node NEXT to node IN, and shifts right. In NMOS dynamic circuit, it is necessary to reset floating node IN behind an active line by reset transistors.

Figure 4-b shows the shift register circuit of NMOS dynamic circuit with the vertical image flip function. Flip switches are used in the flip mode and signal of the shift register shifts to the reverse direction. Reset transistors are used for resetting latter floating part in the shift resister behind an active line in the flip mode. The added reset transistors are also used for resetting former floating part in the shift resister before an active line in the normal mode and thus prevents malfunction of the shift register.

4. Suppression of the black spot phenomenon under high luminance

Black spot phenomenon occurs under very strong incident light which is known as a peculiar image trouble to a CIS. A CIS has a CDS circuit for Fixed Pattern Noise reduction. It takes the difference between reset level and signal level of FD. When the level of incidence light rises far over saturation, the excess photoelectrons overflow into the FD. FD potential is fixed at a low level and the image of high luminance subject like the sun turns black as shown in Fig. 2(a).

To solve this problem we introduce an original on-chip signal compensation circuit. Figure 3 shows the circuit configuration and potential diagrams. As compared with the conventional circuit, the skip transistor is added in parallel with the clamping capacitor (Ccp). Fig. 3-b indicates potential diagrams under standard light and high luminance light. At a standard optical condition, the potential change in the vertical signal line is conducted to sampling capacitor node (Sig) through the Ccp. At a high luminance light condition, the potential of the vertical signal line greatly rises exceeding the gate potential of skip transistor. Then the Sig node potential is fixed to the vertical signal line level. The skip transistor replaces the sensor signal with the signal higher than the saturation level as shown in Fig. 2(b). With this signal compensation function the black spot is eliminated.

5. Sensor Characteristics

We have developed 1/3.2-inch 2M-pixel image sensor. Figure 5 shows the chip micrograph of the 2M-pixel sensor. Table 1 shows the typical sensor characteristics. Very low dark current of 60electrons/s has been realized based on a simple single channel NMOS process and high image quality has been obtained under illuminance of 5lx as shown in Figure 6. Moreover, the low power consumption of 45mW has been achieved at the power-supply voltage of 2.9V and pixel clock of 19MHz.

Acknowledgments: The authors acknowledge contributions of other members of this project.

References: [1] Kenji Mabuchi, "CMOS Image Sensor Using a Floating Diffusion Driving Buried Photodiode," ISSCC Dig. Tech. Papers, pp. 112-113,Feb.2004.

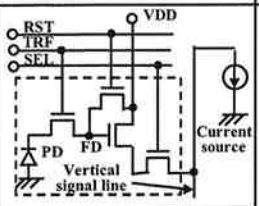
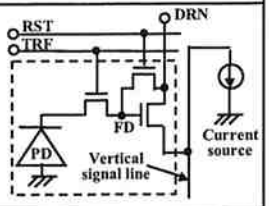
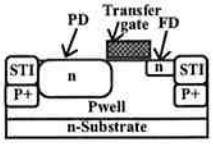
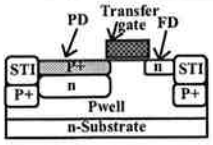
	Conventional CMOS Image Sensor	ν Maicovicon ™
Pixel Circuit		
Technology	2-Poly 3-metal 0.18 μ m CMOS	1-Poly 2-metal 0.18 μ m NMOS
Pixel Size	2.8 μ m/Pixel	2.8 μ m/Pixel
Transistor	4 Transistor/Pixel	3 Transistor/Pixel
Fill Factor	10%	30%
Pixel Structure		
Image Accumulation for 2 seconds at 60℃		

Figure 1 Pixel Structure Comparison

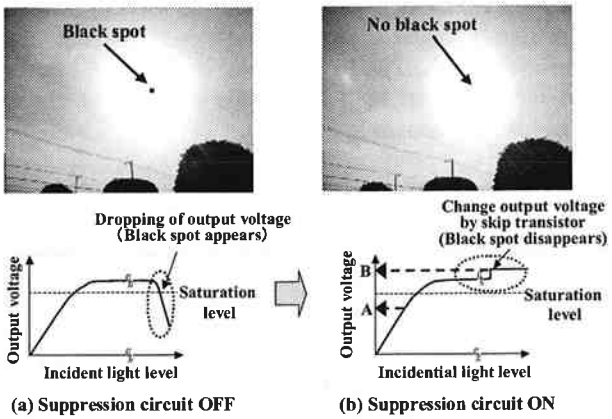


Figure2 Suppression of black spot under high luminance

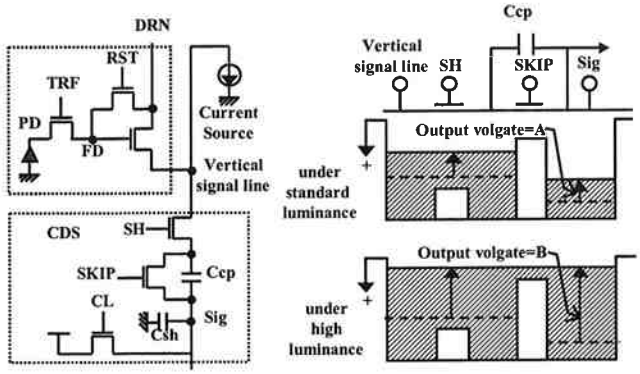


Figure 3 Suppression circuit of black spot

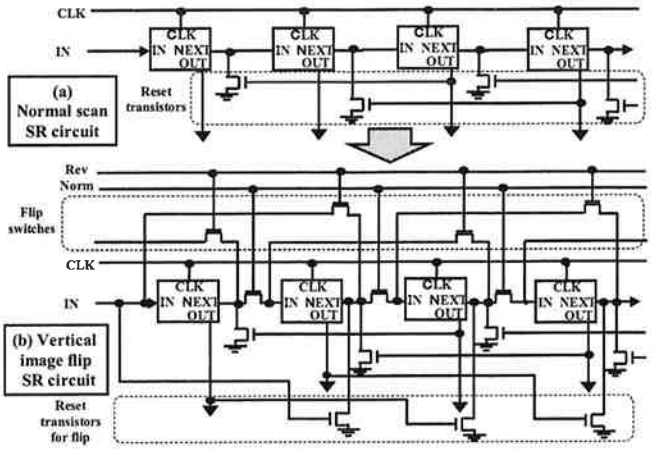


Figure 4 Vertical shift resister circuit

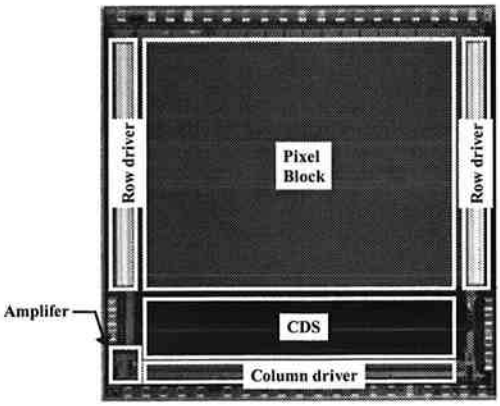


Figure 5 Chip micrograph

Scanning method	Progressive scan
Optical size	1/3.2 inch
Number of total pixels	1734(H) × 1261(V) mach of UXGA format
Supply voltage	2.9V(typ.)
Pixel rate	19MHz
Frame rate	7.5 frames/s
Power consumption	45mW(typ.)
Pixel size	2.8(H) μ m× 2.8(V) μ m
Fill factor	30%
Sensitivity	3500 electrons at 1050nit,F8,15fps
Saturation signal	6000 electrons
Dark current	60 electrons/s at 60℃
RMS random noise	6 electrons
Functions	Image reversal ,skip readout

Table 1 Sensor characteristics

Figure 6 Sample images