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CMOS Image Sensor Using SOI-MOS/Photodiode Composite Photodetector Device

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1. Introduction

Image processing unit on SOI is of great interest to facilitate system integration on SOI chips. This is because SOI-CMOS can construct very-high speed and low power circuits and peculiar characteristics of SOI such as semi-transparency of the active layer can offers a new function.

The pn junction photodiode on SOI has, however, low sensitivity as it is compared with bulk devices since the active layer is thin. To overcome this drawback, we have proposed a SOI-MOS/photodiode composite device[1]. In the composite device the photocurrent from the junction photodetector is amplified by the bipolar action of the MOSFET of partially-depleted type. In the previous report, we have demonstrated the operation of the composite photodetector using junction diodes fabricated in bulk (substrate) Si. In this work, SOI-MOS/photodiode composite device fully fabricated on an SOI active layer using lateral pn junction diode (see Fig. 1) are investigated. In addition, the operation of a CMOS line sensor using the composite device is demonstrated.

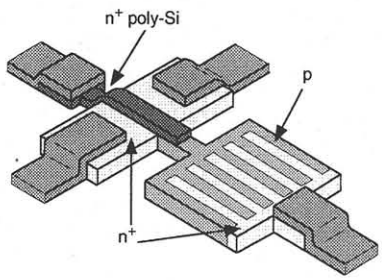

Figure 1: Structure of the photodetector composed of a lateral pn junction diode and a MOSFET on SOI.

2. Fabrication of the device

Devices were fabricated using p-type SIMOX wafer (T_{SOI} = 200 nm, T_{BOX} = 400 nm, $\rho = 20 \sim 30$ Ωcm). The SOI MOSFET was of partially depleted type. The gate poly-Si was doped to be n^+-type for n-channel in order to increase the current amplification factor of the lateral bipolar action in MOSFETs[2]. In order to investigate the effect of the presence of the gate electrode, composite devices having a lateral BJT, which is similar to MOSFET but no gate electrode was placed, were also fabricated. The thickness of the gate poly-Si was about 150 nm. The gate oxide thickness was 30 nm. The gate length was 2.0 μm. The SOI MOSFET has a body contact region under the gate electrode. The lateral junction photodiode was p/n^+ type. It was formed in the SOI layer. The p-type region was direct by connected to the body of the MOSFET through the body-tie. The photodiode size was 50×50 μm^2 and the junction length was 1260 μm.

3. Characteristic of Composite Device

Figure 2 shows responsivity of a composite device and a photodiode measured at various wavelength. The spectra have two peaks with the maximum at about 450 nm. This is due to the interference of the light. The shape of the responsivity spectrum of the composite device is almost similar to that of the photodiode, which indicates that the output of the composite device is the result of amplification of photocurrent generated in the photodiode. The current amplification factor is almost independent of the wavelength and is about 4. In the case of the composite device in which the photodiode was fabricated in the substrate Si, the current amplification factor of about 8 was obtained[1]. The reason why the composite device with lateral junction diode is smaller than the device with bulk junction diode can be attributed to the current dependent amplification factor of the lateral bipolar action of the MOSFET.

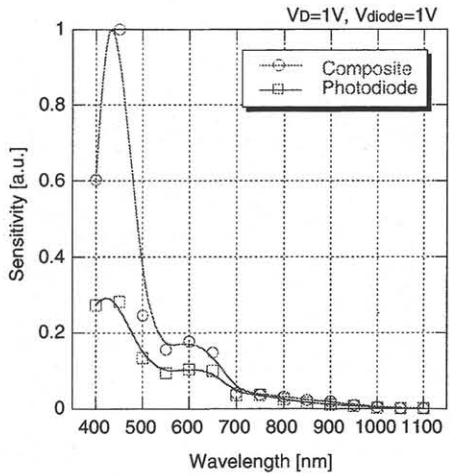

Figure 2: Responsivity spectra obtained from an n-channel/pn^+ composite device having the gate width/gate length of 10 μm/2.0 μm and a photodiode.

Figure 3 shows the linearity of the composite device. The device shows almost linear response over 3 decades. But the linearity becomes worse as the illumination intensity decreases. This is due to the fact that the dark current is rather high in the present device.

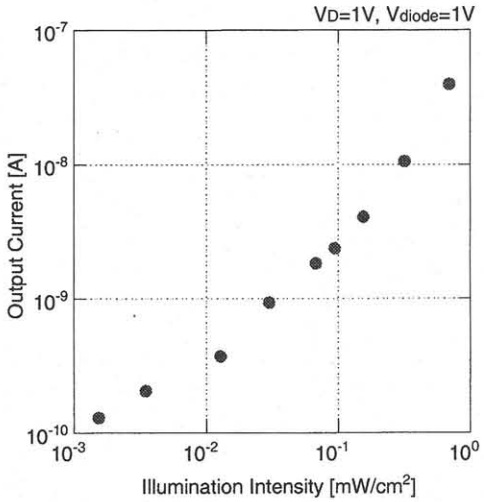

Figure 3: Change with the illumination intensity in output current of the composite device.

In Fig. 4, output signals observed for a composite device and a photodiode was compared. In addition, a signal observed for a device composed of a lateral BJT (similar to MOSFET, but no gate) and a photodiode was shown in the figure. These were obtained by connecting an external resistor of 100 kΩ. The results clearly demonstrate that the SOI-MOSFET/photodiode composite device can output stable signal which is much higher than the level of photodiode. Also, the signal level of the SOI-MOSFET/photodiode composite device is higher than that of lateral-BJT/photodiode composite device. This difference is owing to the fact that, due to the presence of the gate electrode, SOI-MOSFETs have higher current amplification factor than lateral BJTs as far as the workfunction of the gate electrode is properly chosen.

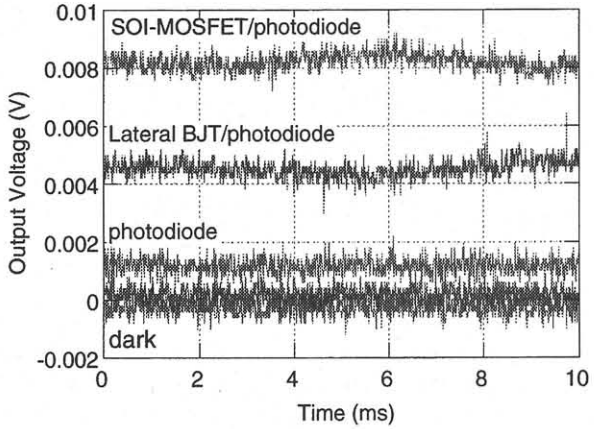

Figure 4: Output voltage of the pixels of three types.

4. CMOS line sensor

As the prototype, 24 pixel line sensors having the composite device in each pixel were fabricated. The shift-resistor circuit was constituted of D-type flip flop and was designed and fabricated using SOI-CMOS. The device parameters were almost the same as described in the above. Two aluminum-interconnect layers were used to fabricate the line sensor. Figure 5 shows a view of a part of the line sensor in which the SOI-MOSFET/photodiode composite device was used in the pixel.

Figure 6 shows the output signal observed for the CMOS line sensor with the composite device, as it is compared with the signal of a line sensor with pixels having only photodiode. We can see that each pixel in the line sensor with composite device output a signal whose level is higher than the line sensor with only photodiode.

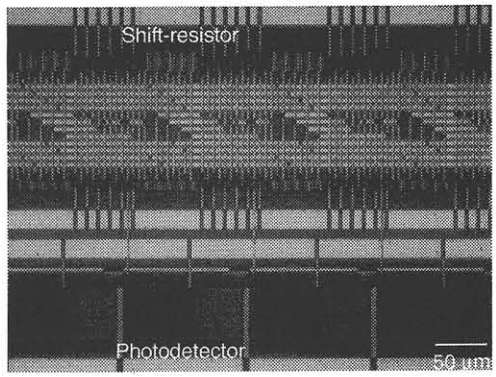

Figure 5: Top view of a part of the line sensor on SOI, contacting the composite device in each pixel.

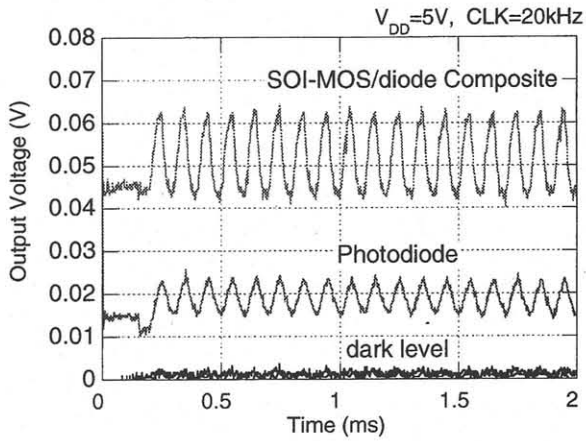

Figure 6: Output signal of the 24 pixel line sensor.

5. Conclusion

Owing to the lateral bipolar action of partially depleted SOI-MOSFET, SOI-MOSFET/photodiode composite device can compose a high sensitivity photosensing unit on SOI. The operation of a CMOS line sensor was demonstrated.

Acknowledgement

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References

[1] Y. Uryu and T. Asano: Jpn. J. Appl. Phys. **40** (2001) 169.

[2] W. Zhang et. al.: IEEE Electron Device Lett. **19** (1998) 435.