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SOI-MOS/Diode Composite Photodetector Device

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1. Introduction

Integration of photodetector and CMOS circuits on SOI wafers is of great interest in realizing low cost, low power imaging system that includes signal processing function. Moreover, semi-transparent characteristic of SOI for the visible light can provide a multiple plane imaging which can be applied to a novel system such as robot control[1]. As pixel size of image sensor shrinks and frame rate increases, it is required to increase the sensitivity of the photodetector. It has been reported that SOI MOSFET itself has highly-sensitive photodetection function due to the lateral bipolar effect[2][3].

In this paper, we report a new photodetector device composed of a photodiode and an SOI-MOS. Figure 1 shows schematic cross-section of the device. A photodiode is connected with the floating body of the SOI MOSFET which is of partially depleted type. Photogenerated carriers in the photodiode are accumulated in the floating body and forward-bias the source/body junction to induce the lateral bipolar action in the MOSFET structure. As a result, the photocurrent of the photodiode is amplified.

In the present study, results from test devices in which the photodiode is fabricated in the substrate of a SIMOX wafer are reported. Both n-channel and p-channel MOSFETs are tested. Current amplification up to about 70 times is demonstrated.

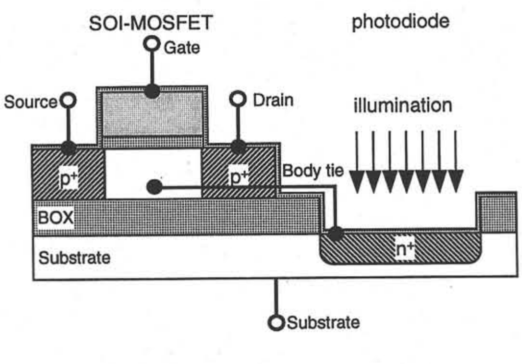

Figure 1: Schematic cross-section of proposed device.

2. Fabrication of the device

The composite device was fabricated using p-type SIMOX wafer (T_{SOI} = 200 nm, T_{BOX} = 400 nm, $\rho = 20 \sim 30\ \Omega$cm). The SOI MOSFET was of partially depleted type. The SOI MOSFET has a body contact region under the gate electrode, which is connected with photodiode using aluminum. The gate poly-Si of the SOI MOSFETs were doped to be n^+-type for n-channel and p^+-type for p-channel. The thickness of the gate poly-Si was about 150 nm. The gate oxide thickness was 30 nm. MOSFETs having the gate length down to 0.6 μm were fabricated. The photodiode was fabricated in the substrate after removing the buried oxide. The photodiode was n^+/p type for p-channel MOSFET device and p/n^+ type for n-channel MOSFET device. The photodiode size was $25\times25\ \mu m^2$. Figure 2 shows top view of the fabricated device.

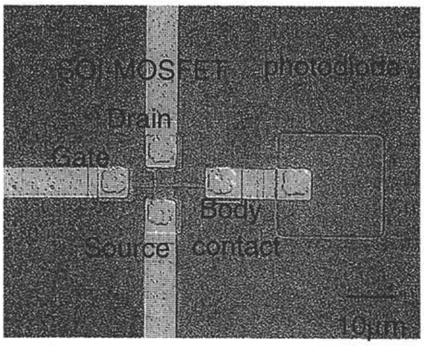

Figure 2: Top view of the composite device.

3. Results

Photodetection characteristic has been investigated under conditions of diode reverse bias = 1 V and the floating gate. The floating gate condition showed a higher current amplification than fixing the gate potential[3]. The output drain photocurrent characteristics of a p-channel SOI MOSFET/n^+p diode composite device is shown Fig. 3. The composite device outputs drain current depending on the illumination intensity. The output drain current as a function of illumination intensity is shown in Fig. 4 for p-channel/n^+p device having various gate length. The output drain current is found to be almost proportional to illumination intensity. In addition, the drain current is found to increase with decreasing the gate length of SOI MOSFET down to 0.8 μm. Similar photodetection characteristic was obtained for n-channel/pn^+ composite devices.

The output drain current of the p-channel/n^+p composite device as a function the gate length is shown in Fig. 5. The photocurrent measured for the photodiode

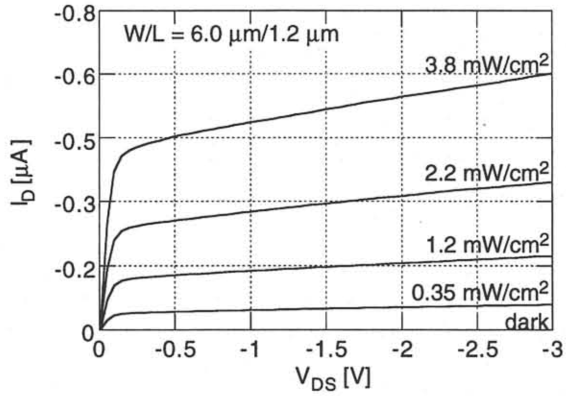

Figure 3: The drain current characteristic of the composite device (W/L = 6.0 μm/1.2 μm) at various illumination intensity. The device is composed of p-channel SOI MOSFET/n$^+$p diode.

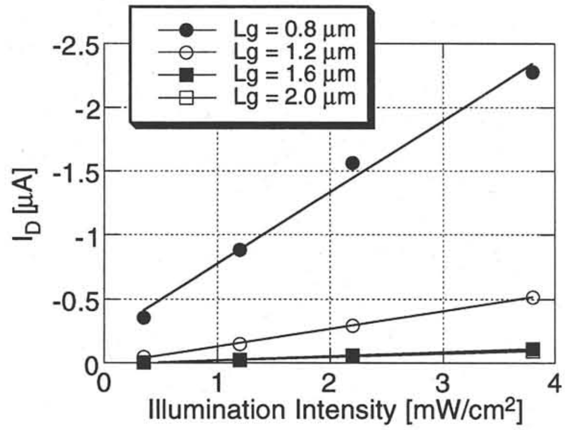

Figure 4: Output drain current versus illumination intensity for the p-channel/n$^+$p composite device (V_{DS} = -1V).

of each device was also plotted in the figure. We can see that the drain current of the composite device under illumination increases with the shrinkage of the gate length. But the drain dark current (leakage current) also increases when the gate length decreases. When the gate length is shorter than 0.6 μm, the drain dark current is higher than photodiode photocurrent.

The current gain, which is defined as the ratio of the drain current to diode current under illumination is shown in Fig. 6. Results obtained from both p-channel/n$^+$p and n-channel/pn$^+$ devices are show in the figure. We can see that the current gain increases with decreasing the gate length. When the gate length of the p-channel/n$^+$p device is 0.8 μm, the drain current is about 70 times as much as the diode photocurrent.

5. Conclusion

The optical response of SOI MOSFET/photodiode composite device has been investigated. Amplification of diode photocurrent by the lateral bipolar effect of the SOI MOSFET has been observed. Current gain up to about 70 was obtained using p-channel/n$^+$p device. We have also observed the current amplification in composite devices of lateral photodiodes fabricated in the SOI film.

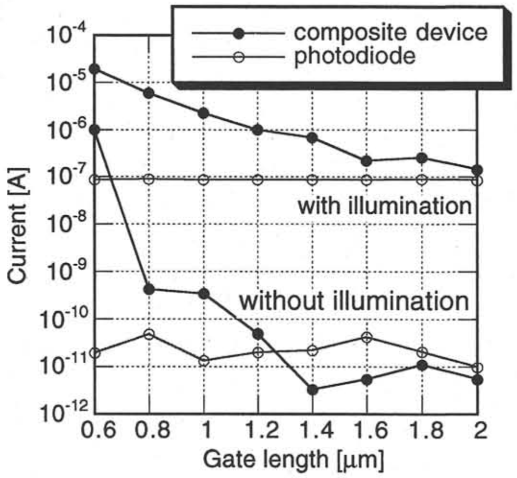

Figure 5: Change with the gate length in output current of p-channel/n$^+$p composite device. Photodiode current measured for each device was also plotted.

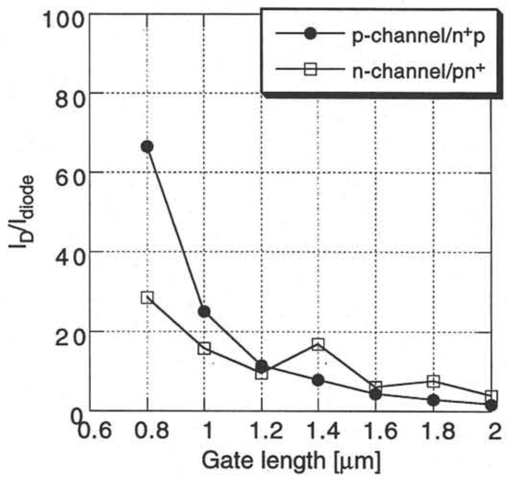

Figure 6: Current gain of the composite device as a function of the gate length. Results for both p-channel/n$^+$p and n-channel/pn$^+$ device were plotted.

References

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