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Adjacent Channel Crosstalk in 0.18-µm Si CMOS Photodiode Arrays with Body Contact

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1. Introduction

Monolithically integrated multichannel architectures are required for low cost and high speed communication [1]-[2]. The system performance degrades when crosstalk increases. Therefore, the impact of crosstalk must be considered, including optical crosstalk and electrical crosstalk [2]. In recent Si-based photodiodes (PDs) research, the substrate coupling is an issue due to the common substrate. The lossy substrate not only induces slow diffusion photocarriers but also causes adjacent channel crosstalk. Fabricating on Silicon-on-Insulator substrate can reduce the problem [3], but is not cost-effective. In this study, two 4-channel 850 nm Si PD arrays fabricated in standard 0.18-µm CMOS technology with body grounded and floating are used to study the adjacent channel crosstalk characteristics.

2. Photodiode array design

Fig. 1 shows a three-diamensional (3-D) schematic structure of the proposed PD in array which is fabricated in standard 0.18-µm CMOS mixed-signal process from United Microelectronics Corporation (UMC) without process modifications. The n/p implant is used for n- and p-type ohmic contacts, respectively. The STI oxide is used for forming isolation regions between active devices to reduce surface leakage and extend depletion region. Moreover, it can enchance breakdown characteristics and improve responsivity. When PD is operated in the avalanche region, the n-well, p-well and p-substrate region are depleted strongly and form a wide absorption region. The n/p well and STI are placed at minimal distance defined by the design rule to reduce the long transit time of photocarriers.

Additionally, the body contact design formed by p-implant and p-well is connected to the substrate. And it surrounds the active device as a guard ring to collect some of the slow diffusion photocarriers. Moreover, the low resistance path provided by grounded body can absorb coupling power from adjacent channels. The active area is 50×50 µm^2. Fig. 2 shows two types of 4-channel PD array designs with interchannel separation of 250 µm pitches. Fig. 2 (a) presents the PD array with body floating (BF), and Fig. 2 (b) shows the PD array with body grounded (BG).

In order to reduce optical coupling, metal-1 is provided as metal shield to block the unwanted illumination into the deep substrate between adjacent channels. And separated bias scheme is used to reduce electrical crosstalk from power supply.

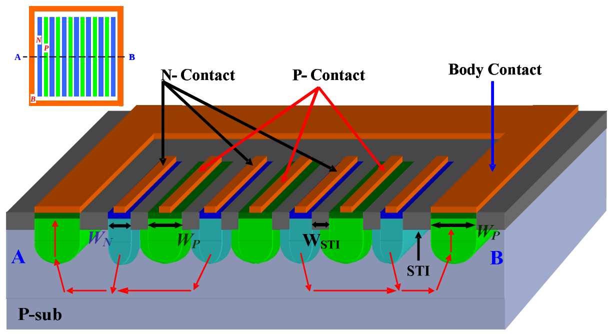

Fig. 1 A 3-D schematic structure of the proposed PD with body contact.

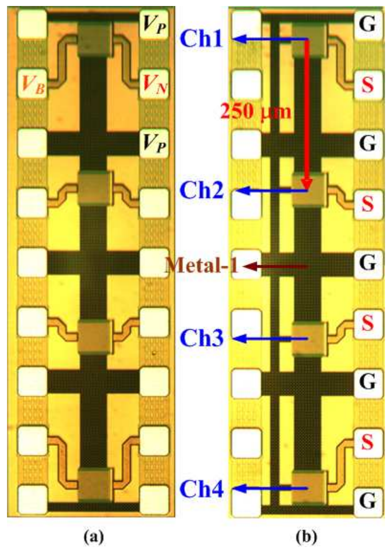

Fig. 2 Chip photo of two types of 4-channel Si PD array design: (a) with body floating; (b) with body grounded.

3. Measurement results and discussion

In the measurement setup of 3-dB bandwidth, the New Focus 850-nm 10 Gb/s VCSEL is connected to one port and the PD is through the bias-tee connected to the other port of an Anritsu 37397D 65 GHz optical network analyzer. The PD arrays are measured via on-wafer probing through ground-signal-ground-signal-ground (GSGSG) probe with 100 µm pitches. All of the PD arrays in this work are biased at avalanche region (about 15 V to 15.1 V) and the photocurrent of each channel is about 550 µA with incident optical power of 550 µW. Fig. 3 shows the measured frequency response for the PD array with body floating. The PD array shows a 3-dB bandwidth of 2.1 GHz to 2.5 GHz in channel 1 to channel 4. The crosstalk was measured by coupling the optical signal into one channel and measure the RF output at adjacent channels [2]. It is shown that crosstalk at f_{-3dB} is around -30 dB to -35 dB.

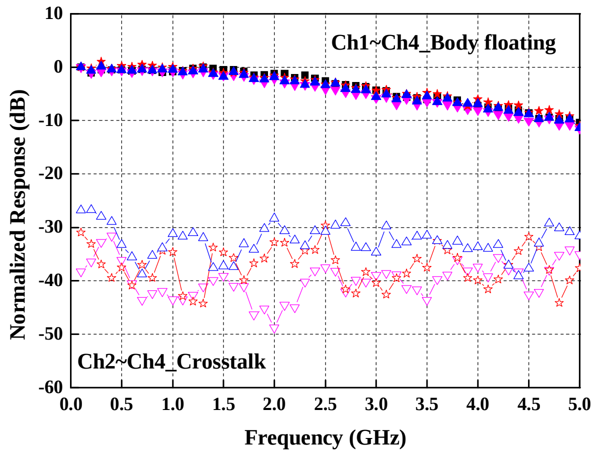

Fig. 3 Measured normalized frequency response and adjacent channel crosstalk of 4-channel PD array with body floating.

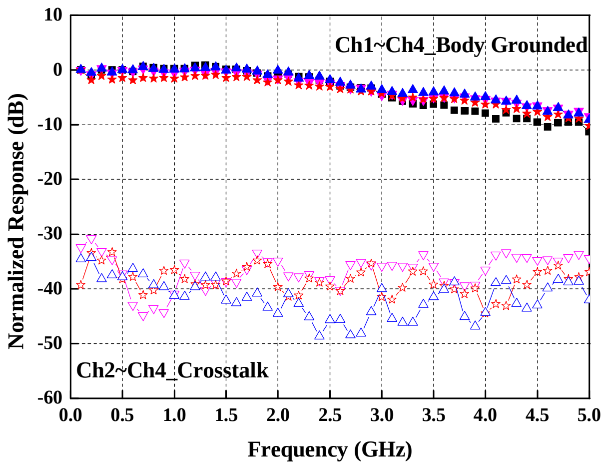

Fig. 4 Measured normalized frequency response and adjacent channel crosstalk of 4-channel PD array with body grounded.

As shown in Fig. 4, the PD array with body grounded achieves 3-dB bandwidth of 2.4 GHz to 2.7 GHz among 4 channels. A higher bandwidth is observed due to the elimination of slow diffusion photocarriers from body current. Furthermore, the grounded body guard ring can provide a low resistance path to absorb the coupling signal from adjacent channel via substrate. Therefore, crosstalk is improved about 3 to 12 dB while comparing with the ones with body floating. Crosstalk penalty is also investigated in this work. Fig. 5 depicts the calculated crosstalk penalty based on one of the measured crosstalk data among 3-dB bandwidth. The crosstalk penalty is defined and calculated as:

$$-10\log\left[1-6\times10^{(\varepsilon_{dB}/20)}\right] \quad [4]$$

Where ε_{dB} is crosstalk in decibels. Table I summarized the crosstalk performance of PD arrays in this study.

4. Conclusion

We have presented two Si PD arrays in 0.18-μm CMOS technology for crosstalk study. The Si PD array with body grounded shows better crosstalk performance than the one with body floating. The grounded body contact not only removes the slow diffusion photocarriers (better f_{-3dB}) but also plays an important role in absorbing the coupling signals between PDs. It is shown that crosstalk at f_{-3dB} for PD with body grounded is around -37 dB to -45 dB.

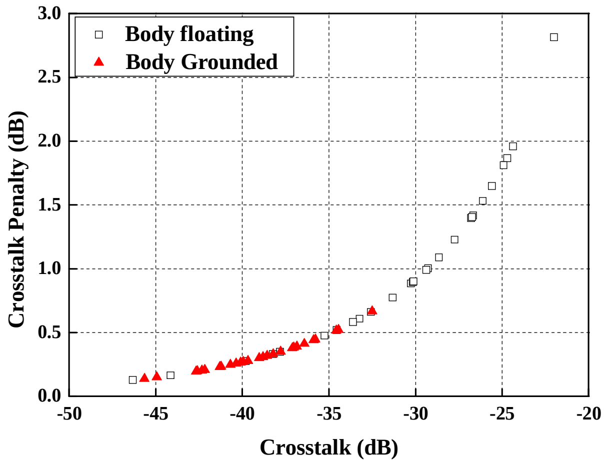

Fig. 5 Measured crosstalk characteristics between channel 3 and channel 4.

Table I Summary of PD arrays crosstalk performance

Adjacent/Main channel		2/1	3/2	4/3
Crosstalk @f_{-3dB} (dB)	BF	-34.9	-30.0	-33.9
	BG	-37.3	-37.6	-45.6
Crosstalk penalty	BF	0.50	0.90	0.56
@f_{-3dB} (dB)	BG	0.37	0.35	0.14

5. Reference

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