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A High Performance Photodetector Suitable for Visible Light and Near IR Applications

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1. Introduction

The optical pickups of nowadays are operating at 780nm (CD-ROM) and at 650nm (DVD), and the future systems will rely on the blue-ray (410nm) to increase the storage capacity. Integrating photodetectors with high spectral responsivity over the whole visible and the near infrared light is of growing interest. At the same time, creating the photodetectors based on the technical compatibility with mainstream silicon technology benefits cost reduction of the optical storage system and allows the realization of analog or digital circuits on the same chip with these photodetectors.

In this work, the methodology of creating a high performance photodetector in commercial 0.35 μm SiGe BiCMOS process is provided. The detector is called the phototransistor photodetector (PTPD). The PTPD accepts wide incident light power range. It also shows excellent photo-to-dark current ratio for the entire visible light band.

2. Device Structure And Operation

The PTPD includes a shallow surface photodetector (SPD) and a conventional hetrojunction bipolar transistor (HBT). Fig. 1 illustrates the cross-sectional structure of the proposed PTPD. The SPD is a diode built by the poly-Si/SiGe-base junction. Both the emitter and SPD are defined at the same process step of poly-Si deposition and etching. Fig. 2 demonstrates that the intensity of light start to decay exponentially from the surface of poly-Si layer along the direction toward the bulk. The SPD enhances light absorption, especially for blue ray.

The working principle of PTPD is like the conventional phototransistor with floating base [1]. The light detecting regions, BC junction and SPD, generate the photo-carries (holes) which are swept into the same neutral base region. Then the integrated HBT amplifies the signal. Although the PTPD has four terminals, it is usually biased only with V_{CE}. This maintains the convenience to integrate with periphery circuits in many applications.

3. Characterization and Discussion

The dark current of the PTPD was first verified by using HP 4156. The dark current density of the PTPD was shown in Fig. 3 to be similar to that of a phototransistor. Fig. 4 reveals the measured collector current under various bias voltages and light intensities. The result shows that the V_{CE} can be as low as 0.3 V for normal operation. Low V_{CE} favors low dark current. Fig. 5 shows the measured collector current under various incident light power. It implies that excellent photo-to-dark current ratio can be obtained in the PTPD. The light source used in this measurement was a tungsten lamp. IR and UV filters were used during the experiment to ensure that the incident light had wavelength from 400nm to 750nm. Even when the incident light intensity was 1 Lux, the PTPD still achieved significant photocurrent over the dark current. Table I tabulates the comparison among a couple of detectors in BiCMOS process reported in recent years for optical storage application [4][5]. The implementations of Refs. [4] and [5] showed respectable performance. But the resultant photoresponsivities were typically below 1 A/W. Lower responsivity results in larger detector area for specified current output at specified light power. Besides, the biased voltage for the PIN is as high as 17V [5]. It is not desirable for low-V portable device applications. Our experimental results demonstrate that the proposed PTPD has a high responsivity in visible light band with acceptable biasing voltage and dark current.

4. Conclusions

With commercial SiGe BiCMOS technology, a new high performance photodetector, the PTPD, has been demonstrated. The detector exhibits high responsivity in the visible light band and can be used for applications such as BlueDVD, DVD or CD-ROM.

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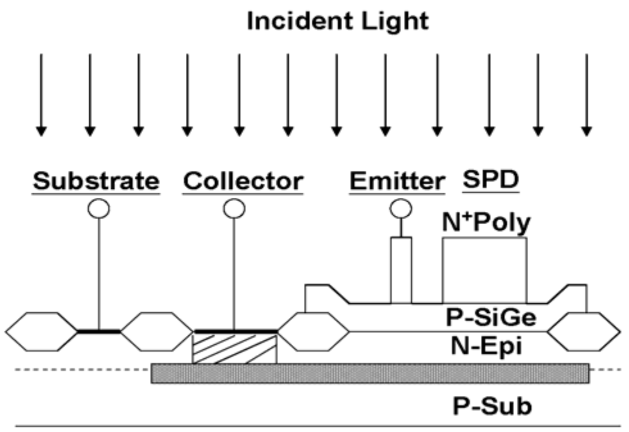

Fig. 1 The cross-section of the proposed PTPD.

Table I. The comparison of the photodetectors in optical storage system application.

	Meinhardt et al. [4]	Zemecek et al. [5]	This Work
Light Wavelength (nm)	410 / 660 / 785	410 / 660	450 / 670 / 780
Responsivity (A/W)	0.21 / 0.42 / 0.53	0.25 / 0.42	5.69 / 9.47 / 7.11
Detector Type	Diode	PIN Finger-Diode	PTPD
Biased Voltage (V)	1	17	Vce=1
Detecting Junction	BC	PIN	BC & SPD
Device Size (μm^2)	625.0	1963.5	525.0
Dark Current	~7pA	0.36 pA	1.8 pA
Commercial Process	0.35μm SiGe:C BiCMOS	0.5μm BiCMOS	0.35μm SiGe BiCMOS

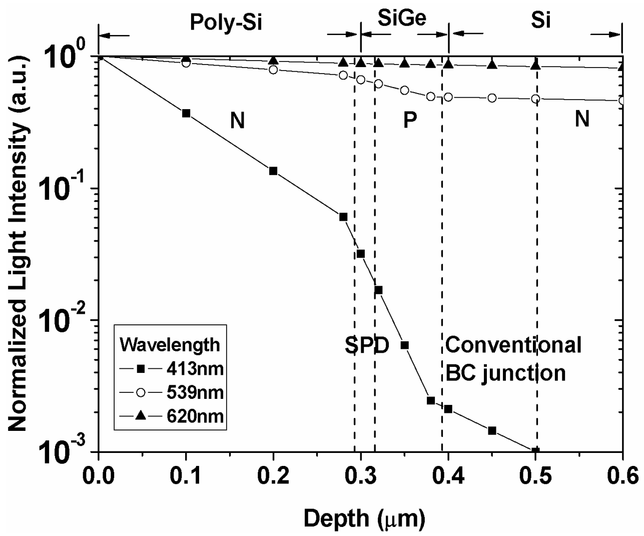

Fig. 2 The calculated light power distribution under various incident light. The absorption coefficients used are provided by [2] [3].

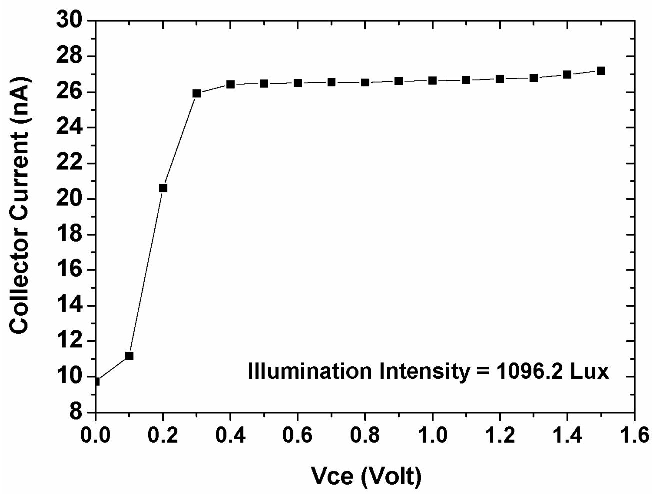

Fig. 4 The measured collector current under various Vce.

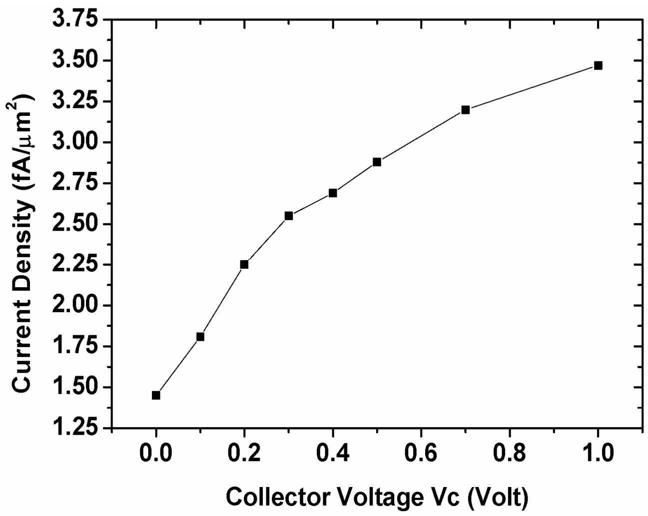

Fig. 3 The measured dark current density of the PTPD.

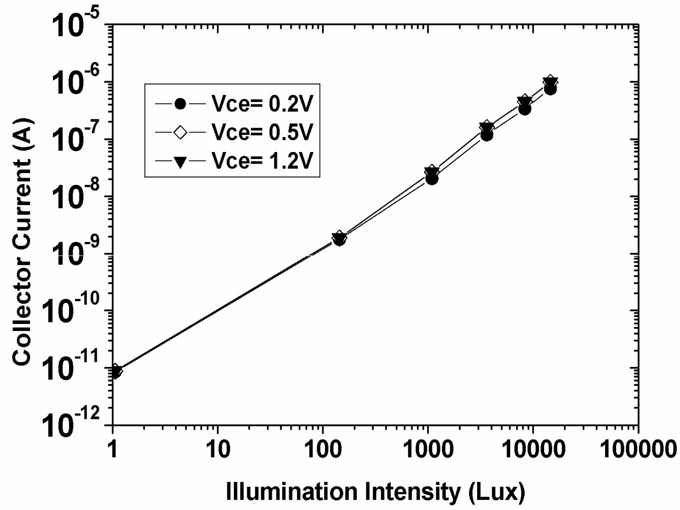

Fig. 5 The measured collector current of the DUT (25 um x 21um) with various incident light power.