Submitted to 2018 CSMANTECH Conference, Austin, Texas (Student Paper)

Process Optimization and Characterization of 25 GHz Bandwidth 850 nm P-i-N Photodetector for 50 Gb/s Optical Links

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Keywords: P-i-N Photodetector, Bandwidth, Dark Current, Optical Links

Abstract

GaAs P-i-N photodetector has been fabricated and characterized to act as receivers in 50 Gb/s optical links. The fabricated photodetector with a 20 um mesa diameter has shown to achieve 26 GHz bandwidth with dark current less than 1 nA from room temperature to 85°C operation.

Introduction

The development of 850 nm oxide-confined VCSEL and high-speed photodetector has been driven by the increasing demand for more efficient short-haul optical fiber links. A directly modulated 850 nm VCSEL with 57 Gb/s error-free data transmission at room temperature [1] and 50 Gb/s at 85°C [2] has been reported recently. In order to construct optoelectronic links with such high speed VCSELs, it is necessary to have a high speed optical receiver with sufficient bandwidth. In this work, we report the fabrication and microwave characterization of high speed 850 nm GaAs based P-i-N photodetector (PD) with 25 GHz bandwidth. The dark current of this high speed P-i-N photodetector is less than 1nA at both room temperature and 85°C at -4V reverse bias.

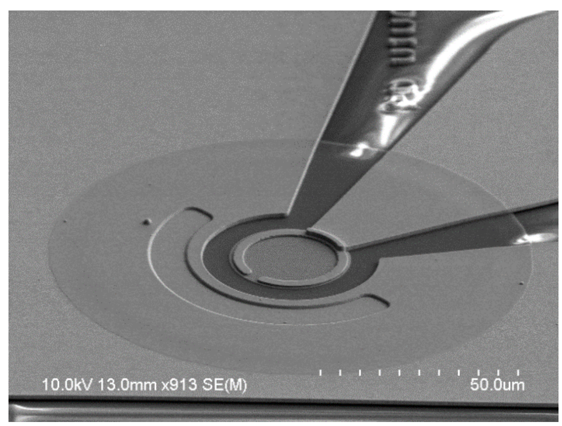
High-Speed Process Optimization

A circular aperture was chosen for the purpose of vertical surface illumination and compatibility with a high speed VCSEL. The PD has an $Al_{0.2}Ga_{0.8}As$ contact window to prevent any undesirable absorption and a 0.75 um GaAs intrinsic absorption region, making it suitable with a VCSEL operating at 850 nm [3]. The fabricated device after P- and N- contact deposition is passivated with BCB followed by a via opened to access the N-contact. The anti-reflective coating is subsequently deposited after top metal deposition. A scanning electron microscopy (SEM) picture of the complete coplanar high speed P-i-N PD is shown in Fig. 1.

DC and RF Characterization

After the device was fabricated, the measurement of dark current was performed for PDs with mesa diameters of 15, 20 and 30 µm. Figure 2 shows all the measured dark current remains below 1nA from room temperature up to 85°C for a PD with 20 µm mesa diameter. Figure 3 shows the corresponding measurement block diagram with a UIUC 27 GHz direct-modulated 850 nm VCSEL [4] used as the light source for the bandwidth extraction and responsivity measurement.

Fig. 1. SEM of the completed P-i-N photodetector.



Light coupling between the VCSEL and the photodiode is done using a set of Lightwave probes and OM4 fiber. The typical responsivity of a 20 µm PD is around 0.3 A/W. In order to characterize the 3dB bandwidth of photodetector, the frequency response of VCSEL needs to be determined by performing 2-port S-parameter measurement with the aid of Newport 1414-50 25 GHz receiver and PNA-X Network Analyzer N5247A. By subtracting the known VCSEL transfer function ($S_{21,VCSEL}$) from the measured frequency response ($S_{21,Measured}$), we can obtain the frequency response of photodetector alone ($S_{21,PD}$). All the three-frequency responses are shown in Fig. 4 and Fig. 5, respectively with $I_{bias} = 9$ mA in VCSEL and $V_{applied} = -3$ V in photodetector. The extracted bandwidth of the 20 µm PD is around 26 GHz with the fitting curve (light blue) shown in Fig. 5.

Since the capacitance of the depletion region and the parasitic capacitance between contact pads are two main parameters that limit the frequency response of the PDs, we then use the equivalent circuit model with measured S-parameter data to extract the capacitance and resistance inside the PDs [3]. Fig. 6 shows the extracted junction capacitance versus active area. The parasitic pad capacitance was extracted to be 45 fF by performing one port S-parameter measurement.

CONCLUSION

In this work, a 850 nm P-i-N photodetector has been optimized for 50 Gb/s optical communication with dark current below 1 nA from room temperature to 85°C at -4V. Apart from the photosensitivity of 0.3 A/W, the bandwidth of 26 GHz can be achieved with 20 um PD. Microwave characterization has been performed to extract the junction capacitance in order to analyze the limiting factor of the bandwidth performance.

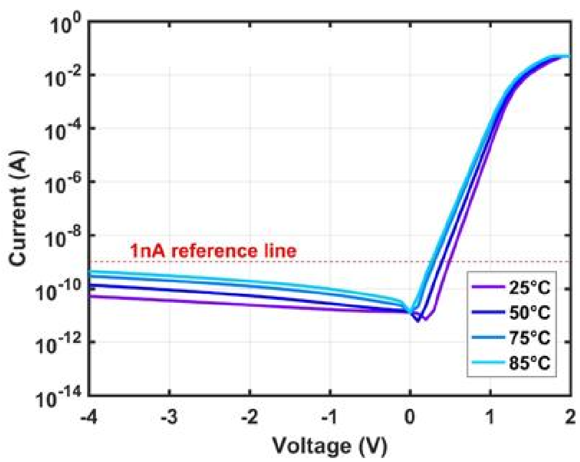


Fig. 2. Measured dark current versus applied voltage from 25°C to 85°C.

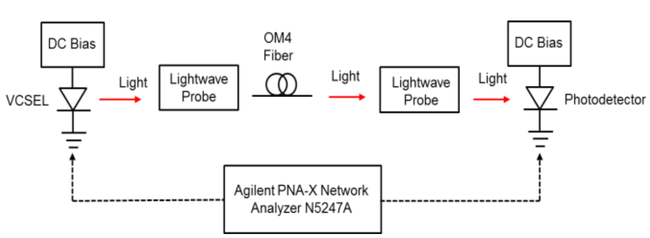


Fig. 3. Block diagram of VCSEL-Photodetector link.

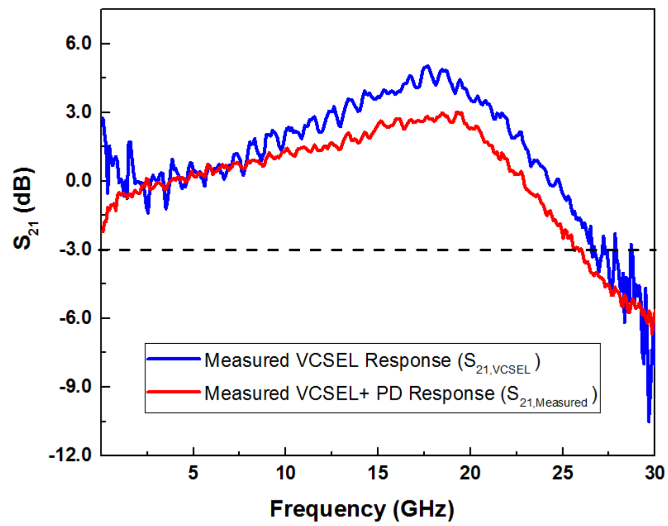


Fig. 4. Measured frequency response ($S_{21,Measured}$), VCSEL frequency response ($S_{21,VCSEL}$).

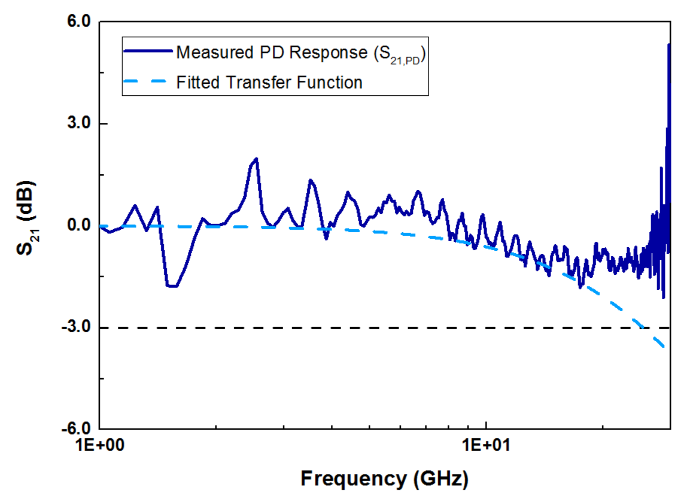


Fig. 5. Photodetector frequency response ($S_{21,PD}$) which is acquired from the subtraction of $S_{21,VCSEL}$ from $S_{21,Measured}$. The extracted bandwidth is around 26 GHz.

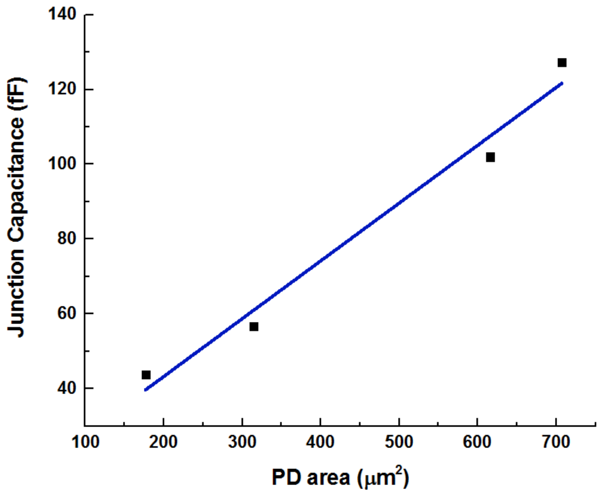


Fig. 6. Extracted junction capacitance versus PD area.

ACKNOWLEDGEMENT

This project is also supported by the National Science Foundation under grant 1640196, and the Nanoelectronics Research Corporation (NERC), a wholly-owned subsidiary of the Semiconductor Research Corporation (SRC), through Electronic-Photonic Integration Using the Transistor Laser for Energy-Efficient Computing, a Nanoelectronics Research Initiative (SRC-NRI) under Research Task ID 2697.001-Transistor Laser Based Circuits and Devices. The authors would also like to thank Foxconn Interconnect Technology for research support.

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ACRONYMS

VCSEL: Vertical Cavity Surface Emission Laser
BCB: Benzocyclobutene