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10-Gb/s InGaAs P-I-N photodetector with planar buried heterostructure

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1. Introduction

InP/InGaAs P-I-N photodetectors have been used extensively in optical communications nowadays due to their good electron transport properties and their ability to absorb radiation in the 1.0 - 1.7 μm wavelength region efficiently. High speed (OC-192, 10Gb/s) is becoming a necessity in modern fiber communication application. To evaluate the performance of an InP/InGaAs P-I-N photodetector, it is necessary to consider its responsivity, dark current, quantum efficiency, reliability and operation speed [1,2]. Very recently we proposed a top-illuminated planer buried heterostructure photodetector (BH-PD) [3]. Compared with mesa-type photodetectors, it is known that planar-type devices are more reliable [4]. Using the BH-PD structure, it was found that we can effectively reduce the capacitance of the space charge (depletion) region below dielectric layer and thus enhance operation speed of the InP/InGaAs P-I-N photodetector without sacrificing its optical and electrical properties. However, many properties of the proposed BH-PD are still unknown. In this study, we report noise characteristics of the BH-PD. Aging characteristic and eye-diagram of the fabricated device were also measure.

2. Experimental

Samples used in this study were prepared by metalorganic chemical vapor deposition (MOCVD) Standard photolithography was then used to form a mesa opening. Subsequently, we immersed the samples in HBr solution to form a mesa with a depth of 4.3-μm. We then loaded the samples onto the MOCVD reactor to fill the etched region with semi-insulating (SI) InP (n = 5x10^{10} cm^{-3}). Ti-Au was then deposited onto contact layer and the 55 μm diameter bonding pad to serve as the p-type electrode by e-beam evaporation. Wafers were then lapped and polished down to 250 μm and the polished backside was coated with Ti-Pt-Au n-contact metal followed by alloying at 420^{o}C for 30 sec. Figures 1 show a schematic cross-sectional diagram of the BH-PD proposed in this study. An HP-4155B semiconductor parameter analyzer and an HP-4284A LCR meter were used to measure current-voltage (I-V) and capacitance-voltage (C-V) characteristics of the fabricated devices. To evaluate operation speed of the devices, we used an Agilent 8703B 20 GHz lightwave component analyzers to measure 3dB-frequency of the fabricated BH-PDs. Aging tests were also performed. Furthermore, the OC-192 receiving performances of the TO-46 can-packed fiber-optic receiver module comprising the BH-PD and TIA were also characterized.

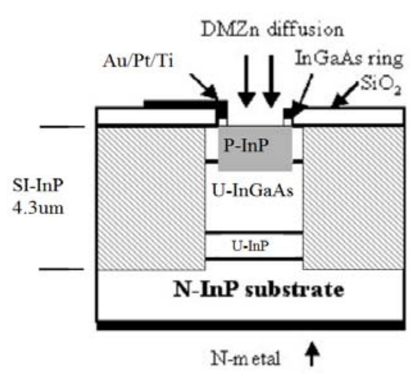

Figure 1 Schematic cross-sectional diagram of the InGaAs P-I-N BH-PD .

3. Results and Discussion

Figure 2 shows I-V characteristic of the fabricated BH-PD measured in dark. With -5 V applied bias, it was found that dark current of the BH-PD was 21.6 pA. It was also found that breakdown voltage (> 1×10^{-6} A) was large than 45 V. C-V characteristic measured from the fabricated BH-PD was also plotted in figure 2. It can be seen that measured capacitance of the BH-PD was 0.267 pF when biased at -5 V. To determine 3-dB bandwidth of the devices, we measured frequency response of the photodetectors by mounting the BH-PD chips onto SMA connectors. As shown in figure 3, it was found that measured 3-dB bandwidth of the fabricated BH-PD could reach 12.4 GHz with 1310 nm excitation and -5 V bias. The large bandwidth should again be attributed to the reduce space charge (depletion) capacitance.

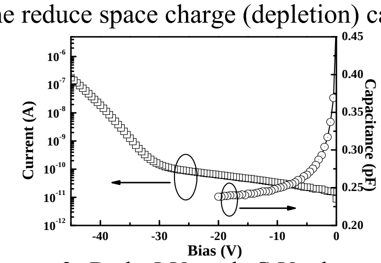

Figure 2 Dark I-V and C-V characteristics of the proposed BH-PD measured at room temperature.

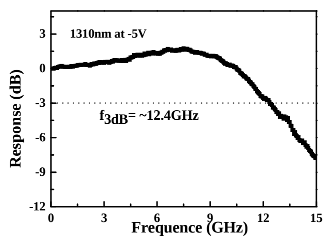

Figure 3 Measured frequency response of the fabricated devices on SMA @ 1310 nm.

Aging test was also preformed by applying a -5 V bias onto 10 BH-PD chips at 100°C for 1000 hours. Figure 4 shows dark current measured during burn-in tests. During the aging tests, we applied a -5 V bias onto 10 BH-PD chips at 100°C. It can be seen that the increment in reverse leakage currents were all less than 20% for the 10 BH-PD chips. Such an observation suggests that re-growth and the subsequent processes will not damage these photodetectors. Eye-diagram analysis at 10.3 Gb/s is also performed to characterize the data receiving performance of the BH-PD in a simulated OC-192 fiber-optic network. This is done by applying a -3.3 V bias onto the BH-PD with a nonreturn-to-zero (NRZ) of a 2^{31}-1 optical pseudorandom bit sequence (PRBS). Figure 5 shows the back-to-back eye pattern of 1310 nm LC ROSA TIA measured at the BH-PD output. It was found that the sensitivity was -19 dBm at a bit-error-ratio (BER) of 1×10^{-12} and a extinction ratio of 7 dB.

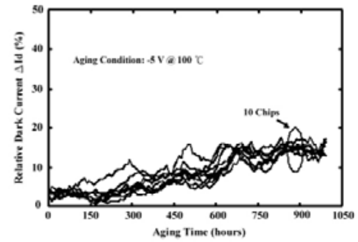

Figure 4 Dark current measured during aging tests, we applied a -5 V bias onto 10 BH-PD chips at 100°C

It was also found that the mask margin, peak-to-peak jitter (PPJ) and rising time were 64%, 12.24 and 30.2 ps, respectively. These results indicate that the BH-PD proposed in this study can be used in OC-192 fiber-optic communication systems.

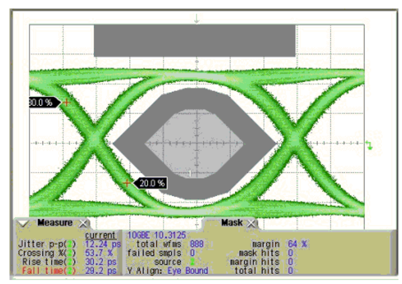

Figure 5 Back-to-back eye pattern of 1310 nm LC ROSA TIA measured at the BH-PD output.

4. Conclusion

In summary, we have successfully demonstrated and fabricated the high performance planar InGaAs P-I-N BH PD. By introducing mesa etching and refilling with lower concentration InP. The electrical, optical and aging test characteristics were meet with commercial PD specification. The eye diagram show wide and clear opening for 1310nm light source at 10.3 Gb/s. The high quality characteristic of InGaAs P-I-N BH PD is an attractive alternative for OC-192 applications.

4. Referance

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