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Reduced Mesa-Sidewall Leakage Current in InGaAs/InP MSM Photodetector by BCB Sidewall Process

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1. Introduction

Interdigitated metal-semiconductor-metal (MSM) Schottky barrier photodetectors (PDs) based on the InGaAs/InP material system have been the subject of research for use in a long wavelength communication system. The MSM photodetectors with the advantages of a small input capacitance and compatibility with electronic devices have been successfully applied to high speed optical fiber communication. One problem with the MSM structure is its dark current. The dark current in a MSM photodetectors can be reduced by Schottky barrier enhancement and fabrication technologies. As dark current of a PD decreases, the minimum detectable power becomes smaller, resulting in increasing the sensitivity of the PDs. In this report, we used the benzocycloubtene (BCB) as the mesa-sidewall passivation to avoid the contacting problem between the schottky metal feeder and sidewalls [1]. The BCB passivated MSM PDs can reduce the dark current down to nA. Additionally, the low-k BCB (ε_r=2.7) can also reduce the parasitic capacitance from the metal pads.

2. Device structures and fabrication

The epitaxial layers, shown in Fig. 1 were grown using the molecular beam epitaxy (MBE) on semi-insulating InP substrates. The structure consists of a 200 nm $In_{0.52}Al_{0.48}As$ (E_g=1.48 eV) barrier layer, a 300 nm $In_{0.53}Ga_{0.47}As$ absorption layer (E_g=0.79 eV), followed by a 50 nm graded layer to reduce the bandgap discontinuity [2], and finally a 20 nm $In_{0.52}Al_{0.48}As$ Schottky barrier enhanced layer on top.

The photodetector fabrication was realized by the use of conventional lithography and lift-off techniques. An $H_3PO_4/H_2O_2/H_2O$ (1:1:20) solution was used for mesa etching. Then, the sample was spun by BCB on the device mesa-sidewall (Fig. 1), where the BCB is the negative photo-resister. After spinning the BCB, the same mask of the mesa etch was used to remove the BCB on the mesa surface. The Fig. 2 is the SEM photograph of mesa profile, where the mesa sidewalls are fully covered by the BCB layer. The Schottky contacts were formed by electron beam evaporating Ti(30nm)/Pt(25nm)/Au(100nm) metal series. The final pad contact metal was Ti(30nm)/Al(500nm)/Au(100nm). This developed process concludes the success of interdigitated finger metal insulating from mesa sidewall by inserting a BCB insulator on sidewall region [3-4].

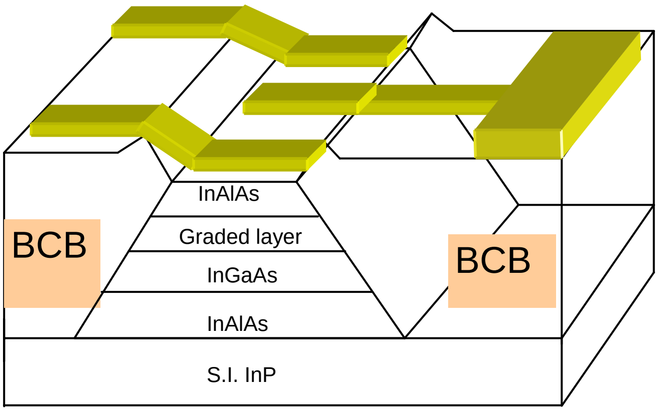

Fig. 1 The 3-D perspective of the BCB sidewall process MSM photodetector.

3. Device DC and Pulse Response

To study device sidewall leakage, we measured the photodetector dark current and photocurrent; for a comparison MSM PDs without the sidewalls passivation are also included. The device I-V curves are shown in Fig. 3. The input power was 200 μW at a 1550 nm wavelength. The dark current density of the PD without BCB sidewall-passivation was 11nA/μm² at 3V.

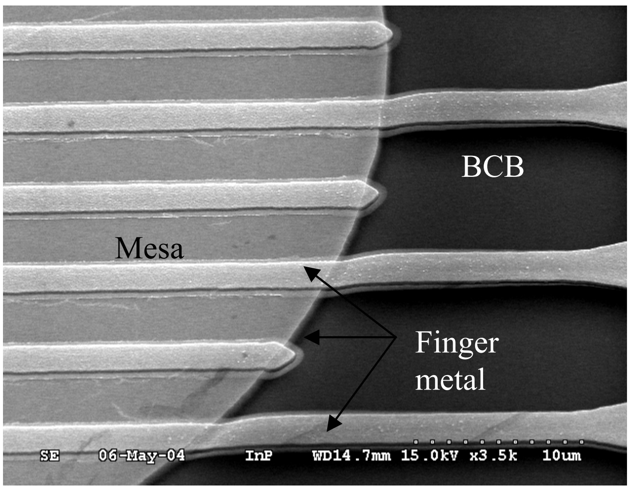

Fig. 2 SEM photograph of the BCB sidewall process device.

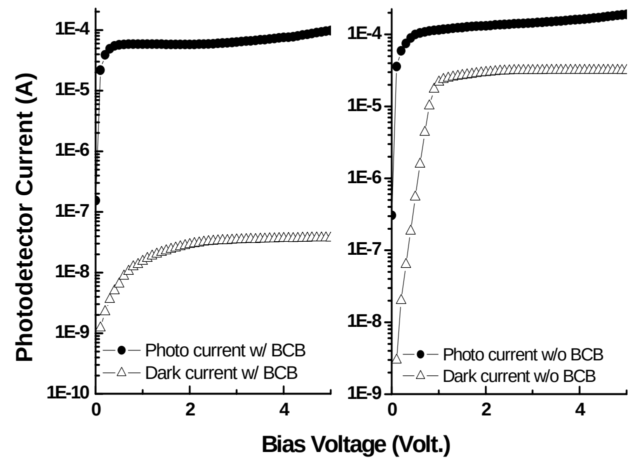

Fig. 3 Bias dependent photocurrent, illuminated by 1550 nm laser.

After the BCB passivation, the dark current density decreased to 5.7pA/μm^2. Therefore, the BCB passivation can improve the dark current of the photodetector. Fig. 4 shows the impulse response of a BCB passivated InGaAs MSM PD at a 3V bias. The impulse response of the MSM photodetector reveals an FWHM of 55ps, which is corresponding to a bandwidth of 6 GHz. The equivalent circuit of a MSM PD is shown in Fig. 5. By fitting the measured S-parameters, the equivalent circuit model of a PD can be obtained. Table 1 shows the comparisons for both PDs, and the R_2 representing the leakage dark current is substantially increased by this sidewall BCB passivation technique.

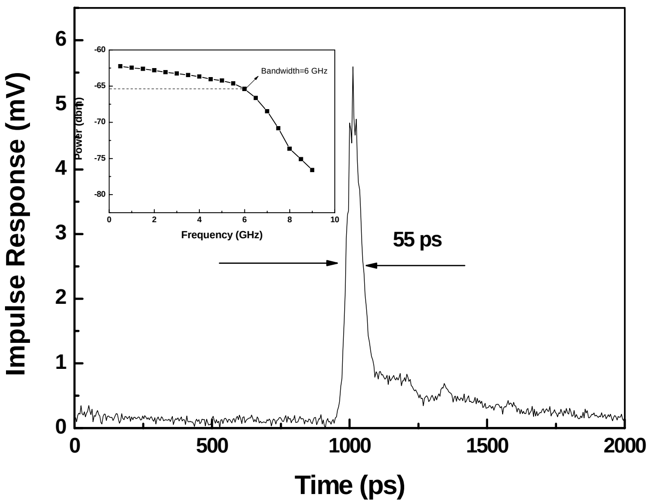

Fig. 4 Impulse response of MSM photodetector on InP substrate at 3V bias incidented by a 1550 nm laser.

4. Conclusions

We proposed a BCB sidewall process for improving device mesa leakage current of the InGaAs/InP MSM photodetector. By using this technology, the device I-V characteristics and the associated sensitivity can be substantially improved.

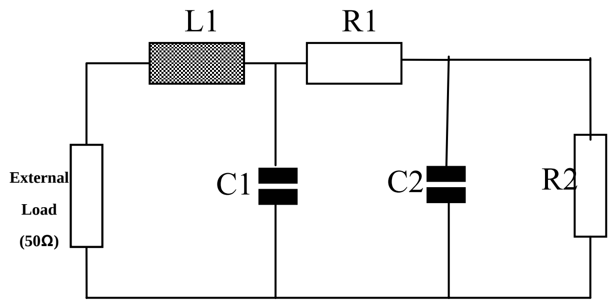

Fig. 5 Equivalent circuit model extracted from the measured S parameters.

Table 1 Comparisons of equivalent circuit model of BCB and non-BCB passivated PDs

	L1	C1	C2	R1	R2
BCB	39pH	35.5fF	475fF	43.5Ω	30KΩ
Non-BCB	39pH	37.5fF	360fF	46.5Ω	10KΩ

Acknowledgments

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