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On-Chip Integration of RF Termination Resistor and Backside Via Hole in InP-Based Mach-Zehnder Modulator for Compact Coherent Transceiver

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Abstract

We have demonstrated on-chip integration of RF termination resistor and backside via hole in InP-based in-phase/quadrature Mach-Zehnder modulator (IQ-MZM) for compact coherent transceiver. Downsizing of the footprint by 59 % was achieved compared with conventional configuration of chip and external RF termination. Good uniformity of the termination resistor within - 4.5 to +1.0 % for designed value was obtained over 4-inch wafer.

1. Introduction

Increase of internet traffic accelerates the introduction of the compact digital coherent transceivers for high-density optical ports. InP-based dual-polarization in-phase/quadrature Mach-Zehnder modulator (DP-IQ-MZM) [1,2] is one of the principal device and occupies relatively large area in the coherent transceiver module. The DP-IQ-MZM chip has four MZMs that are driven by 4 pairs of RF signals. Thus, as many as 8 chip-resistors are located around the DP-IQ-MZM chip for terminating RF signals after modulation. In addition, extensive output RF pads array is needed on the DP-IQ-MZM chip. The number of output RF pads is 12 at “SGS” configuration, and is 16 at “GSSG” configuration. Terminating RF signals on DP-IQ-MZM chip is very effective for downsizing the transceiver. In this paper, we demonstrated on-chip integration of RF termination resistors and backside via holes [3] in InP-based Mach-Zehnder modulator using the 4inch-diamter wafer process for the compact coherent transceiver.

2. Device structure and fabrication process

Figure 1(a) shows the schematic diagram of conventional RF termination configuration. There are RF pads for both input and output RF signals on the chip. Output RF pads are wired to the termination resistors which exist outside of the chip and lead to the ground pads. In order to minimize this footprint, termination resistors and ground pads should be integrated on the DP-IQ-MZM chip, resulting removal of output RF pads, as shown in fig. 1(b). The configuration of fig. 1(b) still remains the termination line to a pad. Therefore the backside via hole was formed through a DP-IQ-MZM chip and the backside of the chip was metalized by gold plating and connected to ground, as shown in fig. 1(c). Using these on-chip integration technologies and optimization of the chip layout, we achieved downsizing of the footprint by 59 % compared to conventional configuration [1].

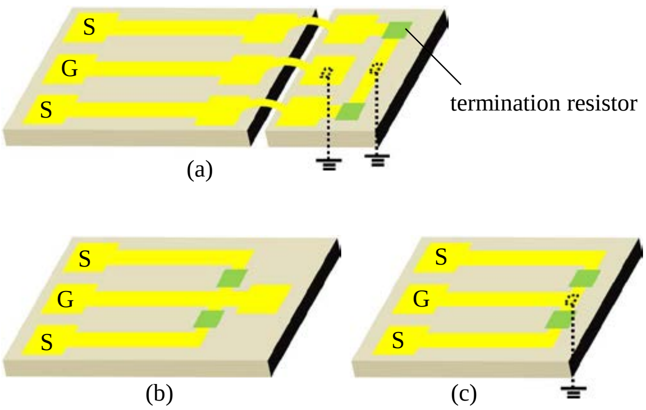

Figure 1 Schematic diagrams of (a) conventional optical device configuration using RF signals, (b) integration of termination resistors, (c) integration of termination resistors and backside via hole.

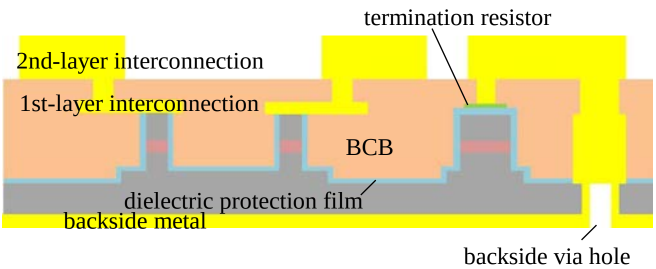

Figure 2 Schematic diagram of cross-sectional MZM integrated with termination resistor and backside via hole.

Figure 2 shows the schematic diagram of cross-sectional MZM integrated with RF termination resistor and backside via hole. The fabrication process is as follows. At first, the undoped core layer consisting of the AlGaInAs MQW structure was grown on a semi-insulating 4-inch InP wafer by an OMVPE growth. Deep ridge waveguide stripes and electrical isolation mesas for the MZM array were formed through standard optical *i*-line stepper lithography and RIE processes, respectively. Then, the dielectric protection film was deposited on surfaces of deep-ridge waveguide stripes. RF termination resistors and n-side ohmic electrodes were formed. Termination resistors were formed by NiCrSi sputter. Wafer surface was planarized by benzocyclobutene (BCB) and BCB/dielectric protection film apertures for p-side ohmic electrodes were formed through photolithography and RIE processes. After forming contact holes to n-side ohmic electrodes by etching BCB, 1st-layer interconnections were formed by gold plating. Again, wafer surface was planarized by BCB and contact holes to the 1st-layer interconnections were formed by etching BCB. The 2nd-layer interconnections were formed by gold plating. After polishing wafer backside, backside via holes were formed by HI-based ICP etching [3].

3. Performance

Figure 3 shows the histogram of resistance value for the termination resistor on a 4-inch diameter. The measured resistance had a good uniformity within - 4.5 to +1.0 % for designed value. As compared to the uniformity of external termination resistor within +/- 4.5%, which was fabricated by metallization and trimming, the distribution of the integrated termination resistors was much smaller.

Figure 4 shows the differential small-signal frequency response for IQ-MZM integrated with RF termination resistors. We confirmed low reflection characteristics in the on-chip integration of RF termination resistors.

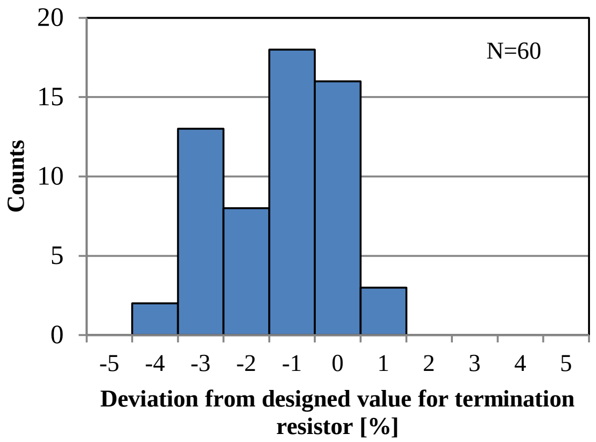

Figure 3 Histogram of deviation from designed value for termination resistor on a 4-inch diameter wafer.

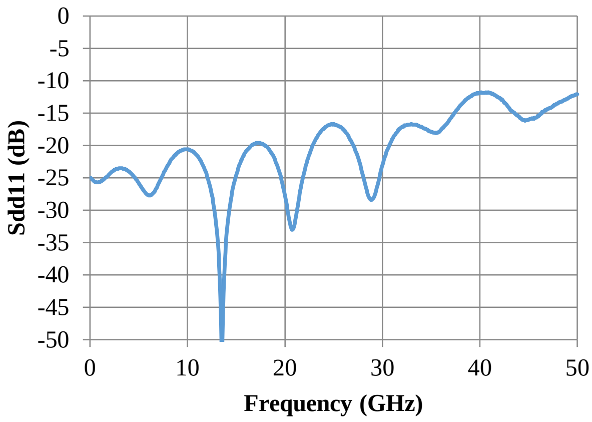

Figure 4 Differential small-signal frequency response for IQ-MZM integrated with RF termination resistor.

4. Conclusions

We have demonstrated on-chip integration of RF termination resistor and backside via hole in InP-based MZM using the 4-inch diameter wafer process. Downsizing of the footprint by 59 % was achieved compared with conventional configuration of chip and external RF termination. The good uniformity of the termination resistor was obtained within - 4.5 to +1.0 % for designed value. These results indicate that integrated IQ-MZM can be suitable for compact transceiver.

References

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