Design Optimization of Ultralow Capacitance InGaAs Waveguide Photodetector on III-V CMOS photonics platform

°Pengyuan Cheng[1], Shinichi Takagi[1], Mitsuru Takenaka[1] (1.Univ. Tokyo)
E-mail: chengpy@mosfet.t.u-tokyo.ac.jp

【Introduction】 To reduce the power consumption, the concept of receiver-less PDs was proposed, which requires ultra-low capacitance (<1fF). We have proposed III-V CMOS photonic platform which has uses a III-V on insulator (III-V-OI) wafer [1][2]. By using the III-V CMOS photonics platform, we have numerically investigated the ultra-low capacitance InGaAs PD [3] with a lateral PIN junction. In this study, we have conducted optimization in the dimensions of the PD to further improve the performance through maximizing the product of light-to-voltage conversion efficiency and 3-dB bandwidth.

【Device Structure】 Figure 1 shows the a schematic of InGaAs rib waveguide PD with a lateral PIN junction on III-V-OI wafer, which is butt-coupled with an a-Si waveguide. Amorphous silicon waveguide deposited by PECVD enables flexible interconnection of III-V-OI active devices [4]. The rib height and length of waveguide PD are optimized to achieve highest product of light-to-voltage conversion efficiency and 3dB bandwidth or lowest power consumption.

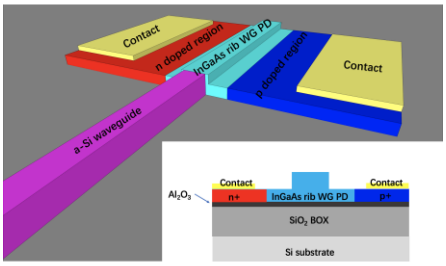

Fig. 1 Schematic of InGaAs waveguide photodetector butt-coupled with a-Si waveguide on III-V-OI wafer. Inset shows the cross-section schematic of InGaAs rib waveguide photodetector.

【Optimization and discussion】 The calculation is conducted under -2 V reverse bias and 20 kΩ load resistance (R_{load}). The rib width of PD is set to be 520 nm to achieve highest mode overlap with a-Si waveguide. The rib height is related to the intrinsic capacitance of PD and the transition time of photo-generated carriers. The responsivity logarithmically increases with the device length but the capacitance is also approximately linear to the device length. The rib height has a little influence on the responsivity. The product of light-to-voltage conversion efficiency and 3-dB bandwidth is inversely proportional to the power consumption per bit and could be calculated directly by responsivity η and bandwidth f_{3dB}: $Product = R_{load} \cdot \eta \cdot f_{3dB}$. Figure 2(a) shows the relation of the product and power consumption and rib height under 5-µm device length. The PD with the rib height of 170 nm achieves maximum product and lowest power consumption, and the difference of the product in different rib height are small which reveals the design tolerance in rib height. Figure 2(b) shows the relation of the product and power consumption and device length under 170 nm rib height and maximum product appears in 3 µm length. Ultra-small absorber-volume device with 3 µm length and 170 nm rib height is expected to achieve extreme low power consumption of 0.23 fJ/bit. This study reveals the potential of ultra-low capacitance waveguide InGaAs-OI photodetector and will guide the further fabrication.

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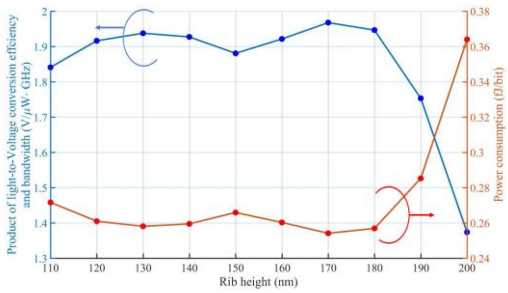
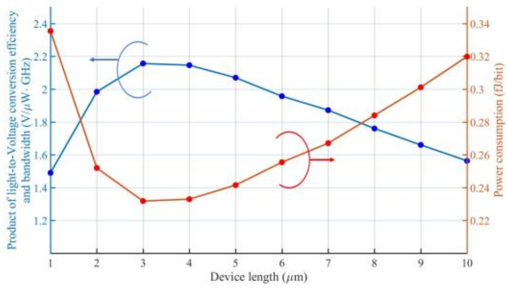


(a)



(b)

Fig. 2 (a) Relation of product of light-to-voltage conversion efficiency and 3 dB bandwidth and power consumption per bit and rib height; (b) Relation of product of light-to-voltage conversion efficiency and 3 dB bandwidth and power consumption per bit and device length.

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