Design of ultra-thin InGaAs membrane photodetector on Si slot waveguide

°Wu Dongrui[1], Kasidit Toprasertpong[1], Shinichi Takagi[1], Mitsuru Takenaka[1] (1.Univ. Tokyo)
E-mail: wdr@mosfet.t.u-tokyo.ac.jp

【Introduction】A photodetector (PD) is one of the critical devices in a photonic network, which limits the communication capacity due to its huge energy consumption [1]. In particular, the trans-impedance amplifier (TIA) for photodetection introduces an extra power consumption, footprint, and noise. One solution is to employ a receiver-less configuration where a load resistor with high impedance is used to convert photocurrent into voltage without a TIA. Such configuration requires an ultra-low capacitance (~fF) PD to maintain a high RC-limited bandwidth. In this study, we propose an ultra-thin InGaAs membrane photodetector on a Si slot waveguide, which is able to achieve high-responsivity, low capacitance, and high bandwidth simultaneously.

【Device structure】Fig. 1 shows a schematic of the proposed PD. A 20-nm-thick InGaAs membrane is bonded on a Si slot waveguide. By preparing a lateral PIN junction in the InGaAs membrane, photo-generated electron-hole pairs are separated and collected by the n- and p-doped regions, respectively. An ultra-thin InGaAs membrane does not change the original optical mode profile of a slot waveguide so much, enabling a high optical confinement in the InGaAs layer. Since the parasitic capacitance reduced with the thickness of the InGaAs membrane, the total capacitance is expected to be less than that of a conventional Si hybrid PD.

【Result and discussion】Fig. 2 shows the numerical analysis of optical absorption at a 1550 nm wavelength as a function of PD length. It can be seen that an optical absorption greater than 90% is achievable at 25-μm length even with an ultra-thin InGaAs membrane. Fig. 3 shows the device capacitance as a function of PD length with varied widths of i-InGaAs. Owing to the ultra-thin membrane structure, the total capacitance is significantly lower than 1 fF even when the PD length is greater than 25 μm. we can achieve a capacitance less than 1 fF. When a load resistance is assumed to be 20 kΩ, the total bandwidth is estimated to be 29 GHz by taking into account the RC constant and carrier transit time across the i-InGaAs region.

【Acknowledgement】This work was partly commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

[1] Assefa S, Xia F, Green W M J, et al. IEEE Journal of Selected Topics in Quantum Electronics, 2010, 16(5): 1376-1385.

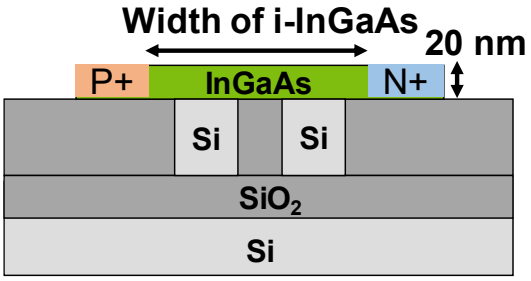

Fig. 1 Cross section & top view of the membrane photodetector.

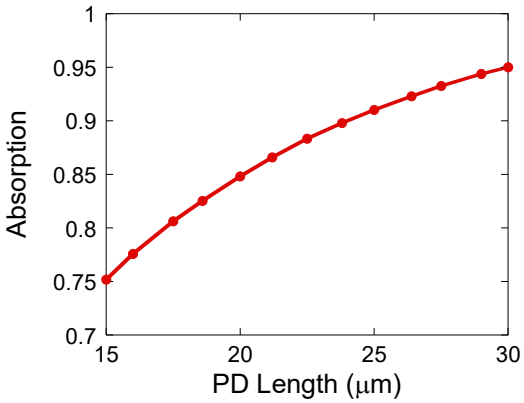

Fig. 2. Optical absorption as a function of PD length.

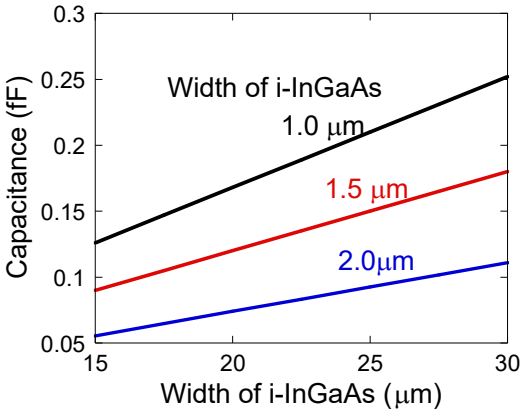

Fig. 3. PD capacitance as a function of PD length with varied widths of i-InGaAs.