High density photonic integration on an InP membrane

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ABSTRACT

Emerging applications such as light detection and ranging (LiDAR), on-chip interconnect and neuromorphic photonics demand higher complexity and integration density in photonic integrated circuits (PICs). Conventional InP PICs, although offers seamless integration of actives and passives, cannot meet this demand. In this talk, a InP membrane photonics platform will be presented and its recent progress will be reviewed. It features sub-micron waveguides together with native amplifiers. Therefore it has potential to achieving active-passive photonic integration with order-of-magnitude higher density and complexity.

Keywords: indium phosphide, photonic integrated circuit, membrane, waveguide, amplifier

1. INTRODUCTION

Photonic integrated circuits (PICs) have become the key enabler for latest transceiver standards for telecom and datacom, as well as high-performance optical sensors [1]. The number of active and passive components increases rapidly as the specific application evolves. For instance, the integrated coherent transceiver has reached to nearly 2000 components on a single chip [2]. Emerging applications, such as the light detection and ranging (LiDAR) [3], on-chip interconnect [4] and neuromorphic computing [5] appreciate fully integrated systems on chip, and have put new challenges to the PIC technologies. They require orders of magnitude more parallel channels and an explosion of the number of components, for both active and passive components.

The InP Membrane on Silicon (IMOS) platform [6, 7] is a promising solution to the growing demand of density and complexity. It features sub-micron waveguides, allowing for micron-sized bends, resonators and couplers, as well as native optical amplifiers without the need of assembly or heterogeneous integration. In this presentation, we will provide an overview of recent progress made on this platform.

2. RECENT PROGRESS ON THE IMOS PLATFORM

2.1 Native Optical Amplifier

The optical amplifier building block on the IMOS platform is based on a twin-guide structure [8], where the active waveguide layer containing multi-quantum wells (MQWs) and the passive waveguide layer are stacked vertically by epitaxial growth. Coupling of light between the two waveguide layers is through adiabatic tapers. The net modal gain of over 100 cm^{-1} generated from 8 MQWs is comparable to that in conventional InP PIC platforms. Based on this building block, several lasers, such as distributed feedback (DFB) laser, distributed Bragg reflector (DBR) laser and micro-ring-based tunable laser, have been demonstrated [7]. Recently the multimode capability of such amplifier have been investigated with the assistance of on-chip mode division multiplexers (MDMs) [9]. The gain of both TE0 and TE1 modes in the amplifier has been examined. Net modal gain of 6 dB and 4 dB have been measured for TE0 and TE1 modes, respectively [10]. The lower gain for TE1 mode is mainly attributed to the excess loss induced by the MDM couplers. This shows strong evidence that the same amplifier can be reused for multiple modes, therefore potentially boost the efficiency of such power-hungry devices and reduce the number of amplifiers required for a complex circuit.

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2.2 Ultrafast Photodiode

An ultrafast photodiode based on uni-travelling carrier (UTC) configuration has been demonstrated [11]. The device is depicted in Figure 1(a). The 3 dB electrical bandwidth exceeds 110 GHz which is the limit of the instrument. The UTC photodiode on IMOS platform takes advantage of the double-sided processing [12] to optimize the position of the metal electrodes with respect to the waveguide, without significantly increasing the optical loss. Ultralow junction capacitance (as low as 5 pF) has been obtained. Such device can find application in high-speed optical interconnect as well as terahertz radiation generation for 6G communication and sensing.

2.3 Microheater

To enable highly efficient tuning of the phase in the waveguides, which is of high demand in integrated optical phased arrays (OPAs), a novel microheater has been proposed and demonstrated on IMOS platform [13]. With only a length of 13μm, a π phase shift can be achieved with high efficiency (2.26 mW/π) and fast response time (11 μs), thanks to the high thermo-optic coefficient of InP and the epitaxially grown conductive layer with low optical loss. The device is record small and energy efficient among state-of-the-art non-resonant microheaters. Comparing to resonator-based microheaters using a slow light effect, our device offers much wider optical bandwidth (100 nm versus few nm) at similar energy efficiency.

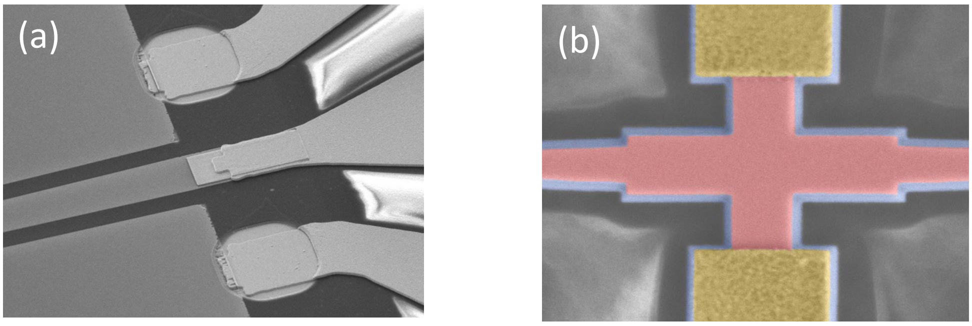

Figure 1. (a) Scanning electron microscope (SEM) picture of the ultrafast UTC photodiode. (b) SEM picture of the microheater.

3. CONCLUSION

Recent progress at technology level and building block level on the IMOS platform shows that it is a high-potential technology solution for the ever-growing demand in PIC complexity and integration density.

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