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Double-sided processing for membrane-based photonic integration

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Abstract: double-sided processing, as a fabrication technology dedicated for membrane photonics, gives rise to new design optimizations. This paper reports latest achievements of this processing scheme in an InP-membrane-on-silicon (IMOS) platform, with a focus on a high bandwidth (>67 GHz) photodetector. Furthermore, a novel integration platform based on the double-sided processing is proposed, to integrate high-performance building blocks in a single membrane layer, providing full photonic functionality.

Membrane photonics presents a promising platform technology for the realization of photonic integrated circuits (PICs) on silicon [1, 2]. High-performance devices covering full functionality need to be developed on this platform. Double-sided processing technology enables a new degree of freedom in device optimization, by designing and fabricating membrane structures from both sides. It is uniquely suitable for the IMOS platform, in which InP membranes can be processed both before and after bonding to a silicon wafer using BCB [1]. As the light only propagates in the InP membrane where all photonic components are located, critical alignment to the silicon wafer during the bonding is not necessary, which assures the practicality of this technology. Also, thanks to the use of BCB, high yield in bonding with processed samples can be achieved.

In the IMOS platform, a high speed uni-traveling carrier photodetector (UTC-PD) is developed. It uses double-sided processing to define p- and n- contacts on opposite sides of the membrane (Fig. 1), leading to a significant reduction of the resistance on the p-side. Since the p-InGaAs absorber in UTC-PDs is usually doped with a gradient, p-contact depositing on the highly doped surface on the bottom of the p-InGaAs layer results in low contact resistance. Moreover, p-contacts defined at the lower side of the mesa can be placed very close to the optical mode, which is crucial for avoiding the excessive series resistance from the thin p-InGaAs layer. Consequently, this results in a very low RC-time constant and a very high 3 dB bandwidth beyond 67 GHz, which is the highest value reported for membrane PDs on silicon so far.

An efficient metal grating coupler is another demonstrated device using the double-sided processing [3]. By depositing silver-based low-loss metal mirrors at the bottom side of the membrane, the grating shows reduced leakage of light to the silicon substrate, resulting in a high coupling efficiency of 54%. Furthermore, the efficiency is independent of the BCB layer thickness. This solves a fundamental problem of membrane photonic circuits: as the BCB layer thickness is not uniform over the wafer, interference between the waves reflected at two interfaces (InP/BCB and BCB/Si) can cause unpredictable variations in coupling efficiency.

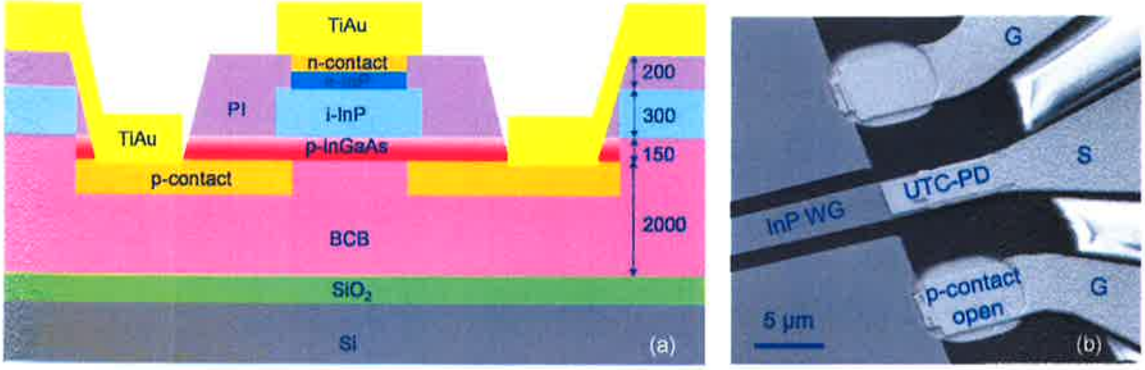

Fig. 28. (a) Cross-section of the UTC-PD. Thickness in nm. (b) SEM photo of the device.

Finally, double-sided processing provides a potential technology to integrate components with different layer-stacks without using multiple regrowth steps. As proposed in Fig. 2, demonstrated devices and existing designs can be integrated monolithically as building blocks on this new platform. These include low-loss waveguides [1], electrically-pumped lasers [2], metal gratings [3], slot-waveguide modulators [4], and high speed UTC-PDs. A remarkable advantage of this integration platform is the optimal material choice for each component. In particular, quantum-wells (QWs) give high efficiency and low threshold for lasers, but they are not efficient as the absorption material in PDs. On the other hand, UTC structures provide high bandwidth and high saturation power to PDs, but they are not compatible with laser structures. To avoid trade-offs on material choices, QW-based lasers and InGaAs-based UTC-PDs can be integrated using the double-sided processing.

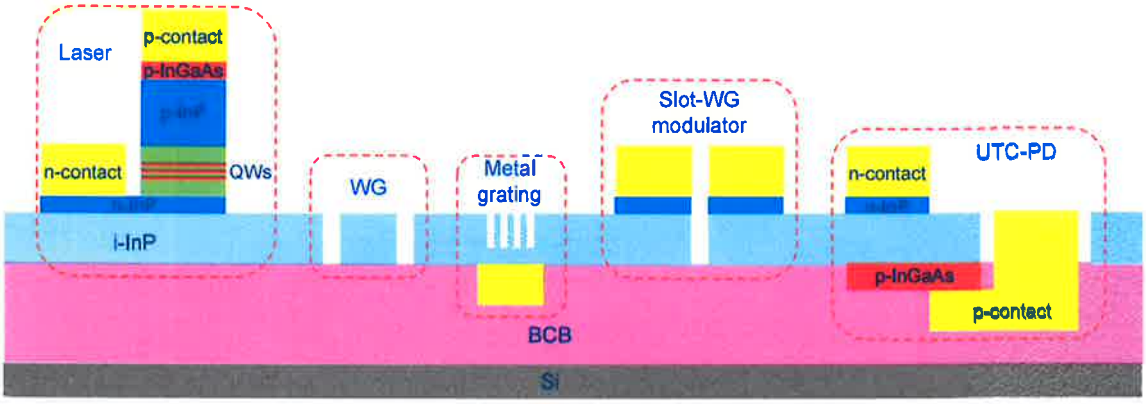

Fig. 29. A new integration platform based on double-sided processing.

In conclusion, double-sided processing promises high performance membrane devices by offering more freedom in design optimization. It is also a potential technology for platform integration of advanced components which are very difficult to integrate using traditional techniques.

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