Submicron Active-Passive Integration for InP-based Membranes on Silicon

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Abstract—**The high vertical index contrast and the small thickness of thin InP-based membrane structures bonded with BCB on Silicon allow the realization of very small devices. To make photonic integrated circuits with both passive and active components in these membranes, active-passive integration on a small scale is essential. In this paper we will present our results on sub-micrometer active areas for membrane applications.**

Keywords-InP-based membrane; active-passive integration; interface morphology; photoluminescence;

I. Introduction

The complexity of photonic integrated circuits (PICs) has been raised significantly these last few years, following Moore's law in Photonics[1]. But to satisfy the need for even further complexity, devices have to be made smaller and less power consuming. InP-based membrane bonded on Si[2](See Fig.1) is a qualified candidate to fulfill this demand. The advantages of this PIC platform are multiple. First of all, we have the main advantage of a membrane structure: high vertical refractive index contrast and low power consumption because of the ultra small size. Secondly, both passive and active functions can be realized in the platform of InP-based materials[3]. Finally, the platform is compatible with Si-on-Insulator (SOI) and CMOS platforms. This makes it possible to use the mature and advanced CMOS Fab technology.

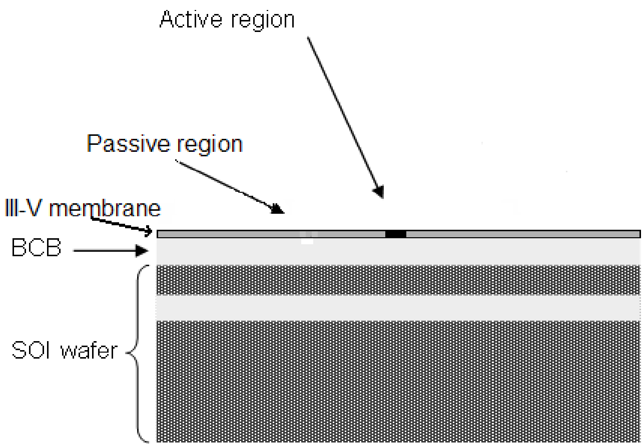

Figure 1. Schematic of InP membrane on SOI platform

Ultra small passive components in the InP membrane, such as waveguides, ring cavities and MMIs, have already been fabricated and these basic components of PICs shows good performance[4] . Since PICs consist of both passive and active components, a successful active-passive integration with sub-micrometer active regions in membranes is an essential step towards complete PICs. In this paper we will present our results on active-passive integration with sub-micrometer active areas. The interface between active and passive areas shows a good quality in terms of morphology. Moreover, we find that in the sub-micrometer size active area, the degradation of the active material(InGaAsP quantum wells) due to processing is limited.

II. Idea and Design

A successful active-passive integration test should satisfy two critical conditions. On one hand, a smooth and flat interface should be realized between the active and passive materials. A coarse interface causes both reflection and scattering loss when light is coupled between active region and the passive regions. Meanwhile a good surface flatness is necessary for processing and bonding of membranes. On the other hand, since the smallest active regions are only around submicron size, it is possible that the active quantum well materials are damaged by the processes, which means that they cannot emit light anymore.

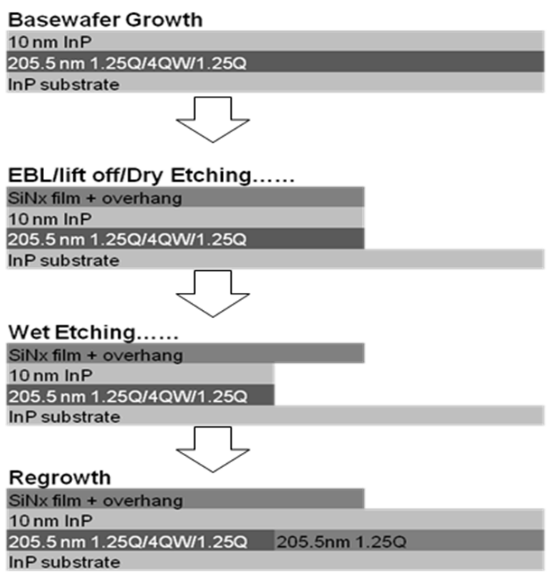

Figure 2. Fabrication process flow

To check the quality of active-passive integrations, active regions of multiple shapes (such as hexagons and octagons) and different orientations are designed. Moreover the sizes of the active regions varies from 250 nm to 2.5 µm in side length.

III. FABRICATION

As it is shown in Fig.2, the starting point is a 200nm quaternary layer (InGaAsP) on InP substrate and this is a typical thickness for membranes. quantum wells which are designed to emit light at 1.55 µm are embedded in InGaAsP layer,. The thin quaternary layer is etched away, except for the places where an active medium is required. Then a regrowth of passive material leads to a passive quaternary layer with local active medium. The wet etching time is optimised so that a flat surface can be realized around the interface between active and passive regions.

IV. CHARACTERIZATION

The characterization focuses on two aspects. On the one hand, the quality of the interface between active and passive materials is checked using Focused Ion Beam etching and SEM inspection. On the other hand, the photoluminescence of small active regions is measured to determine the quality of the remaining quantum well materials.

A. Interface morphology

Fig.3 shows a top view SEM picture of an achieved structure(hexagon bar) with a submicron size. The SiNx mask used for the regrowth is left on the sample, in order to make the active areas visible. The line indicates the position where the cross section picture of Fig.4 is made, by the use of Focused Ion Beam(FIB) etching and SEM. The good quality of the interface and the flatness of the surface can be seen in Fig.4

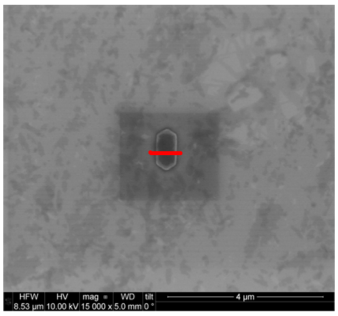

Figure 3. SEM picture

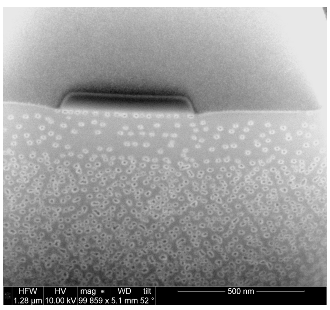

Figure 4. Cross section made by FIB

B. Photoluminescence measurement

Fig.5 shows the photoluminescence of a realized structure under CW pumping by a red laser diode at 660 nm. This spectrum corresponds to the quantum wells emission with a peak centred at 1500nm and this means quantum wells are usable.

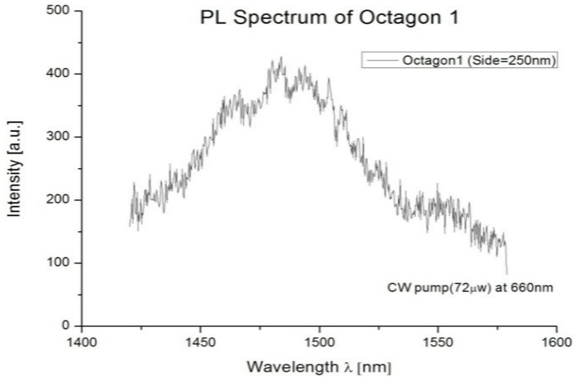

Figure 5. PL spectrum of the submicron achieved region

We observed a blue shift when the size of the active region decreases. We believe that this is due to the quantum intermixing effect[5] caused by defects from dry etching and high temperature during the regrowth process.

V. CONCLUSION

In this paper, we explored the feasibility of active-passive integration within the submicron scale on a quaternary material system (InGaAsP). This is the essential step towards membrane PICs including ultra small active and passive components. The interface between active and passive areas shows a good quality in terms of morphology. Moreover, by using photoluminescence measurement, we find that in the sub-micrometer size active area, the degradation of the active material(InGaAsP QWs) due to processing is limited.

A successful active-passive integration within submicron range will enable us to make very small lasers in InP-based membranes with very small threshhold current and power consumption. Naturally, this is of great interest for applications like single photon sources and digital photonics, such as all optical flip-flops based on coupled lasers

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