Implementation of the Selective Area Growth in the COBRA Generic Photonic Integration Platform

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In this paper we describe the ongoing extension of the COBRA Generic Integration Process towards the creation of building blocks using the Selective Area Growth (SAG) technology as developed at III-V Labs. This technology is being developed with aluminum containing active layers, on which we showed very clean butt-joint regrowth between the active and passive areas. We will present the first results of a fabrication run using the COBRA Generic Photonic Integration with an aluminum containing active layer to compare this with conventional active layers. The next step will be the realization of the SAG-based building blocks.

Introduction

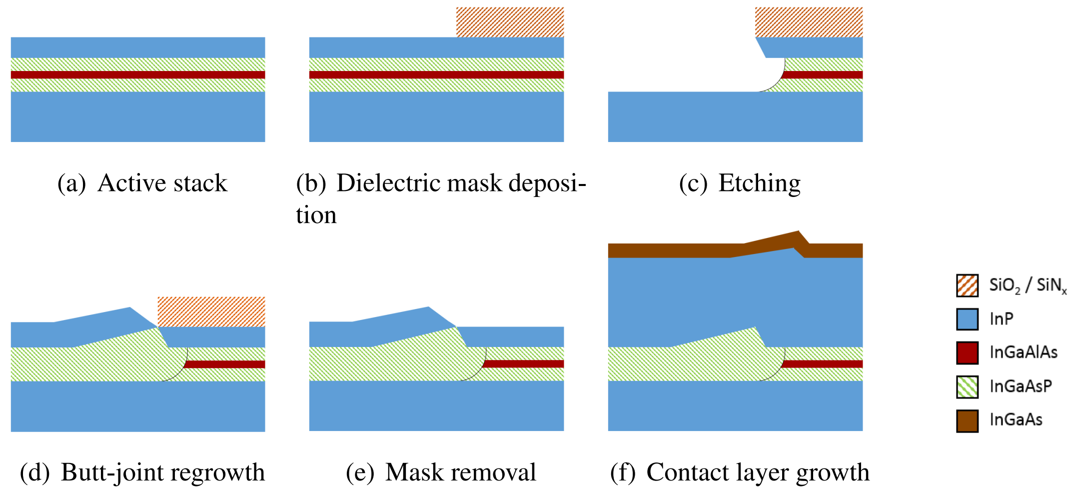
Allowing a fast development of photonic integration is one of the key steps for the improvement of our technology in the near future. In this scope, the Photonic Integrated Circuit (PIC) technology aims to reduce drastically the time of conception and the costs of production for small scale applications, such as research or small innovative companies. It consists in proposing a library of simple photonic devices – known as Building Blocks (BBs) – which can be combined in a circuit-level design to satisfy a broad range of applications. Its success depends on both a good adaptability of devices to different functions, and an optimized generic fabrication process, compatible with any circuit combination.

The part of the European GeTPICs project presented in this work aims integrate the Selective Area Growth (SAG) technique in the COBRA generic platform in order to develop circuits capable of emitting multiple wavelengths at high modulation rate, and extend the number of possible BBs in the platform. The project takes benefits of both the experience of the Alcatel-Lucent III-V Lab in the bandgap engineering assisted by SAG, with which they made efficient optical transmitters [1][2], and the development of the COBRA generic platform by the Eindhoven University of Technology (TU/e). In this way the COBRA platform, which already proposes all needed devices to obtain efficient photonic circuits [3], would at the same time serve as a basis to implement the new devices in a circuit, and be itself extended with a new branch of devices made possible by the integration of SAG in its process.

While the development of SAG is based on aluminum containing quaternary (InGaAlAs) in the III-V Lab, the COBRA platform is so far based on phosphorous containing quaternary material (InGaAsP). Therefore, a first verification of the possibility to obtain a clean butt-joint interface with such a difference in material is necessary. This paper presents the result of this work.

Experiment

A butt-joint technology allows to obtain a sharp waveguide transition between an area for active devices and an area of passive waveguides. It consists in growing epitaxially the passive layer stack next to areas still containing the active layer stack after being etched (See Figure 1). Therefore, the quality of this interface is critical to reduce the losses and the reflections at the interface, and thus to obtain efficient devices.



(a) Active stack (b) Dielectric mask deposition (c) Etching

(d) Butt-joint regrowth (e) Mask removal (f) Contact layer growth

Figure 1: Cross- section of a butt-joint process flow. After the growth, the light travels from side to side across the transition between the passive stack (on the left side) and the active stack (on the right side).

An active layer is first deposited on the InP wafer in an Metal-Organic Vapor Phase Epitaxy (MOVPE) reactor, at 650°C and 150 mbar, using TriMethyl-metal (TM) elements: TMIn, TMGa and TMAl as a source of elements from group III, and arsine and phosphine for the elements from group V. The layer stack consists of the n-doped InP buffer layer, then the light guiding layer, composed of four 7 nm thick Quantum Wells (QW) of InGaAlAs separated by 10 nm thick barriers of InGaAlAs, surrounded by two 210 nm thick Separate Confinement Heterostructure (SCH) layers of InGaAsP alloy. The QW provide either an optical gain or absorption around a central wavelength of 1550 nm, and the SCH, transparent to this wavelength, allow the wave mode to expand in a round shape. In this way, the whole guiding layer is about 500 nm thick (SCH + QW). Then the deposition of a top cladding layer of 200 nm of p-doped InP finishes the p-doped - intrinsic - n-doped (PIN) electrical heterojunction for active devices (See Figure 1(a)). The different layers thicknesses have been chosen in order to be compatible with the standard passive layer stack used in the COBRA process described in the next paragraph.
After the active layer stack deposition on the whole wafer, the areas in which active devices will be fabricated is protected, and the rest of the wafer is etched down to the InP buffer layer. For this step, a mask of dielectric (SiN_x or SiO_2) is deposited to protect the active stripes (See Figure 1(b)), and the wafer is etched using an HCl solution to remove the InP top layer anisotropically, and a KOH/citric acid solution to etch isotropically different quaternary materials in the guiding layer. Wet etching is used in order to both keep a defect-free surface to avoid any problem during the regrowth and use the high selectivity between quaternary materials and InP to stop the etch at the surface of the buffer InP layer (See Figure 1(c)).

The regrowth of the COBRA passive layer stack consists in a 500 nm thick layer of InGaAsP as a light guiding layer, covered by 200 nm of p-doped InP. This regrowth is made at 650°C and 100 mbar, and the precursors are also trimethyl-metals, arsine and phosphine (See Figure 1(e)). Afterwards, the dielectric mask is removed with HF (Figure 1(f)), and the growth of the cladding and contacting layer is performed. It consists in a 1 µm thick p-doped InP layer, followed by 300 nm of InGaAs to improve the electrical contact with the metal later deposited on the surface, and finally a thin passivation layer of InP in deposited to protect the structure during the following processes (See Figure 1(f)).

Results

The SEM image in Figure 2(a) shows the edge of an active stripe obtained following the previously described etching recipe (Step represented in Figure 1(c)). The InP is etched in such a way to obtain an inward slope, and the quaternary materials are etched in a controlled way down to the InP buffer surface in order to regrow the exact designed thickness in a highly reproducible way.

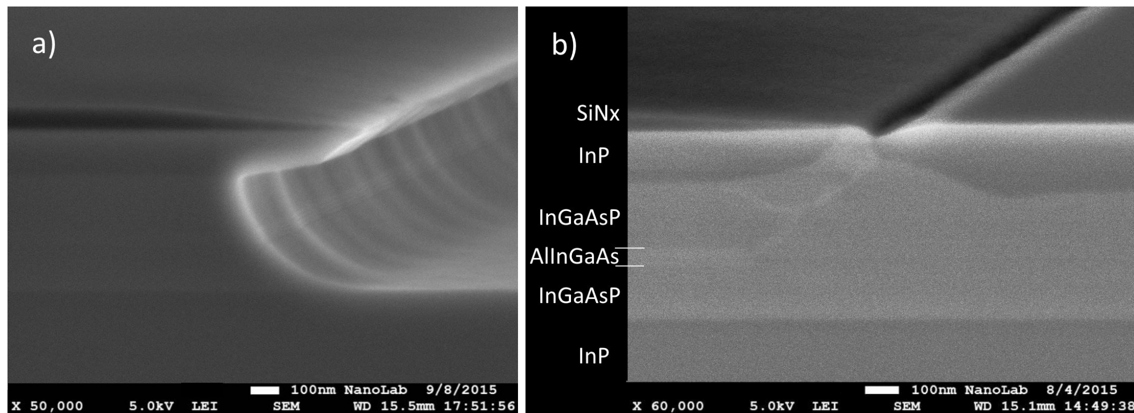


Figure 2: SEM image of the active edge profile a) after etching through the layer stack, and b) after the regrowth of the passive layer stack

It can be noticed that the QW structure does not show a different etch rate compared to the SCH layers, despite of the different material used. A different result has been reported using sulfuric acid in [4], and suggests that citric acid is more practical for mixing aluminum and phosphorous quaternary materials without creating under-etches which may disturb the butt-joint regrowth.

The Figure 2(b) shows an SEM image of the obtained butt-joint interface (Step represented in Figure 1(d)). The cleanliness of the transition and the thickness matching between the active guiding region and the passive one are highly reliable. This result is very promising for fabricating low-loss and low-reflection butt-joint interfaces and thus efficient devices.

In comparison with the butt-joint interface obtained in regular process in the COBRA platform, already showing good optical behavior (See Figure 3(a), and [5]), the newly regrown interface presents very little thickness variations or material defect, which is expected to provide efficient devices.

One can notice in Figure 2 a shrinking of the SiN_x mask on the edge of the active stripe. This is thought to be caused by an under-etch below the resist, but this imperfection did

not disturb the quality of the butt-joint regrowth.
The Figure 3b shows a second test of regrowth which have been performed, and confirms the excellent results obtained previously (Step represented in Figure 1(f)). Once again the butt-joint interface is of high quality and the step difference at the surface of the wafer after growing the cladding InP/InGaAs layer is as low as 170 nm.

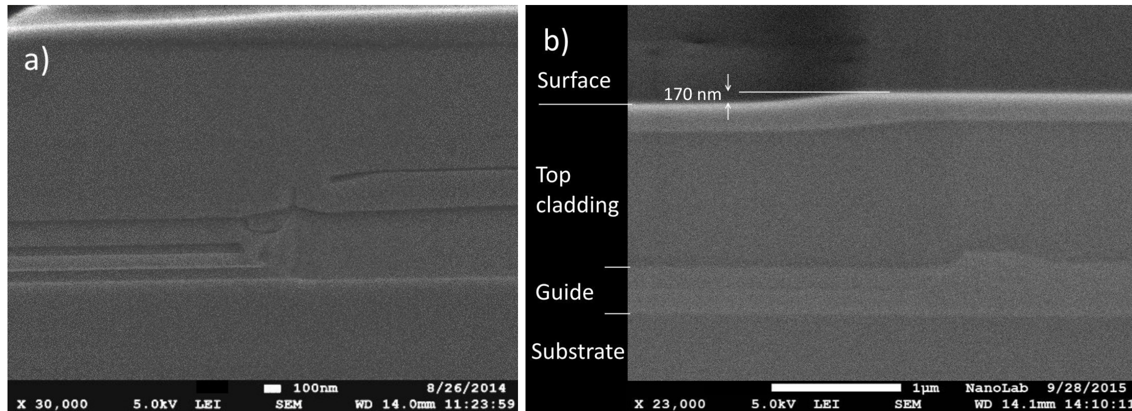


Figure 3: SEM images of butt-joint interface embedded under an InP/InGaAs contact layer a) from a past fabrication, and b) in this work. One can notice the subtle line inside the active guides on the left side of both images, indicating the presence of quantum wells.

Conclusion and Future Developments

These very promising regrowth results show that the COBRA butt-joint fabrication process is compatible for both aluminum containing and phosphorous containing QW in the active structure. The use of aluminum containing QW should not only provide the possibility to use the III-V lab's SAG technique to make novel chips designs, but also a better temperature performance of the devices. We can now proceed confidently with the full fabrication of chips following a design already fabricated in past runs in the COBRA platform. These chips will provide a strong basis for comparing the electro-optic characteristics between phosphorous and aluminum containing QW. Secondly, a set of test structures using SAG is being designed, and will allow the investigation of the possibilities offered by the SAG technology combined with butt-joint regrowth.

References

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