Generic InP-based Photonic Integration Technology Platform for Long Wavelength Applications

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Abstract: In this paper, a generic InP-based photonic integration technology platform for long-wavelength applications is described. This entails some information on the active-passive integration procedure followed by the steps which lead to photonic integrated circuit devices operating in 2 µm wavelength range.

Introduction

Generic photonic integration technology is an approach which offers monolithic fabrication of miniaturized photonic devices with diverse functionalities at a reduced price. This is achieved through development of a standardized integration technology with a library of fully-characterized basic building blocks including passive components, detectors, modulators and the highly-demanded lasers and optical amplifiers (SOAs). In this context, integrated circuits on Indium-phosphide (InP) substrate are of particular interest since both active and passive components are supported.[1] Since the launch of the InP-based generic integration concept in 2007 by the European Network of Excellence (ePIXnet), the COBRA research group together with some other leading partners have successfully demonstrated a number of milestones for devices operating at 1.55 µm. These achievements have triggered the idea to establish a so-called long-wavelength generic platform where devices with operating wavelengths around 2 µm can be fabricated. The wavelength range around 2 µm is of great interest since various gas species have absorption lines in this region (carbon dioxide 2.05 µm, nitrous oxide 2.13 µm and carbon monoxide 2.33 µm) and the absorption of water is very low. This offers a potential for trace-gas monitoring applications in environmental and medical diagnostics. In the next section, we will describe how the generic COBRA platform available for photonic integrated circuit (PIC) fabrication at 1.55 µm is modified for use at longer wavelengths.

Active-passive integration

There are various techniques for semiconductor active-passive integration [2, 3]. Among the reported schemes the butt-joint [4] coupling approach offers maximum flexibility in design of the integration layers. It allows for precise and independent control of thickness and doping concentration in the active and passive sections. Therefore, the COBRA approach in the long wavelength platform is based on butt-joint active-passive integration. It starts with growth of a spot-size convertor layer stack followed by a 600-nm-thick active layer which photoluminescence spectrum is shown in fig. 1.

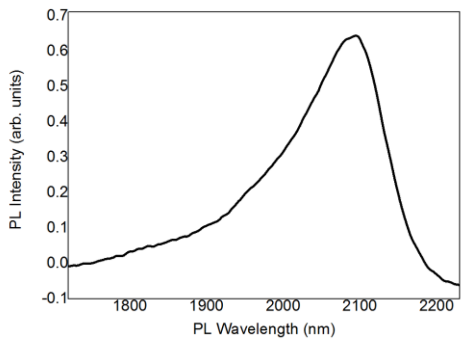

Fig. 1- Photoluminescence spectrum of the long-wavelength active material.

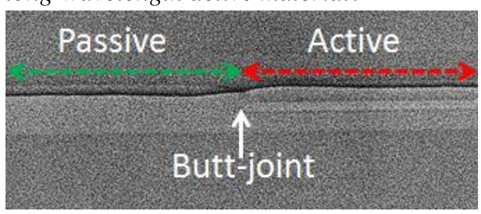

Fig. 2: SEM image of a cross-section through an active-passive butt-joint.

All these steps are done via Metal Organic Vapor Phase Epitaxy (MOVPE). In the next step, a dielectric mask (400-nm-thick layer of SiNx) is deposited and after the lithography and defining the active islands (30-µm-wide with a user-defined length), the active layer is etched away outside the masked region and replaced by a thickness-matched passive quaternary (Q1.25) layer in a regrowth step. Then, the mask layer is removed and the top p-InP cladding layer (1.5-µm-thick) followed by the highly p-doped InGaAs contact layer (300-nm-thick) is grown. Fig. 2 is showing a SEM image of an active-passive butt-joint realized in the long-wavelength platform. Once the wafer is fully grown it undergoes the following processing steps:

Waveguide processing

For the waveguide processing a 600-nm-thick SiNx layer is deposited all over the grown wafer and will be used as the main etching hard mask. The pattern is then written into a positive photoresist via optical contact lithography from which it is then transferred onto the SiNx hard mask layer. The semiconductor etching is a multi-stage process and is done through dry etching, using the ICP machine with an appropriate CH_4:H_2 gas mixture. Fig.3 (left) is showing the building blocks which are achieved in the long-wavelength platform at the end of all the etching steps. Fig.3 (right) is showing a SEM top image of a smooth junction of a passive waveguide running into the active region.

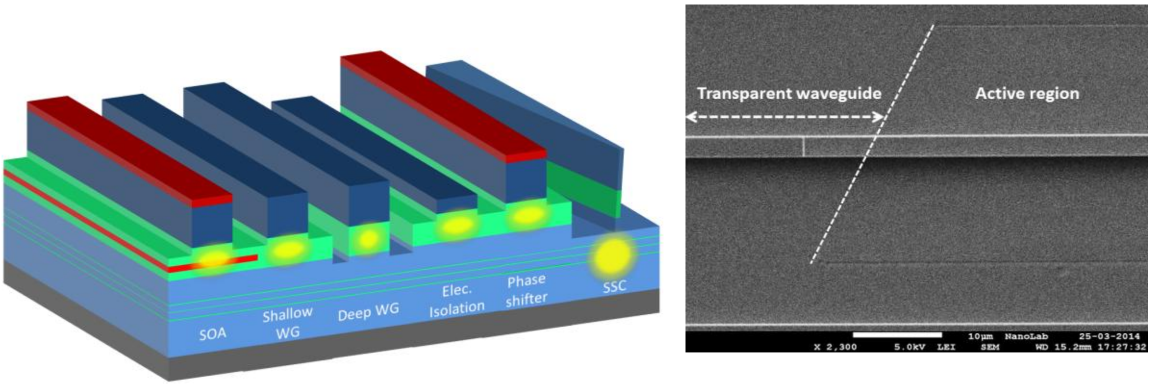

Fig. 3- (Left) Schematic of the building blocks in the long wavelength platform. From left to right, the following components are distinguishable: semiconductor optical amplifier, shallow waveguide, deep waveguide, electrical isolation, phase shifter and laterally-tapered spot-size convertor. (right) top view of the junction between active and passive.

Planarization and metallization

Once all the etching steps are done and the structures are defined, the next step is to deposit a metal layer stack on top of the p-InGaAs contact layer (the red layer on top of the structures in fig.3). However, the entire wafer needs to be planarised before p-metallization. This is done via polyimide spinning, curing at 325°C and then etching back process in polymer RIE (reactive ion etching) to expose top of the contact layer for metal deposition. Thereafter, the lift-off lithography is done followed by the p-metal evaporation. The evaporated metal layer consists of Ti, Pt, Au films with thicknesses of 60, 75, 300 nm, respectively. This is an optimized combination in order to have low contact resistance. Following the p-metal evaporation, the metal lift-off is done by using the Acetone solvent. Then, the wafer backside is cleaned and the n-metal evaporation is done with composition of again, Ti, Pt, Au and thicknesses of 60, 75, 200 nm, respectively. At last the samples are annealed at 325°C for 90 s. This last step prepares the sample for cleaving, mounting and eventual wire bonding.

Conclusion

In this paper, a description of the processing steps in the COBRA generic long-wavelength platform is given. Currently, the first long-wavelength devices are under processing. The characterization of these devices is expected in a short time.

Acknowledgements

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References

1. M. Smit *et al. IET Optoelectronics*,vol 5, Issue 5, pp. 187–194, (2011).
2. T.L Koch *et al. IEEE journal of Quantum Electronics*. 27, pp. 641-653, (1991).
3. T..Kato *et al. Proc. Eur. Conf. On optical communication (ECOC 91)*, paper WeB7-2, (1991).
4. J.J.M. Binsma *et al. IEICE Trans.Electron.*, vol. E80-C, pp. 675-681 (1997).