Extended Abstracts of the 2020 International Conference on Solid State Devices and Materials, VIRTUAL conference, 2020, pp297-298

Backside Integration of III-V/Si Hybrid Laser in a Si-SiN Photonics Platform

Quentin Wilmart, Karim Hassan, Daivid Fowler, Stéphane Malhouitre, Stéphanie Garcia, Karen Ribaud, Jérémy Da Fonseca, Romain Thibon, Christophe Jany and Ségolène Olivier

Univ. Grenoble Alpes, CEA, LETI, F38000 Grenoble, France
E-mail: Quentin.wilmart@cea.fr

Abstract

We report on the fabrication and characterization of multilevel Si/SiN/III-V transmitter circuits. The III-V material is heterogeneously integrated on the backside of the SOI layer in order to make hybrid laser sources. We show single mode operation of a Si/III-V hybrid laser. The chip output is performed via a specially designed backside SiN-Si grating coupler. This result validates the first integration of III-V on the backside of a Si/SiN platform.

1. Introduction

The constantly growing network traffic in data centers requires low cost, high speed and energy efficient transmission solutions [1], [2]. Integrating SiN, a low thermal coefficient material, in a photonics platform allows the realization of wavelength multiplexers with low temperature sensitivity [3], reducing the power consumption of the thermo-electric controllers placed at the packaging level. A Si/SiN platform is therefore an attractive solution to make energy efficient high data rate optical transceivers [4]. On the other hand, integrating III-V material on Si for hybrid laser sources [5], [6] and electro absorption modulators reduces packaging complexity and improves the scalability to a larger number of channels. However, the co- integration of Si, SiN, and III-V is challenging, as it requires several wafer bondings [7]. Depending on the integration path, some part of the fabrication has to be done on the wafer backside (the design of hybrid laser cavities dictates that Si and III-V are less than 150nm apart for efficient optical coupling). Furthermore, when a multi-level backend-of-line (BEOL) is needed for example for the RF connection of the high frequency modulator, the integration of the laser source on the backside of the wafer is mandatory [8].

2. Fabrication

The starting material is a set of 200mm Silicon-on-Insulator wafers. Si (300nm-thick) and SiN (600nm-thick deposited by Plasma Enhanced Chemical Vapor deposition) are first patterned on the wafer frontside. Then a carrier substrate is bonded (intermediate cross section Fig. 1 a), wafers are flipped and the original substrate is removed. The process is resumed on the backside with an amorphous silicon thickening step (500nm-thick Si is necessary for a good III-V/Si effective index matching). The associated patterning step includes feature sizes down to 120nm thus requiring the use of 193-nm UV photolithography with frontside-backside alignment. Notably, the SiN and the amorphous silicon are deposited at low temperature (<350°C) making the process compatible with the BEOL. The multi-quantum well III-V substrate is bonded on the back of Si and patterned. A total of 12 backside patterning levels is necessary to complete the fabrication (final cross section in Fig 1 b and SEM image in Fig. 2 a).

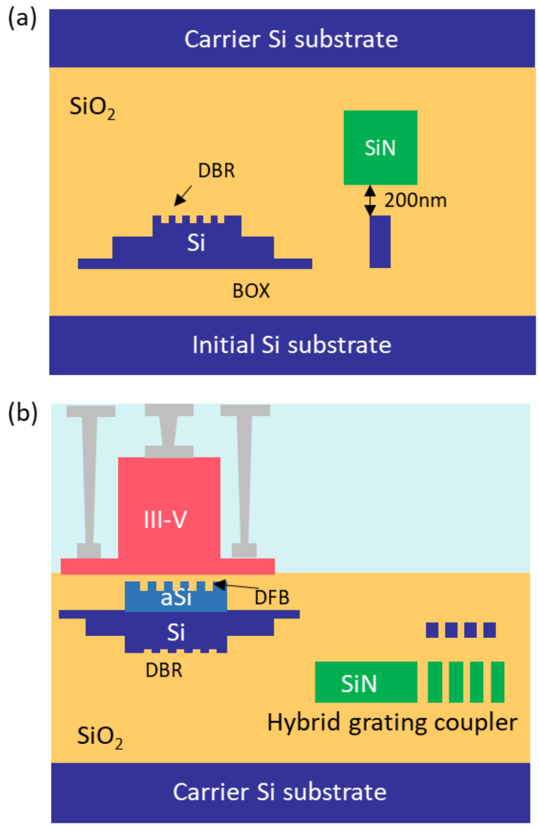

Fig. 1 (a) Cross section schematics at the end of the frontside fabrication, before flipping the wafer. (b) Final cross section with III-V on the backside.

3. Results

The Si/SiN platform includes a Coarse Wavelength Division Multiplexing (CWDM) SiN multiplexer based on Echelle gratings and a SiN/Si hybrid grating fiber coupler specially designed for backside coupling and featuring a 50nm (-1dB) bandwidth (see also [4]). We show the operation of a Distributed FeedBack (DFB) laser (Fig. 2 b). The laser shows a single mode at 1312nm with a side mode suppression ratio of 44dB and an estimated output power (in the waveguides) of 0.8mW. Notably, the hybrid DFB laser is coupled to a SiN waveguide and the chip output is performed through the backside SiN/Si grating fiber coupler. This demonstration is the first realization of a III-V/Si hybrid laser on the backside of an Si/SiN platform.

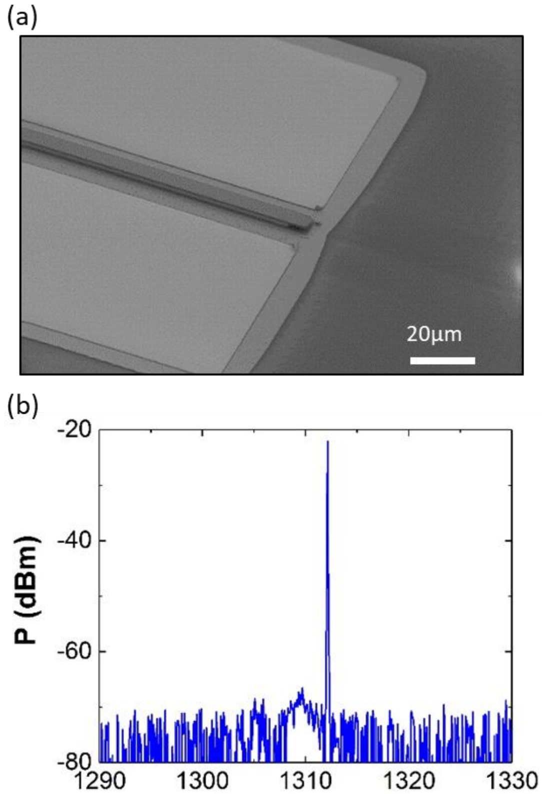

Fig. 2 : (a) Electronic microscope image of the III-V gain section. (b) Si/III-V DFB laser spectrum.

4. Conclusion and perspective

The fabrication of III-V structures on the backside is a promising integration path for wafers coming from industrial foundries with a stabilized process flow: the III-V integration can be done on the backside of 300mm wafers, without any stack modification while remaining CMOS compatible.

Acknowledgements
This work has received funding from the European Union Horizon H2020 Program (H2020-ICT27-2015) under grant agreement COSMICC 688516.

References

[1] B. Szelag *et al.*, « Multiple wavelength silicon photonic 200 mm R+D platform for 25Gb/s and above applications », Brussels, Belgium, mai 2016, p. 98911C, doi: 10.1117/12.2228744.

[2] F. Boeuf *et al.*, « A Silicon Photonics Technology for 400 Gbit/s Applications », in *2019 IEEE International Electron Devices Meeting (IEDM)*, San Francisco, CA, USA, déc. 2019, p. 33.1.1-33.1.4, doi: 10.1109/IEDM19573.2019.8993627.

[3] T. D. Bucio, A. Z. Khokhar, G. Z. Mashanovich, et F. Y. Gardes, « N-rich silicon nitride angled MMI for coarse wavelength division (de)multiplexing in the O-band », *Opt. Lett.*, vol. 43, nº 6, p. 1251, mars 2018, doi: 10.1364/OL.43.001251.

[4] Q. Wilmart *et al.*, « A Versatile Silicon-Silicon Nitride Photonics Platform for Enhanced Functionalities and Applications », *Appl. Sci.*, vol. 9, nº 2, p. 255, janv. 2019, doi: 10.3390/app9020255.

[5] Guang-Hua Duan *et al.*, « Hybrid III--V on Silicon Lasers for Photonic Integrated Circuits on Silicon », *IEEE J. Sel. Top. Quantum Electron.*, vol. 20, nº 4, p. 158-170, juill. 2014, doi: 10.1109/JSTQE.2013.2296752.

[6] B. Szelag *et al.*, « Hybrid III-V/Si DFB laser integration on a 220 mm fully CMOS-compatible silionn photonlcsplotform », in *2017 IEEE International Electron Devices Meeting (IEDM)*, 2017, p. 24–1.

[7] C. Xiang *et al.*, « Narrow-linewidth III-V/Si/Si_3N_4 laser using multilayer heterogeneous integration », *Optica*, vol. 7, nº 1, p. 20, janv. 2020, doi: 10.1364/OPTICA.384026.

[8] J. Durel *et al.*, « First demonstration of a back-side integrated heterogeneous hybrid III-V/Si DBR lasers for Si-photonics applications », in *2016 IEEE International Electron Devices Meeting (IEDM)*, San Francisco, CA, USA, déc. 2016, p. 22.2.1-22.2.4, doi: 10.1109/IEDM.2016.7838471.