Monolithic III-V/SiN co-integration through a butt-coupling scheme towards O-band applications

Ilias Skandalos*, Teerapat Rutiwarut, Thalía Domínguez Bucio, Yaonan Hou, Yasir Noori, Mingchu Tang, Siming Chen, Huiyun Liu and Frederic Y. Gardes

Optoelectronics Research Centre, University of Southampton, Southampton SO17 1BJ, UK
* *Corresponding author: is1f19@soton.ac.uk*

Over the last decade, silicon nitride (SiN) has been proven a promising CMOS-compatible material platform instead of the already established silicon-on-insulator (SOI) [1]. That arises mainly from its tuneable physical and optical properties [2], its wider transparency window (low absorption in visible and NIR) along with its mid-index identity (low propagation loss) [3], its low thermo-optic coefficient (WDM applications) [4] and its low two-photon absorption (TPA) (non-linear applications) [5]. Furthermore, the capability of a low-temperature 350 °C PECVD growth method [2] along with SiN's amorphous identity, renders the back end of line (BEOL) integration with active devices achievable. At the same time, the exploitation of photonic integrated chips (PICs) based on silicon (Si) towards coherent communication applications, is restricted due to the absence of fully integrated optical sources on-chip [6]. Even though progress on the III-V/SiN heterogeneous/hybrid approaches has been reported [7], a large scale monolithic integration of lasers on-chip with compact passive devices, still remains a challenge [8] due to the thick III-V buffer and cladding layers [9].

In this paper, we demonstrate a monolithic III-V/SiN transition on a silicon substrate. The integration of our optically tunable silicon nitride platform [2] with high-gain GaAs-QD multi-layer stack hetero-epitaxially grown on silicon [10] is numerically investigated. In detail, a straight III-V waveguide (n=3.29-3.5) is connected to N-rich SiN waveguides (n=1.9) in a butt-coupling scheme. A Si-rich SiN layer of an intermediate refractive index (n=2.51) is placed at the active-passive interface, so as to alleviate the high-low refractive index difference, while it passivates the III-V waveguide. Using a protective tetraethylorthosilicate (TEOS) layer, a double layer anti-reflective coating (DLARC) is composed towards the minimization of the coupling loss (CL) and parasitic back-reflection (BR). Moreover, we report on a <-30 dB BR and <0.7 dB CL transition based on optical simulations (Lumerical). In addition, preliminary stand-alone characterization results of <2 dB/cm propagation loss and 0.1 dB/90°bending regarding a 1700 nm wide and 1600 nm thick N-rich SiN platform are demonstrated, setting the ground for a future realization of a single-mode Vernier-based laser.

Acknowledgments

The authors would like to acknowledge EPSRC grant QUDOS "EP/T028475/1".

References

1. R. Baets et al., Optical Fiber Communication Conference, p. Th3J.1, (2016).
2. T. Domínguez Bucio et al., J. Phys. D: Appl. Phys., vol. 50, no. 2, p. 025106, (2017)
3. D. J. Blumenthal et al., Proc. IEEE, vol. 106, no. 12, pp. 2209–2231, (2018).
4. T. D. Bucio et al., Opt. Lett., vol. 43, no. 6, p. 1251, (2018).
5. C. Lacava et al., Sci Rep, vol. 7, no. 1, p. 22, (2017).
6. C. Cornet et al., Integrated lasers on silicon, London: ISTE Press, (2016).
7. M. Tang et al., Progress in Quantum Electronics, vol. 66, pp. 1–18, (2019).
8. A. Malik et al., Applied Physics Reviews, vol. 8, no. 3, p. 031306, (2021).
9. J. E. Bowers et al., Optical Fiber Communication Conference (OFC) (2019).
10. S. Chen et al., Nature Photonics, vol. 10, p. 6, (2016).