Towards the heterogeneous integration of single-photon sources on SiN using micro-transfer printing

Jasper De Witte[1,2], Atefeh Shadmani[3], Tom Vanackere[1,2], Tom Vandekerckhove[1,2], Peter Lodahl[3], Gunther Roelkens[1,2], Leonardo Midolo[3], Bart Kuyken[1,2] and Dries Van Thourhout[1,2]

[1] Photonics Research Group, Ghent University-imec, Ghent, Belgium, [2]Center for Nano- and Biophotonics (NB-Photonics), Ghent University, Ghent, Belgium, [3]Center for Hybrid Quantum Networks, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark

Recently, highly efficient GaAs-based single-photon sources have matured up to the point where simultaneous high purity and high indistinguishability of single photons can be reliably achieved in nanobeam waveguides.[1] Still, this monolithic GaAs platform suffers from propagation losses in the order of 10 dB/mm due to scattering in waveguides. Heterogeneous integration on low-loss SiN waveguides could overcome this bottleneck towards scalable quantum hardware. For this, we pursue a micro-transfer printing approach, which ultimately should allow for GaAs-on-SiN fabrication compatible with commercial foundry photonic platforms. In the current work, a double-sided tapered GaAs nanobeam is printed on top of a SiN interposer for the first time. A process to print a standalone waveguide of 300 nm width and 160 nm thickness was developed. These dimensions are much smaller and hence more challenging than those for the III-V lasers and photodiodes more commonly integrated on top of Si photonic platforms[2] using a micro-transfer printing approach. We discuss the fabrication and light coupling of these confined GaAs-on-SiN devices.

On its native substrate, a GaAs membrane containing a layer of self-assembled InAs quantum dots is patterned with electron beam lithography and RIE etching. The underlying AlGaAs layer is subsequently dry etched to expose the GaAs substrate. The GaAs device is encapsulated in protective photoresist, which is anchored to the substrate using tethers. After underetching in HCl, this 'coupon' remains suspended and can be picked and placed with our micro-transfer printing tool. Current devices have been printed on a SiN waveguide, patterned in a 300nm LPCVD SiN-layer using electron beam lithography and RIE etching. On top of the SiN-waveguides, a 50 nm thick BCB bonding layer is spin coated. After printing, the photoresist layer is removed and the BCB layer is cured at 280 degrees.

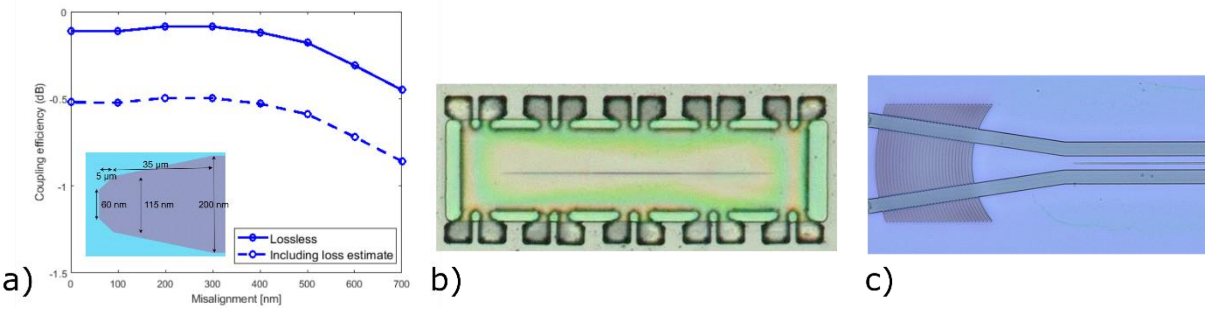

Fig. 1 (a) Simulated coupling efficiency as a function of misalignment, including a rough estimate for the propagation losses. Inset: coupler design (b) Suspended photoresist coupon shielding a GaAs nanobeam (c) SiN circuitry containing a printed nanobeam on top.

After fabrication, the GaAs nanobeam is typically printed with a lateral accuracy better than 750 nm (3σ). A piecewise linear taper design has been optimized for efficient mode coupling tolerant to misalignment and taking into account a tradeoff with propagation losses over its length. Light transmission has been demonstrated with mean overall losses of 3dB per device including in- and outcoupling and propagation losses of the 120 µm long waveguide device. To conclude, we realized GaAs nanobeams on top of a SiN platform with efficient light coupling. After studying the quantum dot emission, we will further improve its single-photon source characteristics similar to existing methods[1], paving the way for large-scale quantum information processing in this heterogeneous platform.

This work is supported by the EU-commission through the ERC-projects 759483 Electric and 884963 Narios.

References

[1] Uppu, R., Eriksen, H. T., Thyrrestrup, H., Uğurlu, A. D., Wang, Y., Scholz, S., Wieck, A. D., Ludwig, A., Löbl, M. C., Warburton, R. J., Lodahl, P., & Midolo, L. On-chip deterministic operation of quantum dots in dual-mode waveguides for a plug-and-play single-photon source. Nat. Comm., 11(1), 1–12, (2020)

[2] Zhang, J., Muliuk, G., Juvert, J., Kumari, S., Goyvaerts, J., Haq, B., Op De Beeck, C., Kuyken, B., Morthier, G., Van Thourhout, D., Baets, R., Lepage, G., Verheyen, P., Van Campenhout, J., Gocalinska, A., O'Callaghan, J., Pelucchi, E., Thomas, K., Corbett, B., … Roelkens, G. III-V-on-Si photonic integrated circuits realized using micro-transfer-printing. APL Photonics, 4(11), (2019)