Foundry SiN as a platform for Heterogeneous Integration at Visible Wavelengths

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***Abstract*—Silicon nitride (Si_3N_4) is an excellent material platform for visible wavelength photonic integrated circuits, in particular, as a host for the heterogeneous/hybrid integration of complementary materials. In this work, we characterise the performance of the Si_3N_4 from LIGENTEC as a base for hybrid integration.**

***Index Terms*—silicon nitride, photonic integrated circuit, visible, heterogeneous integration**

I. INTRODUCTION

The phenomenal success and technological impact of silicon photonics, enhanced with III-V heterogenous integration, is difficult to overstate. However, due to silicon's narrow bandgap, this success has so far been limited to primarily infrared technologies. There are numerous visible light applications which are ready to reap the same scalability, efficiency, and stability improvements offered by photonic integration, and require the development of wide-bandgap, broadly transparent, material platforms with the potential for heterogeneous integration [1].

Silicon nitride is a strong contendor as a base photonic integrated circuit (PIC) platform at visible wavelengths. It features low loss waveguiding [2], reasonable index contrast with silica cladding layers, a wide bandgap, broad transparency range, and a respectable third-order nonlinear refractive index [3]. Crucially, Si_3N_4 foundries are now offering multi-project wafer (MPW) runs with core thicknesses which allow for single-mode operation at visible wavelengths. Furthermore, low-loss Si_3N_4 is an excellent platform for the hybrid or heterogeneous integration with coupons or devices fabricated separately in wide bandgap materials possessing high optical nonlinearities, such as aluminium nitride or lithium niobate [4]–[6]. In all, Si_3N_4 is a platform well-suited for exploring applications which have traditionally been excluded from the benefits of repeatable, high-performance photonic integration.

In this work, we report a detailed characterisation of Si_3N_4 PICs sourced from the commercial foundry, LIGENTEC. Propagation losses from 450 nm to 850 nm are measured, as well as the performance of integrated ring resonators around 635 nm. We also characterize the performance of unbalanced Mach-Zehnders, directional couplers, and the losses upon transitioning from a fully clad waveguide to a thinly clad waveguide. Local thinning of cladding regions is of critical importance for successful vertical coupling to heterogeneously

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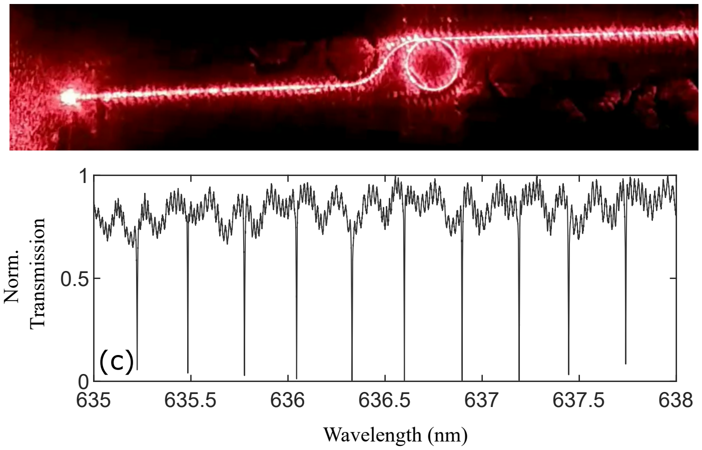

Fig. 1. A ring resonator on resonance and example transmission spectrum.

integrated components, as well as enabling applications such as optical bio-sensing with integrated resonators. Micro-transfer printing of suspended lithium niobite and gallium nitride device coupons are also presented.

II. Experimental and Results

The Si_3N_4 chips measured were part of a MPW run with core thickness of 150 nm. The top oxide cladding is 3.3 μm, while the bottom is 4 μm. A simple lensed fibre injection rig is used in conjunction with a number of fibre coupled laser diodes to measure the propagation loss across the visible spectrum. Propagation losses are $< 1\ dB/cm$ in TE and $< 0.5\ dB/cm$ in TM at wavelengths above 630 nm. A tuneable New Focus Velocity TLB-6704 is used to measure the detailed spectral response of devices, such as high Q-factor ring resonators, over a wavelength range of 635-638 nm as in Fig. 1. Approximately 400 resonances were characterised for a variety of coupling gap separations. A peak intrinsic quality (Q) factor of 3.69×10^6 is measured, while a mean value of 2.28×10^6 is recorded over 10 resonances of a single device.

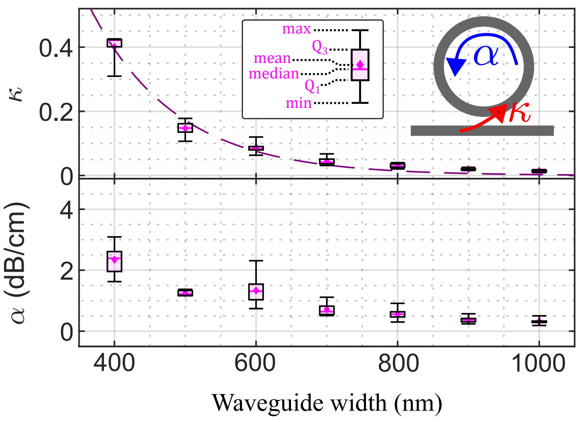

Fig. 2. Power cross-coupling, κ, and distributed ring loss, α, extracted from fits of resonance dips in ring transmission spectra.

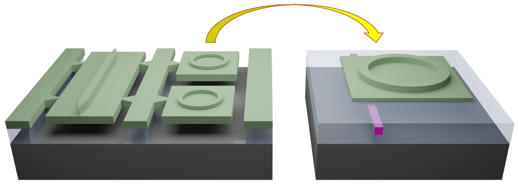

Fig. 3. Schematic of hybrid integration of device coupons with foundry SiN PIC.

The fabrication of MEMs-like suspended devices for transfer-print integration with the Si_3N_4 involves in-house direct write laser lithography and dry-etching in an ICP-RIE. After membrane device isolation with an etch down to the substrate, suspension is achieved with a wet etch targeting the substrate. Micro-transfer printing with polymer micro-stamps can then be used to pick and place suspended devices directly onto the Si_3N_4 receiver chip with high precision, to target vertically coupled devices as in Fig. 3.

III. Conclusion

We will present a detailed analysis of a foundry sourced Si_3N_4 photonic integrated circuit platform for single mode operation at visible wavelengths. Commercially available platforms such as these will be critically important for the next generation of photonic integration at wavelengths outside the transparency windows of traditional foundry PICs like silicon and indium phosphide. However, like those materials, heterogeneous integration will likely play an important role in the development of Si_3N_4 PICs with enhanced functionality; and so we present results towards the integration of gallium nitride and lithium niobate components with the low-loss foundry PICs.

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