Filling the gap of silicon nitride photonic platform functionalities using micro-transfer printing

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Abstract: In this work we demonstrate the heterogeneous integration of active devices on the SiN photonic platform using micro-transfer printing and we will discuss the remaining technological challenges

Photonic integrated circuits enable the miniaturization of key optical functions. Silicon (Si) and silicon nitride (SiN) photonic platforms have proven their maturity based on their compatibility with CMOS technology, giving rise to low cost, compact and scalable optical systems on a chip. Furthermore, in the case of SiN, the wide transparency window extends across the visible and near-infrared spectral regions, making it a strong candidate for numerous applications, including telecom/datacom, quantum technologies and bio-sensing. However, the SiN photonic platform lacks some important functionalities such as optical amplification, modulation, photodetection and intrinsic second order nonlinear frequency conversion. A versatile solution is to heterogeneously integrate devices, based on different materials, using the technique of micro-transfer printing [1] (Fig. 1). As such, diverse functionalities can be added to the SiN photonic platform at the back-end level to retain CMOS compatibility. In this presentation, we will discuss the remaining technological challenges such as SiN-to-device light coupling, wavelength compatibility, post-integration processing, limit of printed device sizes, multiple hetero-integration and scalability. Several recent device demonstrations (tab 1) are discussed to exemplify the current state-of-the-art and challenges.

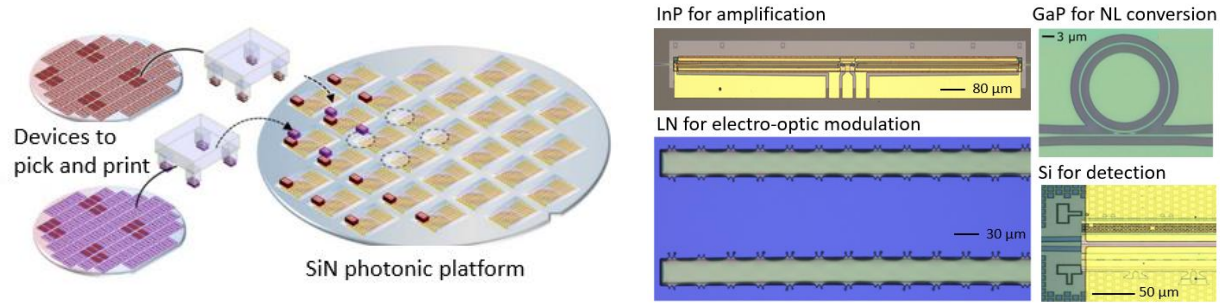

Fig. 1. Illustration of devices hetero-integration on a SiN wafer via micro-transfer printing and microscope pictures of transfer printed devices

Table 1. Overview of the silicon nitride photonic platform properties and examples of micro-transfer printed devices adding new functionalities on the platform

Property / functionality	SiN	Possible micro-transfer printed devices
Transparency window	0.25 to 5 µm	-
Propagation losses	0.01 to 0.1 dB/cm	-
Two-photon absorption	Negligible	-
Industry status	Low-volume production	-
Optical gain	Absent	InGaAs [2] / GaAs [3] / GaN [4] based amplifiers
Fast modulation	No Pockels, no carriers	Lithium niobate (LN) electro-optic modulators [5]
Nonlinear conversion	no intrinsic $\chi^{(2)}$, $\chi^{(3)}$	PPLN [6] / GaP [7] ($\chi^{(2)}$ *and* $\chi^{(3)}$) *waveguides*
Photodetection	No carriers	pin-Si photodiodes (slow) [8] / InGaAs UTC-photodiodes (fast) [9]

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