# PIC Fabrication Platforms for SOI and $Si_3N_4$ in a Flexible Photonic Foundry Concept

**Anna Lena GIESECKE*, Jens BOLTEN, Thorsten WAHLBRINK, Piotr CEGIELSKI, Caroline PORSCHATIS, Daniel SCHALL, Bartos CHMIELAK, Andreas PRINZEN, Holger LERCH, Herbert KLEINJANS**

AMO GmbH, Otto-Blumenthal-Str. 25, Aachen, 52074, Germany

* giesecke@amo.de

We provide unique highly flexible fabrication platforms for integrated photonic circuits based on SOI and $Si_3N_4$ from design to fabrication and characterization of the manufactured devices. The schematic in Fig. 1 depicts different options of our technology platforms. The accessibility of both platforms permits applications from telecom wavelengths to the NIR and visible range, hence the devices are suitable for communication as well as for sensing. AMO has been developing the SOI platform for photonic applications for more than one decade. Waveguide losses and grating couplers have been optimized for both telecom wavelength ranges around 1310 nm and 1550 nm. Critical passive structures such as directional couplers and ring resonators can be fabricated with high precision (Fig. 2b), g)). The passive platform is completed with efficient grating couplers (Fig. a)) (2.5 dB loss) and edge coupling through spot-size converters. In order to maximize the yield of our SOI-based photonic devices fabrication tolerances have been intensively studied and device design as well as processes both for the lithographic definition and for the pattern transfer via reactive ion etching have been optimized accordingly [1].

Active components in SOI such as modulators (Fig. 2f)-i)) and detectors [2] are enabled through ion implantation and optimized annealing steps. Furthermore, the co-integration of 2D-materials such as graphene into the photonic platform has been successfully demonstrated [3,4], enabling the fabrication of high speed photodetectors and heaters. The development of active SOI based components resulted in the fabrication of a transceiver module for an AOC (Fig. 2h)).

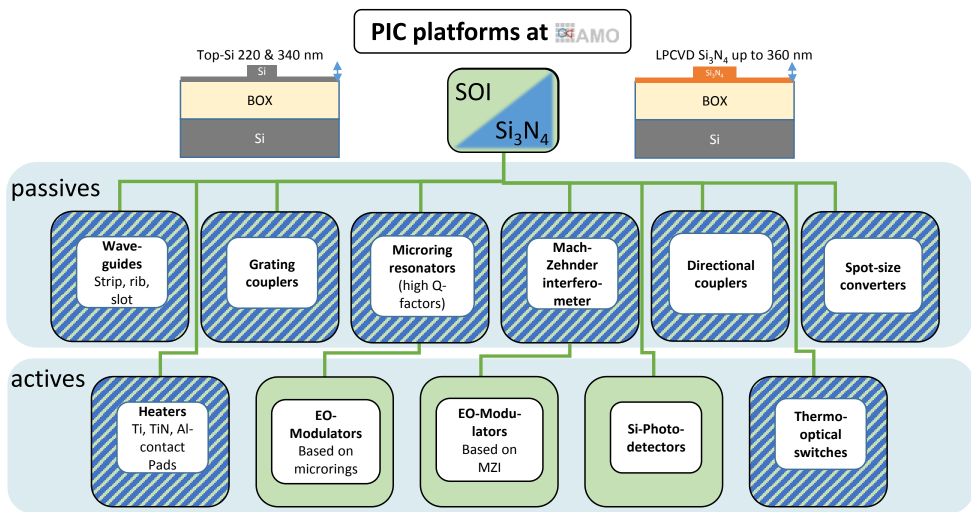


**Fig. 1. PIC platforms at AMO. The hatched boxes show the components available for both SOI and $Si_3N_4$ platform. The green boxes show components only available for SOI.**

To access an even broader wavelength range a second fabrication platform, based on silicon nitride on a thermally grown oxide on a Si substrate, has been developed.

Waveguides, directional couplers and grating couplers have been mainly designed for 1550 nm on a substrate with a thick 6 µm oxide layer and 100 nm thick $Si_3N_4$ layer. The corresponding waveguide losses for this platform do not exceed 0.1 dB/m. Thermal optical switches have been realized with Mach Zehnder interferometers with Ti-heaters [5]. A dedicated LPCVD silicon nitride process offers low stress layers. With this process also thicker waveguides with a height of 360 nm which offer better light confinement are feasible. These waveguide structures have a propagation loss of ~0.6dB/cm (@1550nm).

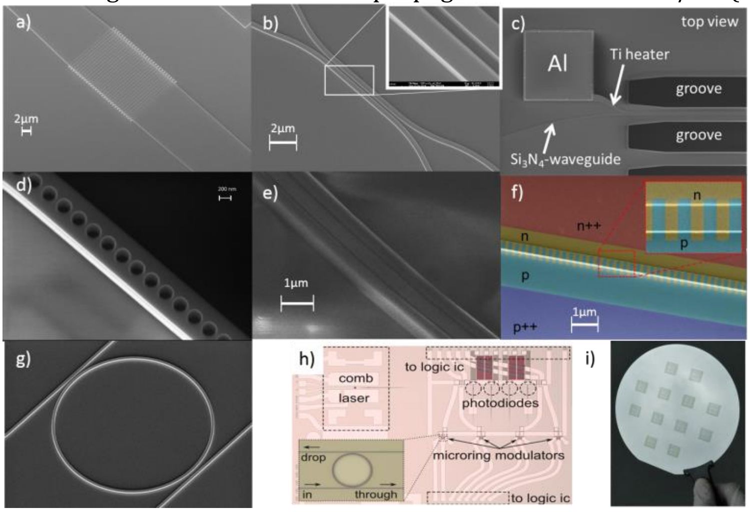


**Fig. 2. Examples of fabricated components and devices with AMO's photonic platform. a) shallow-etched grating coupler, b) directional coupler, c) $Si_3N_4$ thermo-optical switch, d) photonic crystal waveguide, e) double slot ring resonator in $Si_3N_4$, f) interleaved phase shifter with pn-junction width of 150 nm, g) microring resonator, h) transceiver for active optical cable 56 Gbit/s [2], i) SOI wafer with transceiver chips**

A Mix & Match approach of both highest resolution e-beam lithography and fast i-line stepper lithography is available for both the SOI- and the $Si_3N_4$-based fabrication platforms, combining flexibility and high precision with short turnaround times. In this way customized chip and wafer runs can be performed. Fabrication highlights of both photonic platforms as well as the implementation of new materials such as organics and perovskites towards the development of on-chip light sources will be presented.

## Acknowledgement

We acknowledge our past and present projects funded by the European Union which are GAIA, PHOXTROT, PLASMOfab, Synchronics, and SPIRIT as well as the German national projects SHYWA and SASER funded by the BMBF.

## References

[1] A. Prinzen, M. Waldow, H. Kurz, *Fabrication tolerances of SOI based directional couplers and ring resonators*, Optics Express, 21, 14, 17212-17220,

[2] H. Füser et al., *56 Gb/s WDM transmitter module based on silicon microrings using comb lasers*. CLEO: QELS Fundamental Science (pp. JTh2A-66). OSA, 2015

[3] D. Schall et al., *50 GBit/s photodetectors based on wafer-scale graphene for integrated silicon photonic communication systems*. ACS Photonics, 1(9), 781-784, 2014.

[4] D. Schall et al., *Infrared transparent graphene heater for silicon photonic integrated circuits.* Optics express, 24(8), 7871-7878, 2016.

[5] M. A. Piqueras et al., *Photonic Front-End for the next-generation of space SAR applications*. SPIE Remote Sensing (pp. 96391I-96391I). International Society for Optics and Photonics, 2015.