

# Heterogeneous Integration of Uni-Travelling-Carrier Photodiodes using Micro-Transfer-Printing on a Silicon-Nitride Platform

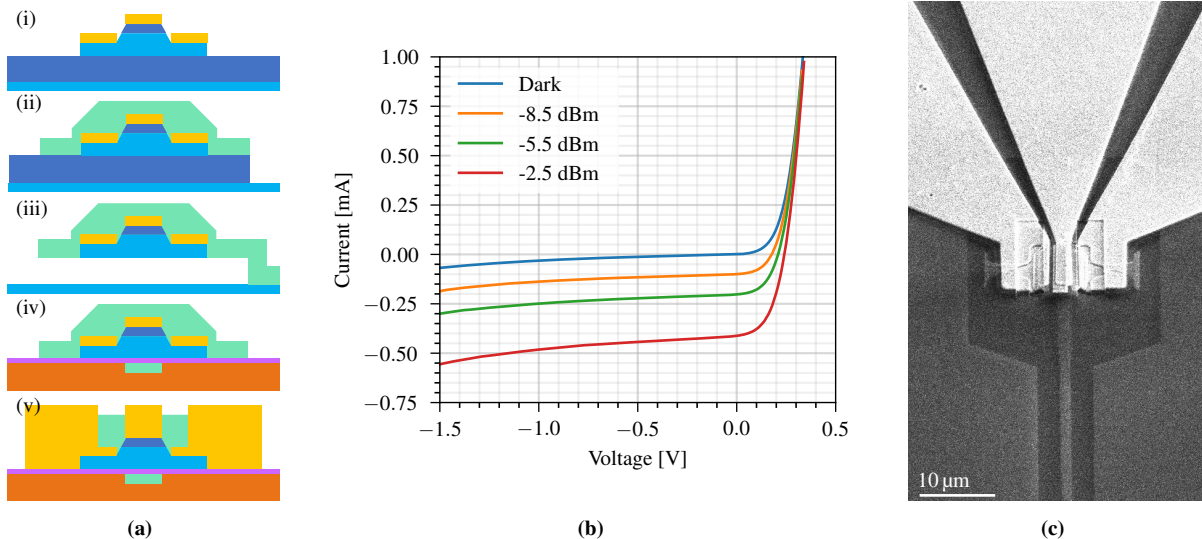
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High-speed photodiodes often compromise responsivity in exchange for a reduced footprint. However, using waveguide photodiodes circumvents this limitation [1]. We combine uni-travelling-carrier photodiodes (UTC PDs) on a silicon nitride (SiN) photonic platform to achieve both high responsivity and high speed detectors. The SiN-platform has excellent properties such as low-loss waveguides and does not suffer from two-photon absorption at high optical power. A high responsivity is obtained through evanescent coupling of waveguide UTC photodiodes to SiN waveguides while still maintaining a small footprint.

The devices are integrated using the micro-transfer-printing ( $\mu$ TP) technology for hybrid integration of different material platforms [2]. First, photodiode chiplets are made in an InP/InGaAs-technology using a standard fabrication flow. The epitaxial layer stack is adapted from [3] and includes a 500 nm thick sacrificial InAlAs release layer. This material is used for its excellent selective underetching properties [4]. Figure 1a summarizes the processing steps to create a waveguide-coupled UTC PD. (i) Photodiodes are made on the source wafer. (ii) The InAlAs release layer is anisotropically etched using a hard mask. (iii) A new SiN layer is deposited and patterned to create tethers to the InP-substrate. The device is under-etched (isotropic) to create a suspended coupon. (iv) The coupon is transfer-printed on a SiN target chip. (v) Vias are etched and metal connections are made.



**Fig. 1** (a) Fabrication steps, (b) IV-curves for different incident on-chip powers, and (c) SEM-image of a  $2 \mu\text{m} \times 10 \mu\text{m}$  waveguide-coupled UTC PD.

The waveguide-coupled PDs show a responsivity of  $0.80 \text{ A/W}$  for a bias voltage of  $-1 \text{ V}$ , illuminated at  $1550 \text{ nm}$ . This corresponds to an external quantum efficiency of  $65 \%$ . We believe this can be further increased for longer devices or by incorporating a reflection-reducing design in the InP subcollector. The IV-characteristic for a PD with an active area of  $2 \mu\text{m} \times 10 \mu\text{m}$  is shown in Figure 1b. High dark currents of  $10\text{-}20 \mu\text{A}$  and  $20\text{-}50 \mu\text{A}$ , at respectively  $-0.5 \text{ V}$  and  $-1.0 \text{ V}$  biasing, are thought to be a result of surface leakage currents, and are currently being investigated and remedied. Given the small surface area of  $20 \mu\text{m}^2$  and the average measured series resistance of  $30 \Omega$ , a high intrinsic bandwidth is expected. This will be verified using RF photoresponse measurements in the near future.

## References

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