“More than Photonics” Solutions:

Micro Transfer Printing at X-FAB

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EPIC Technology Meeting on Electronics & Photonics – Two Sides of One Coin

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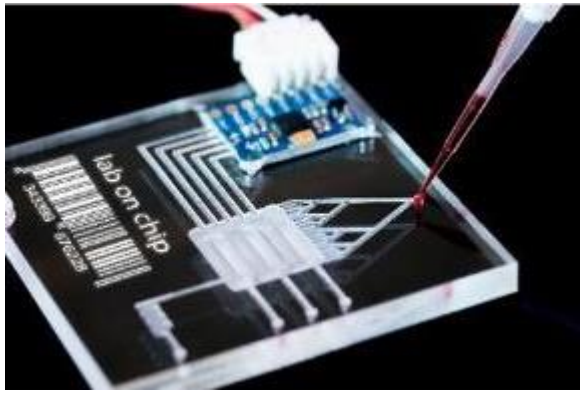
Outline

- Company introduction - Who we are? What do we do?
- X-FAB Photonics activities today - What is „More than Photonics“?
- Microtransfer printing – intro, key benefits and application examples, process flow
- X-FAB microtransfer printing roadmap
- Summary

Who we are

- We are a specialty foundry **offering a unique combination** of analog/mixed-signal, high-voltage and embedded non-volatile memory options with sensor and actuator integration.
- We support **long product lifecycles of 20+ years** and focus on automotive, industrial and medical end markets.
- We provide **best-in-class design** and **prototyping support** to enable first-time-right design.
- All of our sites are **automotive certified**.

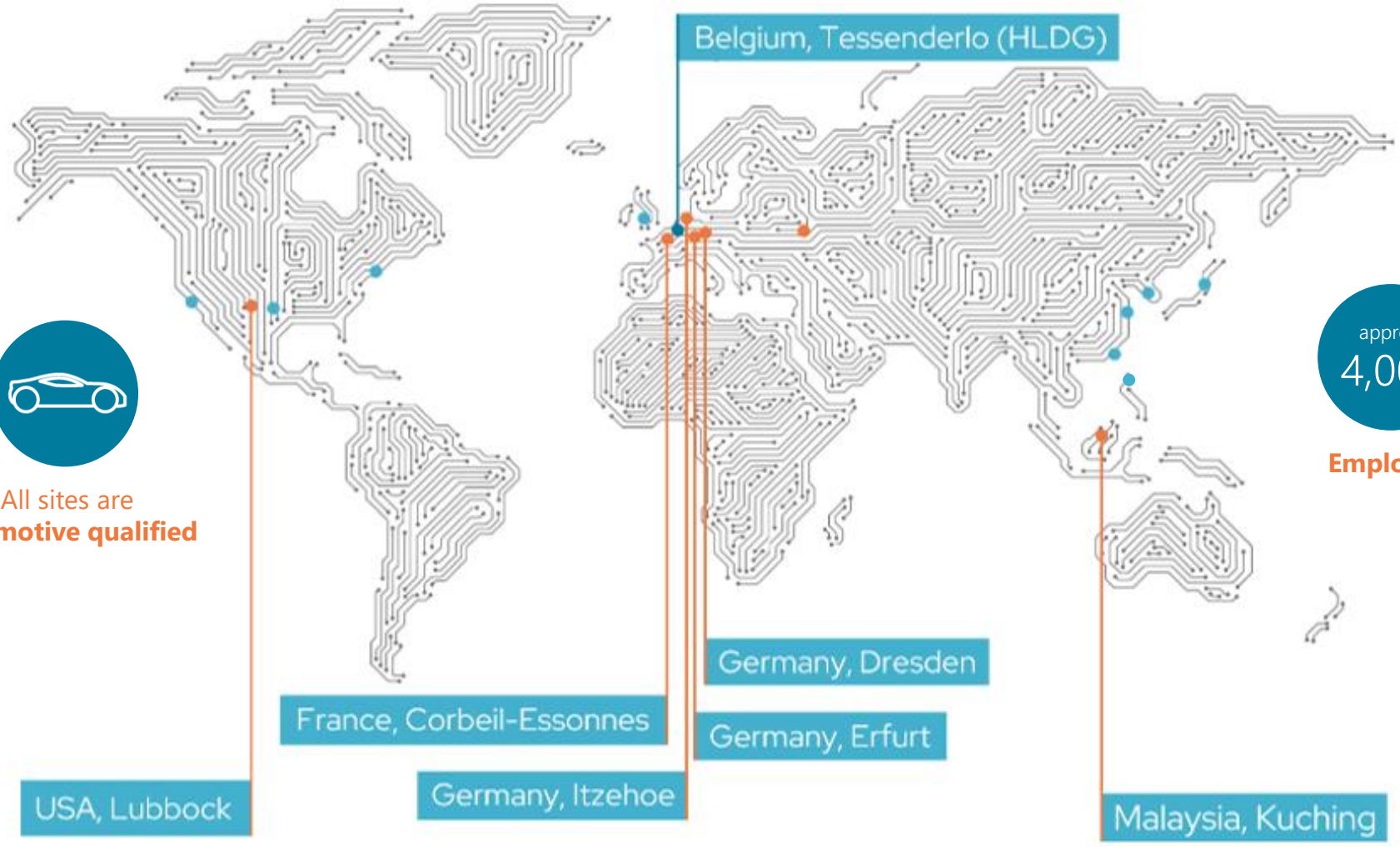


X-FAB at a Glance

6
Manufacturing facilities

All sites are **automotive qualified**

420
Customers in 4 key markets



100,000
Wafer starts per month*

approx. **4,000**
Employees

658 million $
Revenue 2021

Fabs/subsidiaries
Sales offices

*200mm equivalent

More than Making Chips

We think automotive.

X-FAB provides solutions for safe, efficient, comfortable and connected transportation.

- Electrification
- Improved safety
- ADAS
- Environmental protection
- Connected cars and services

We empower the future.

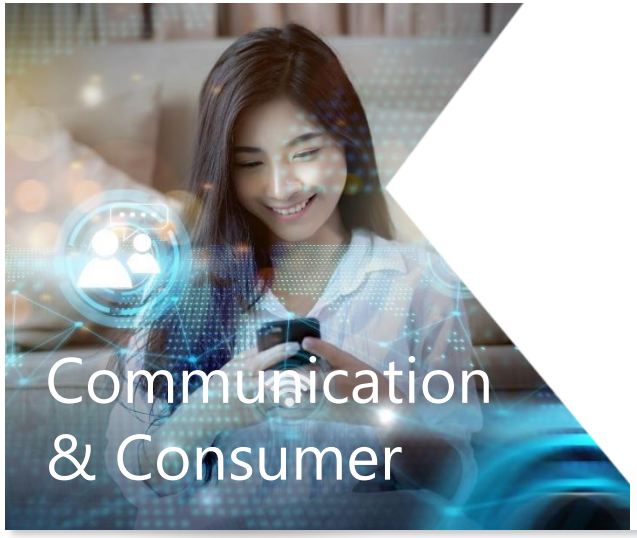
X-FAB enables next generation energy management and automation technologies.

- Power management
- Factory automation, Industry 4.0
- Intelligent drive & motor control
- Smart buildings and cities

We save lives.

X-FAB enables medical products for diagnostics, therapy and analysis.

- Personal medical devices
- Medical equipment
- Lab-on-a-chip



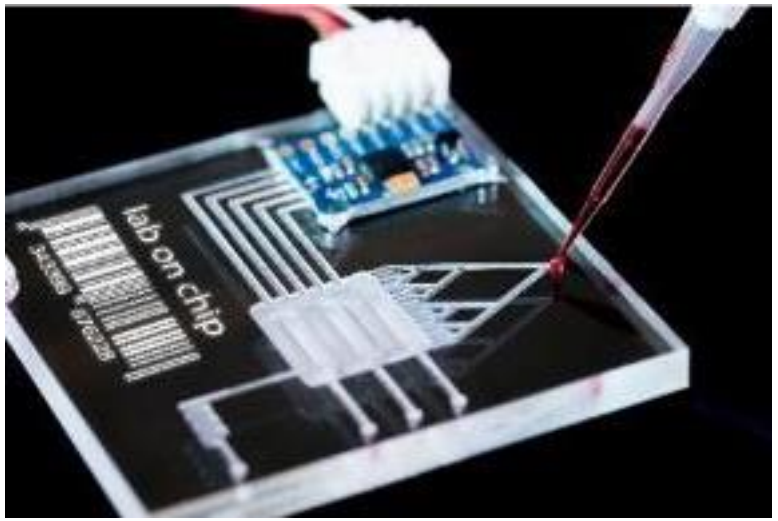
We connect people.

X-FAB technologies integrate seamlessly into your daily life.

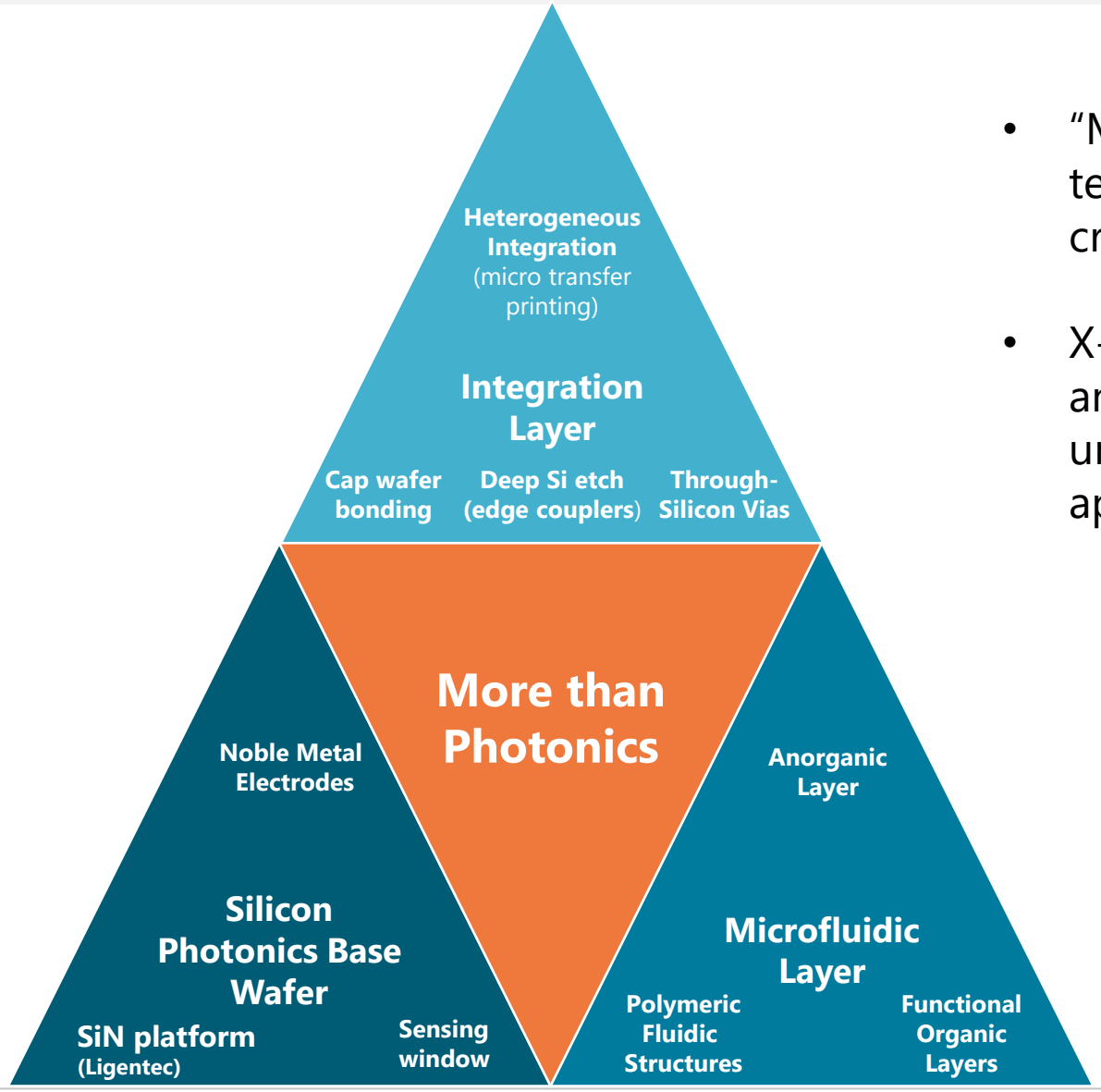
- Smart home
- Connectivity
- Communication
- Appliances and HVAC

X-FAB Photonics Activities Today

- X-FAB is working with multiple customers directly on a broad range of photonic platforms for different applications
  - **Extended CMOS with integrated SiN waveguide for visible light photonics**
    - Main application – biomedicine, lab-on-chip, DNA sequencing
    - Mass production in 2022 after 5 years of joined R&D
  - **Low-loss SiN passive photonics platform in cooperation with Ligentec**
    - Application-agnostic platform that is most suitable for quantum computing, sensing (LIDAR), biomedicine and telecommunication applications
    - Commercial and technical interface via **Ligentec (www.ligentec.com)**
  - **Silicon photonics platform**
    - NIR for close-range telecommunication applications, photonic interposer, biomedicine
    - Currently at feasibility stage, main building blocks/optical components
  - **Exotic materials integration for improved photonic performance**
  - **Microtransfer printing pilot line for heterogeneous integration**



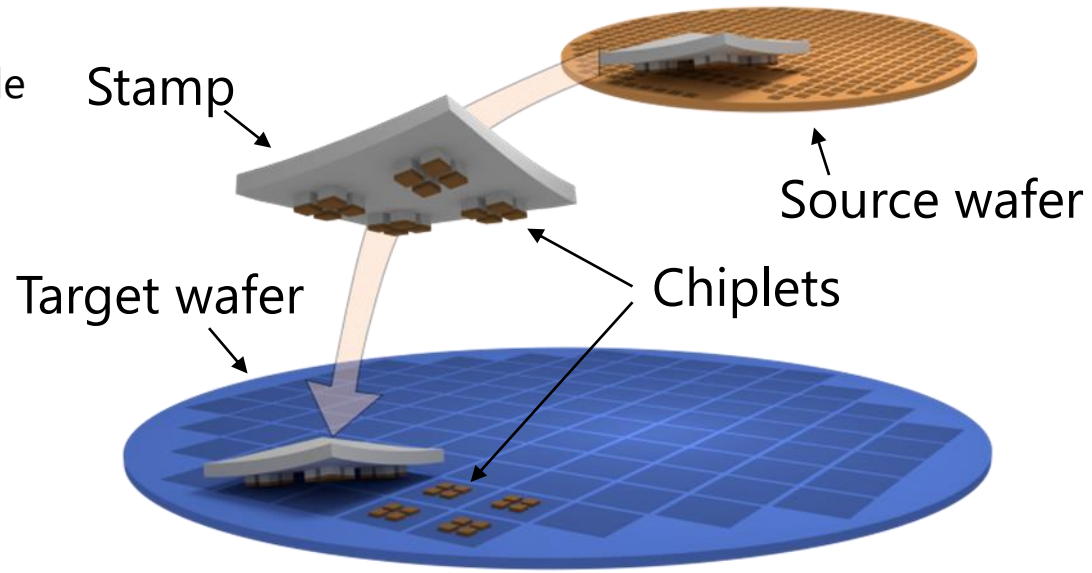
“More than Photonics“ – Enabling Photonics Sensing Solutions

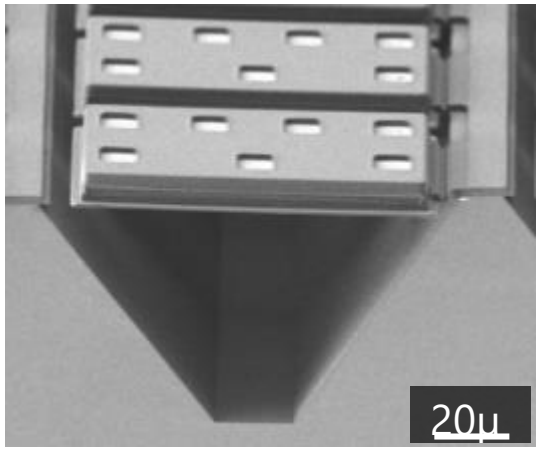


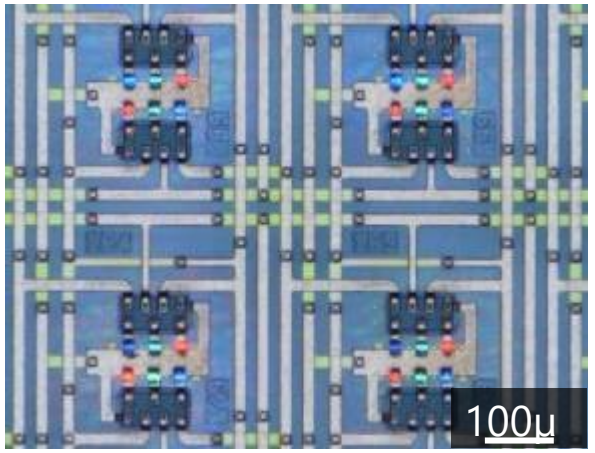
- “More than Photonics” solutions combine multiple technologies on top of the silicon photonics PIC to create innovative Photonic Sensing Solutions
- X-FAB has experience in heterogeneous integration and access to different technologies that enable a unique photonic platform solution tailored for specific applications requirements:
  - Micro Transfer-Printing
  - Noble metals for biofunctionalization
  - Functional layer deposition
  - Post-processing of photonic and hybrid wafers, including deep etching
  - 2.5/3D Integration
  - Integrated Microfluidics

Micro Transfer-Printing

- Massively-parallel pick-and-place wafer-level technology
  - Heterogeneous integration – multiple source wafer materials possible
  - Effective use of source material
  - High yield and alignment precision (below ±1.2um)
- Different source / target wafers for different applications, for example:
  - III-V chiplets transfer to CMOS/photonics wafer (ex. LED, SOA, PD)
  - Photonics chiplets transfer to CMOS wafer (ex. transceiver)
  - CMOS transfer to Photonics wafer (ex. laser driver)
- 200mm printing capabilities
- Electrical routing via RDL metallization, passivation

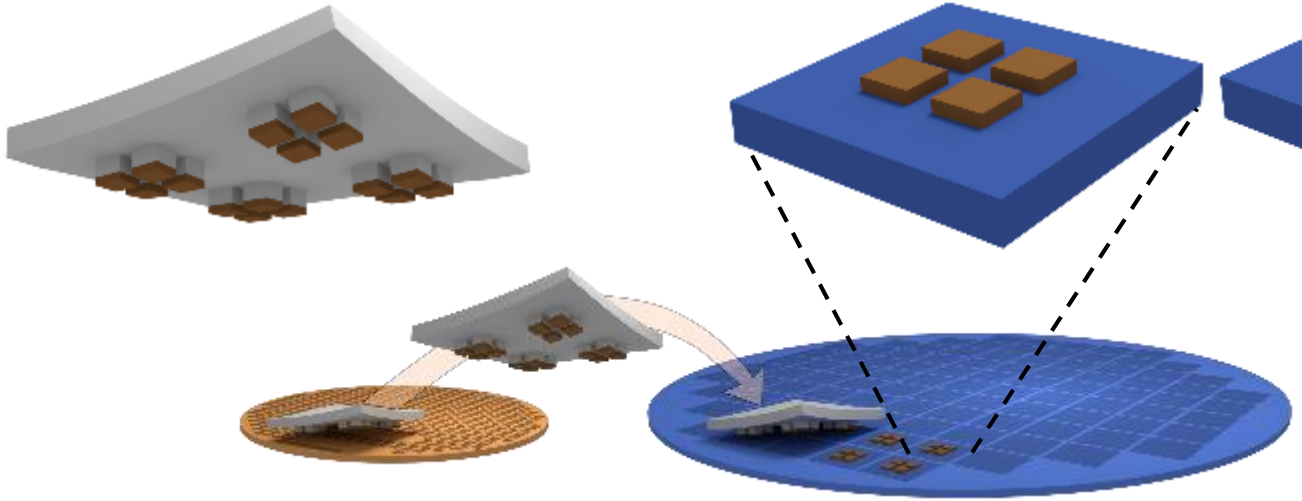






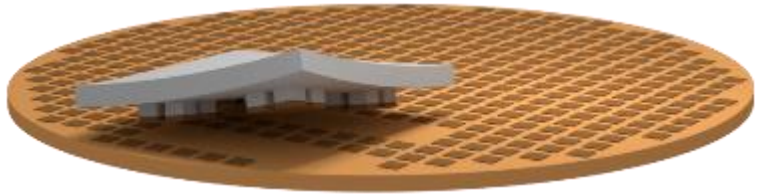
Motivation & Benefits of Transfer-Printing?

› Mass-transfer.

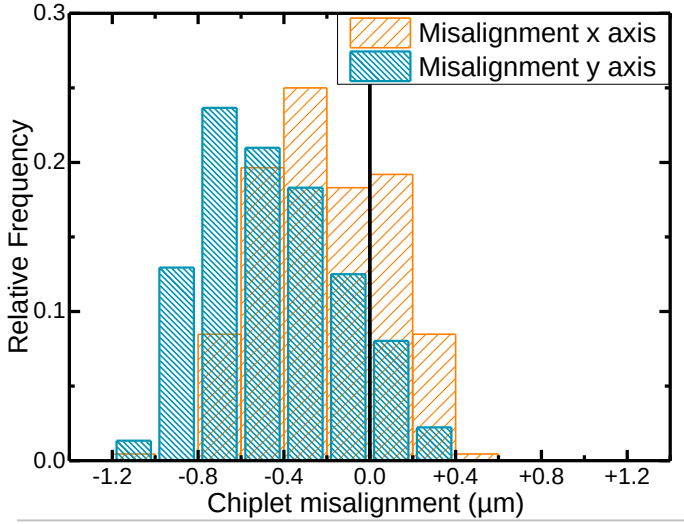


› Heterogeneous integration.

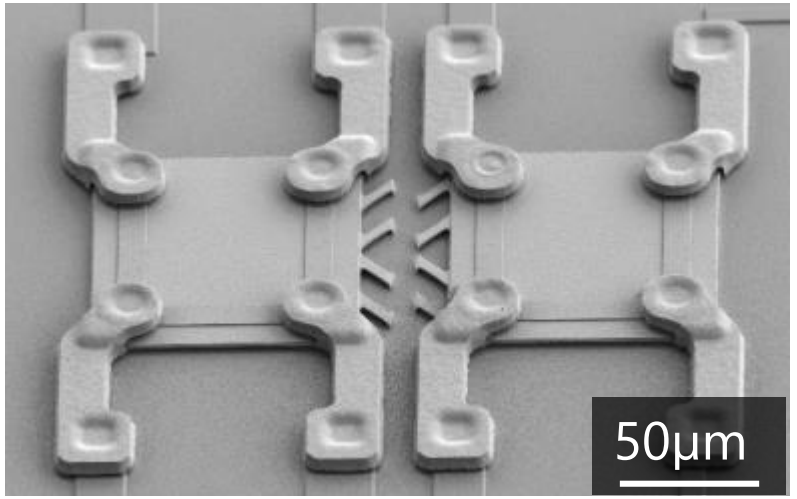
› Effective source utilization



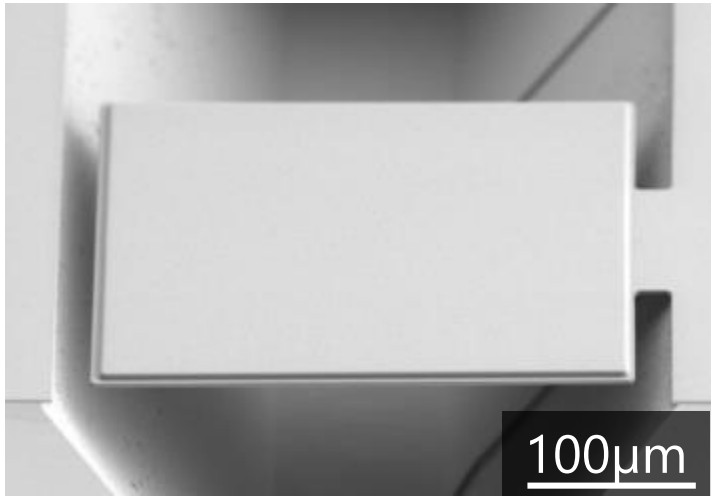
› High placement accuracy.



› Short metallization tracks.

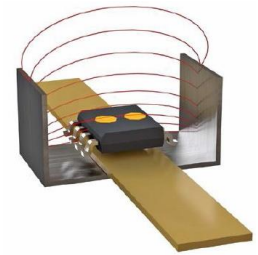


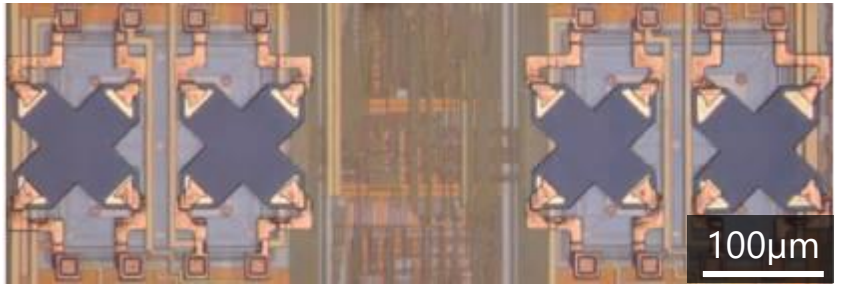
› Small & thin devices.



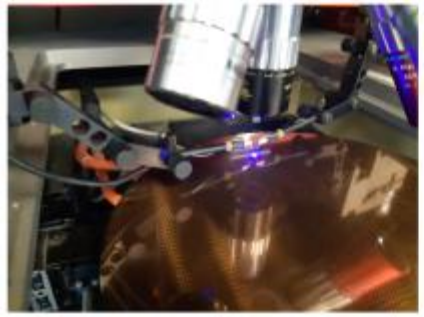
Micro Transfer-Printing Application Examples

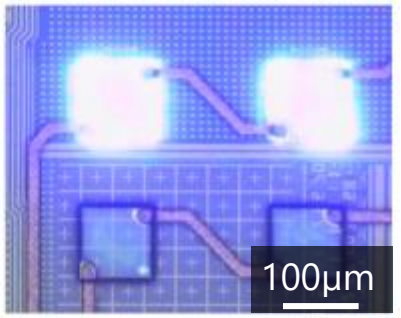
- Integration of GaAs and GaN on CMOS.
  - **GaAs** offers higher electron mobility and improved sensitivity of Hall Plate sensors compared to standard Si.



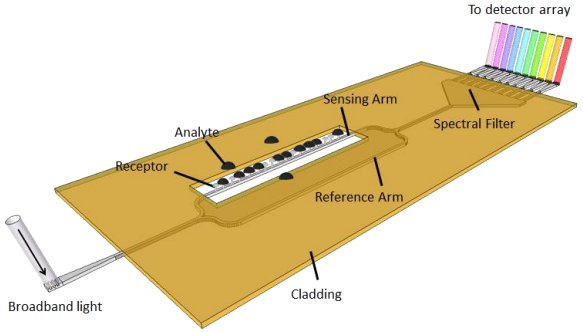


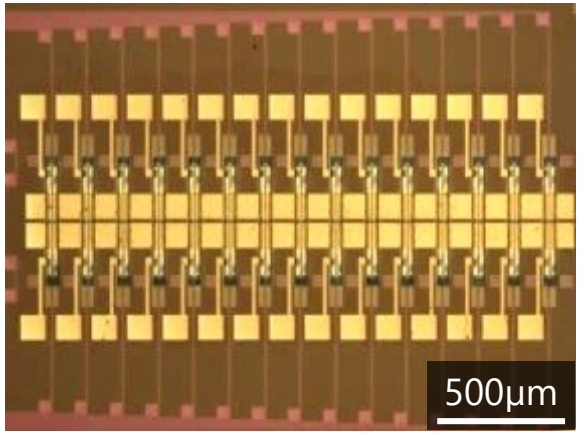
  - **GaN**: reduced package sizes by direct integration of LEDs on driver ICs .



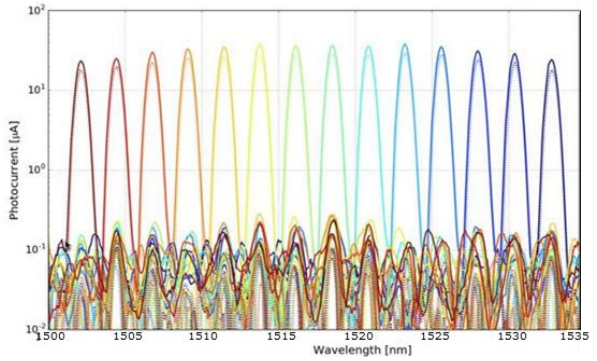


- Integration of InP photodiodes on waveguide circuits.
  - **InP**: Integration of active devices in Si waveguide circuits.

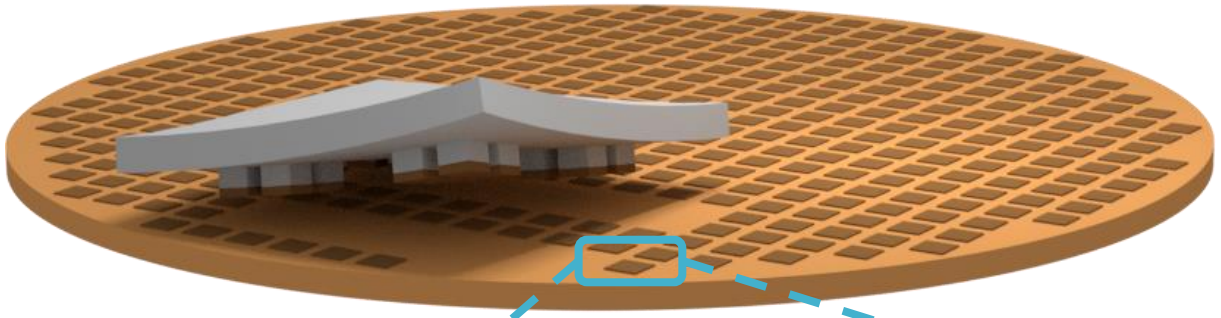




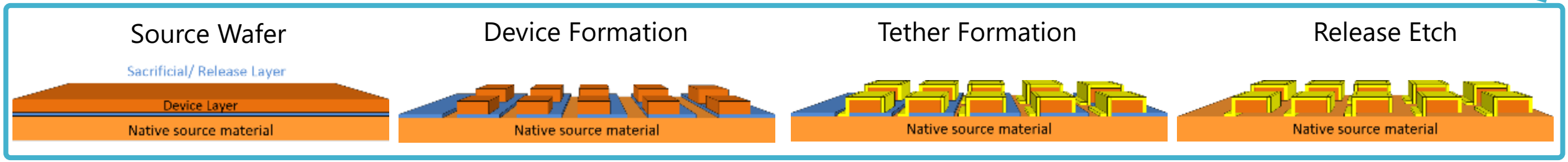
  - Cost and material efficient integration of devices.
  - Benefit of high alignment accuracy.



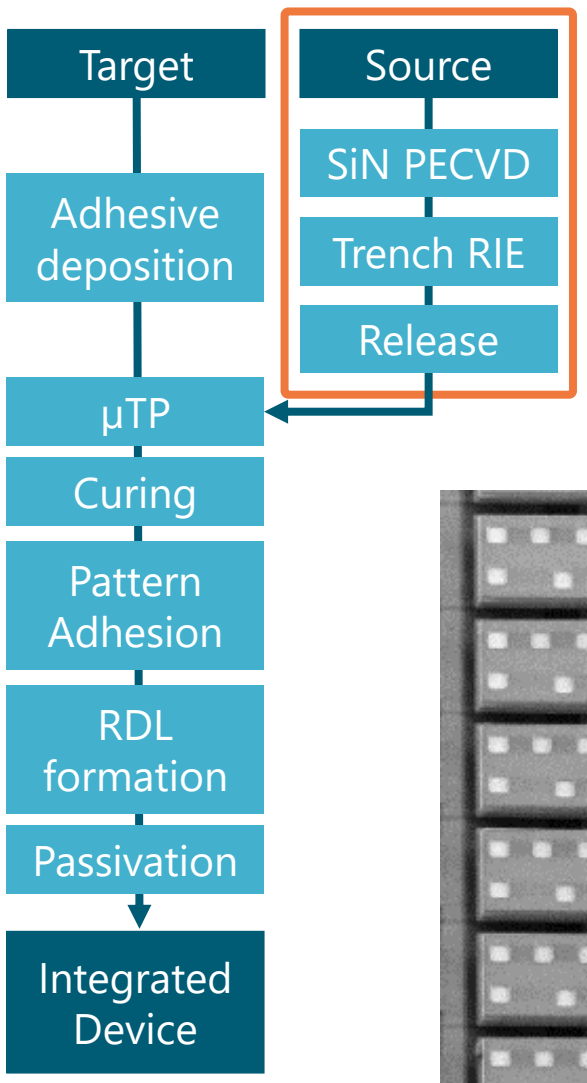
Transfer-printing: A generic process overview



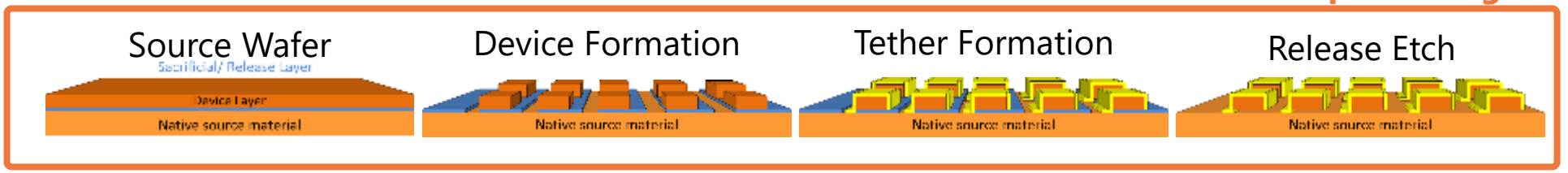
Source wafer/ print-ready processing



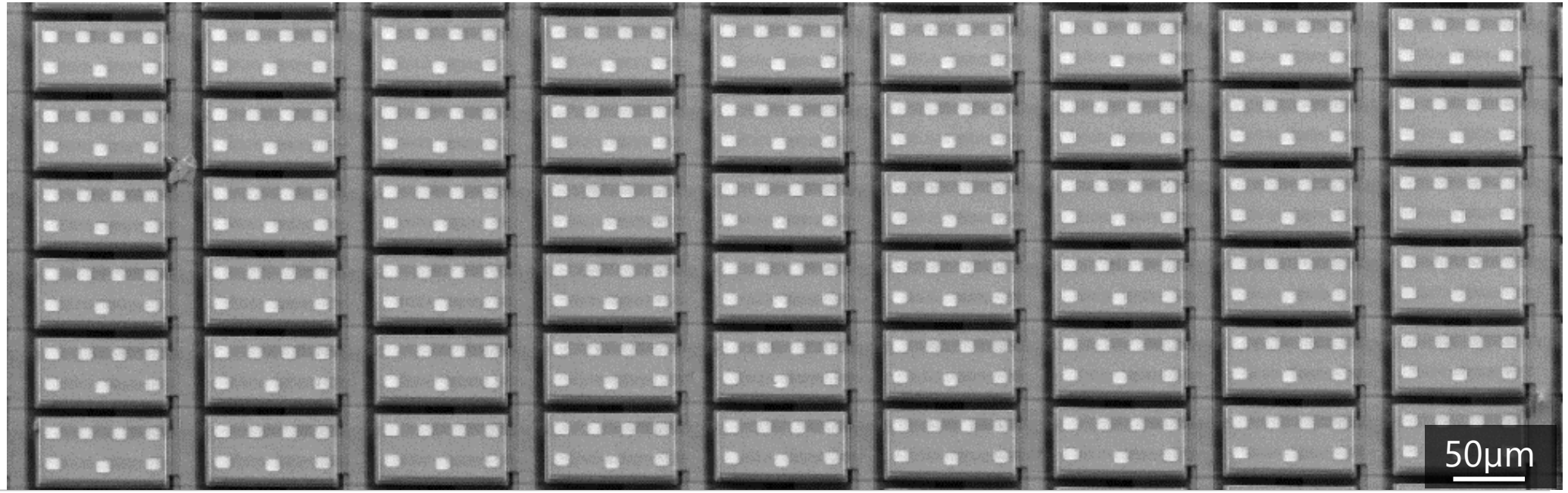
Print-ready CMOS ASICs



Source wafer processing



- 1st approach focuses on the development of „integrateable“/ „print-ready SOI ASICs.
- The CMOS wafer acts as the source wafer for µTP (origin of integrated chiplets).
- SOI (Silicon On Insulator) based technologies are applied.



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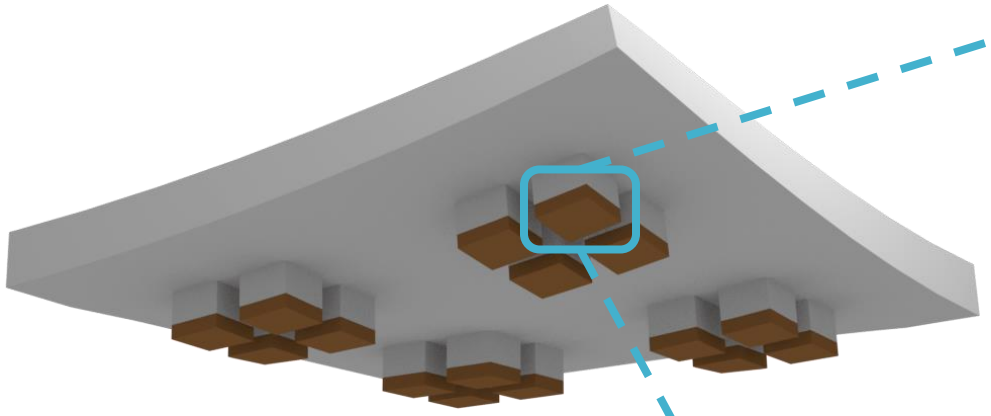
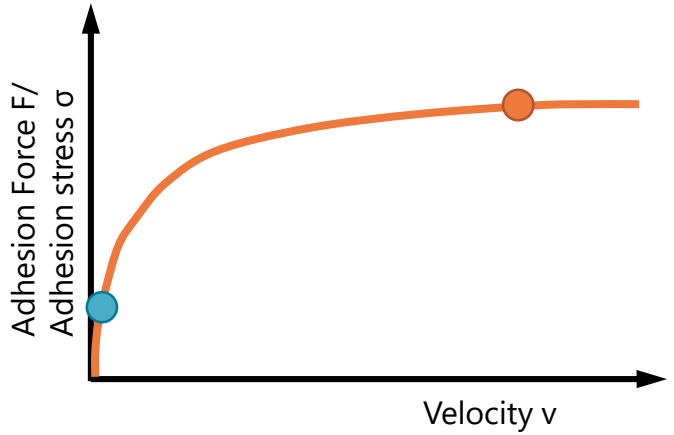
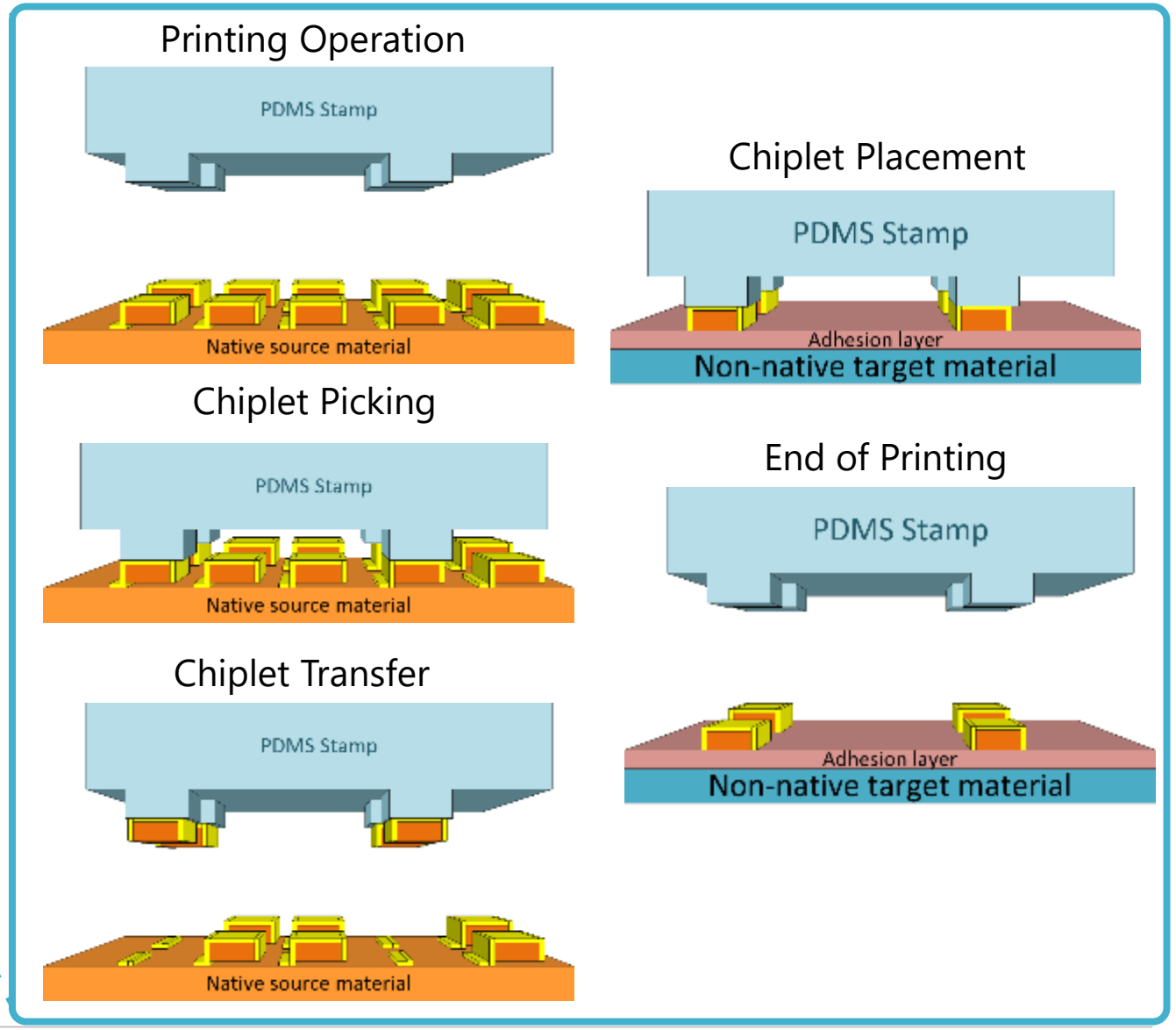


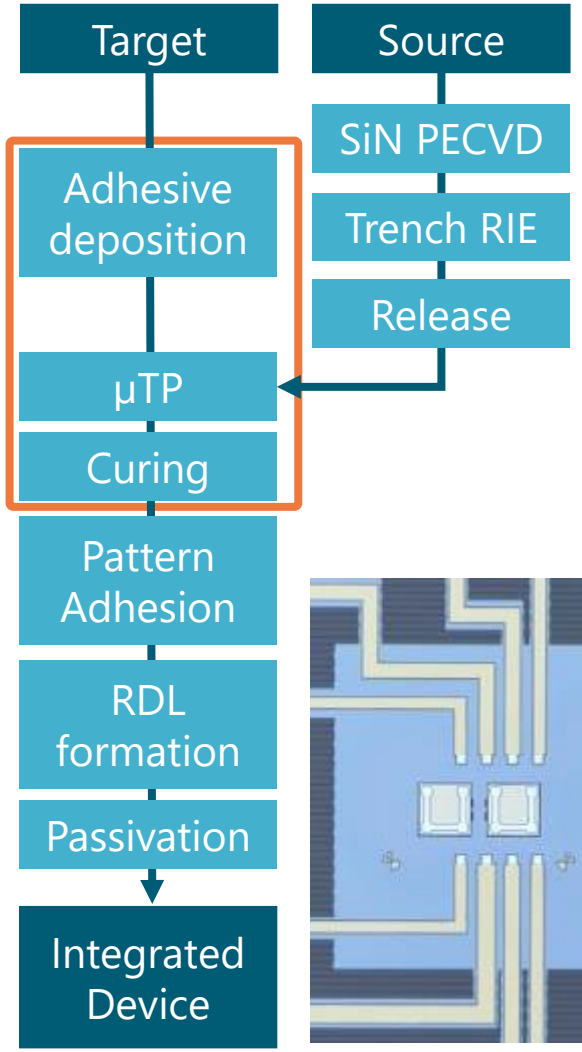
Transfer-printing



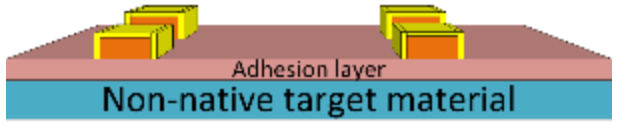


Heterogeneous Integration flow: Transfer-printing

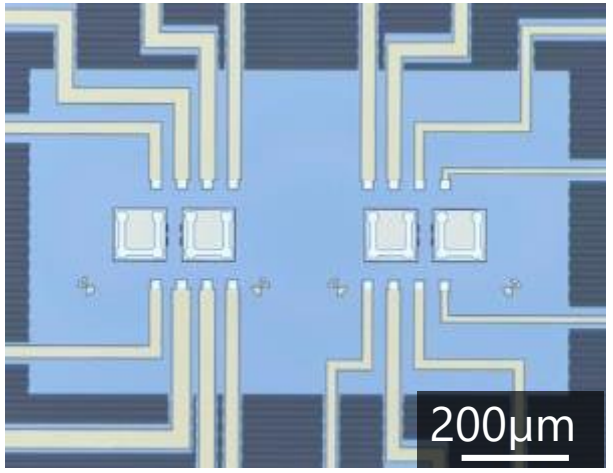
Transfer-printing

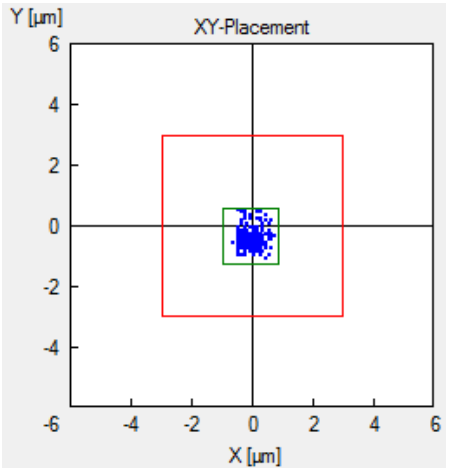


Target cleaning → Adhesive deposition → µTP → Adhesive cure → Metrology



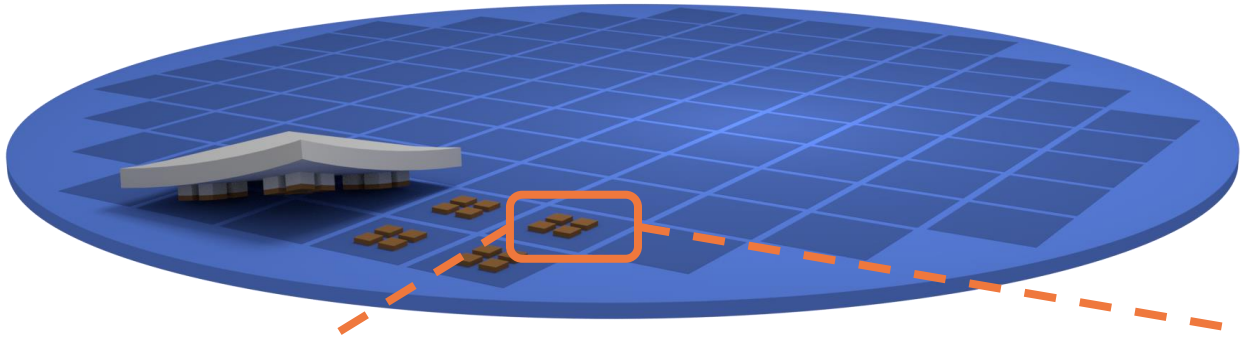
- Relevant parameters/ processes:
  - Print adhesive deposition & cure.
  - PDMS stamp modification.
  - Tool parameters like overdrive & sheer length.
- Based on µTP integration yields > 99.9% with accuracies of 3σ≤0.9µm were demonstrated.



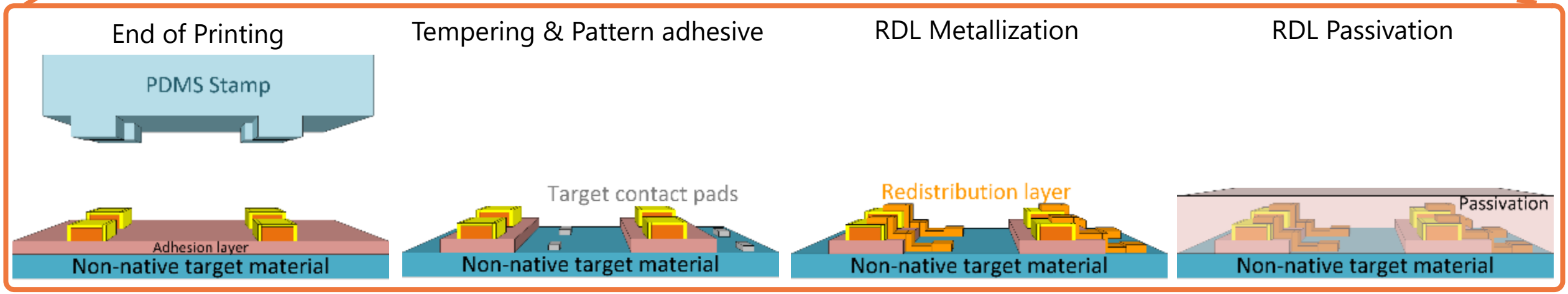


Si based chiplets	
Dimensions	100µm x 100µm x 2µm
Release yield	Up to 100%
Print Yield	>99.9%
Accuracy (after print)	σ≤0.3µm / 3σ≤0.9µm
Accuracy (after cure)	σ≤0.3µm / 3σ≤0.9µm

Transfer-printing: A generic process overview

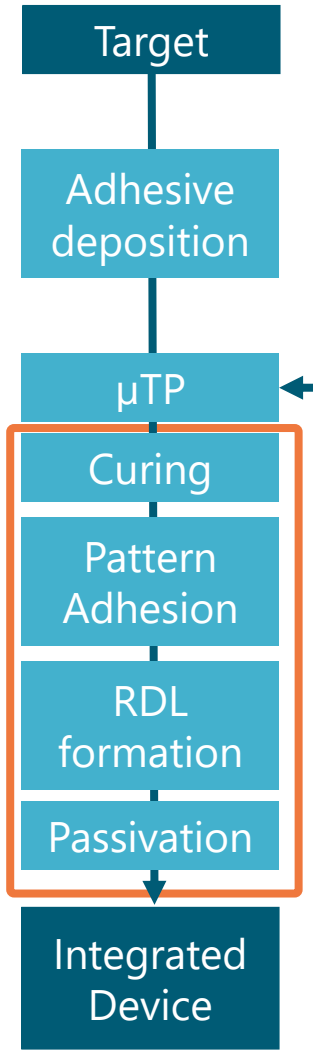


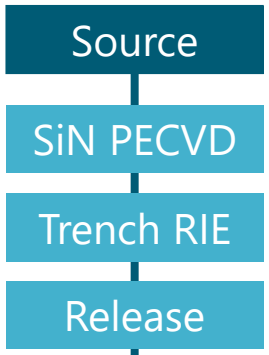
Post-processing

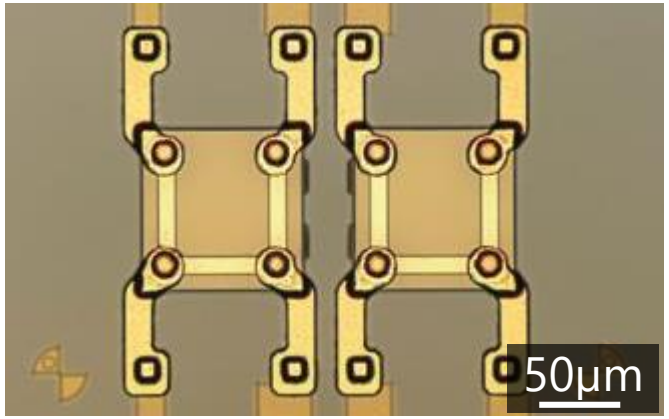


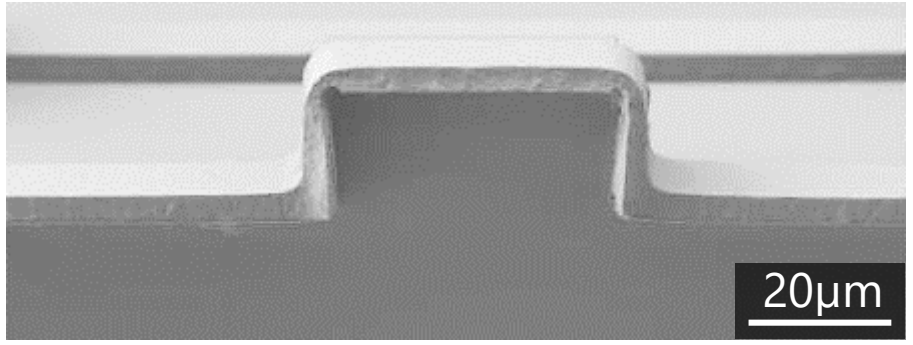
Heterogeneous Integration flow: Post processing

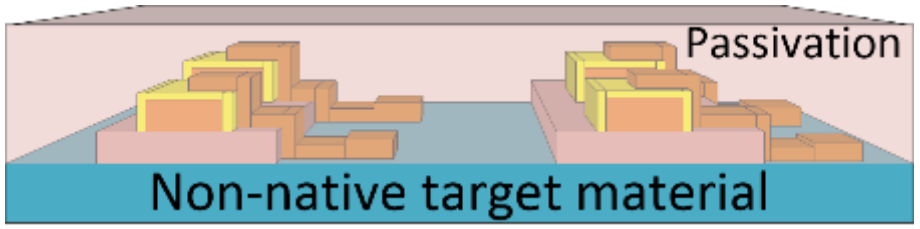
Post-processing



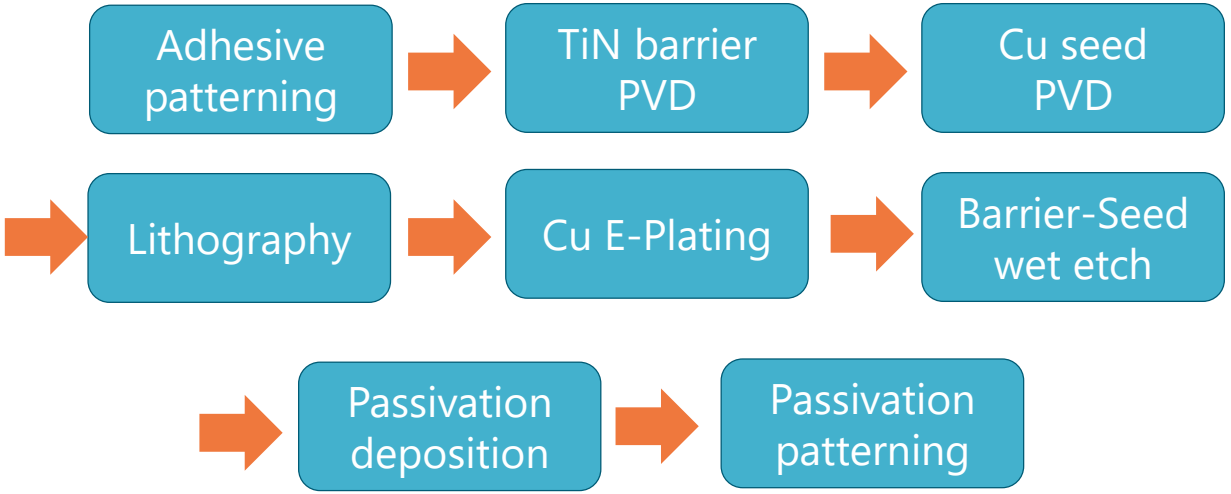








- After µTP the **target pads** are **opened** by RIE.
- **Cu-plating** is used to contact the chiplets.
- 15µm wide Cu-RDL lines can be formed for **chiplet heights** in the range of **2-18µm**.
- Finally, the RDL is passivated with the polymeric adhesion layer.

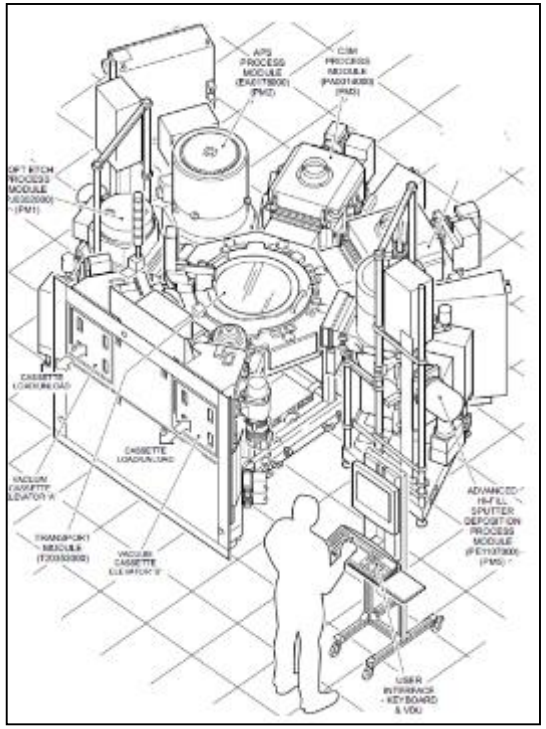


Realization at X-FAB: Transfer-Printing pilot line

Pilot line for µTP at X-FAB

- The pilot line was installed until 2018 within the funded project MICROPRINCE and includes:

SPTS Sigma fxP cluster
RIE, PECVD & sputter



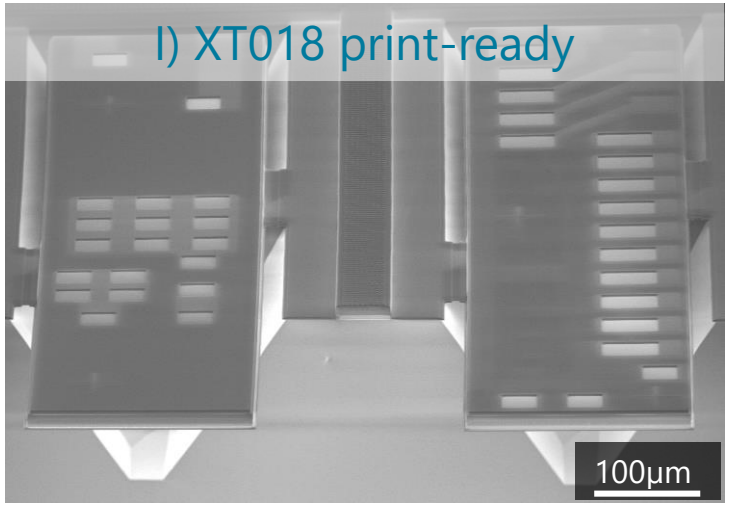
X-Celeprint MTP-177
Transfer-Printer

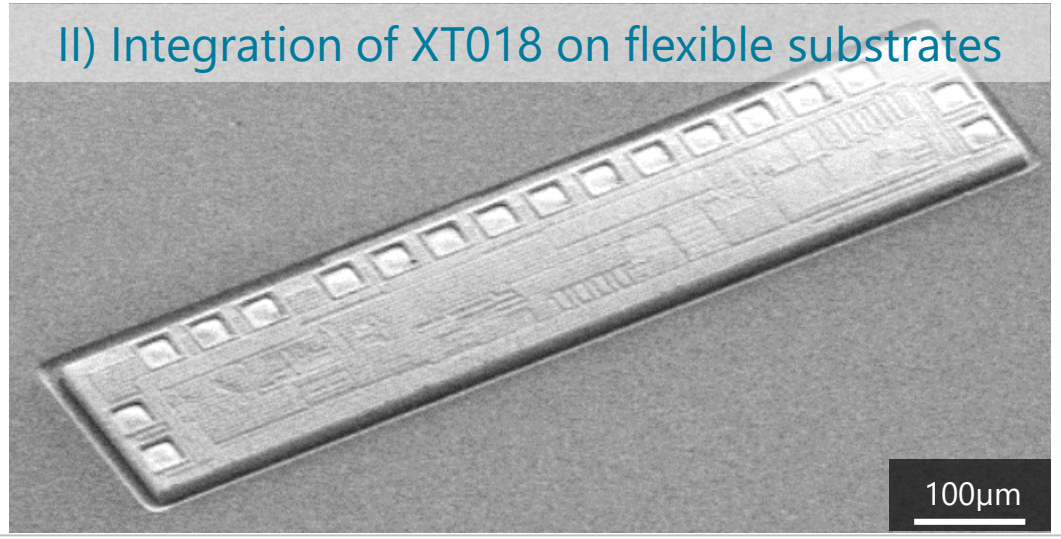
Suess ACS 200
Coater Developer

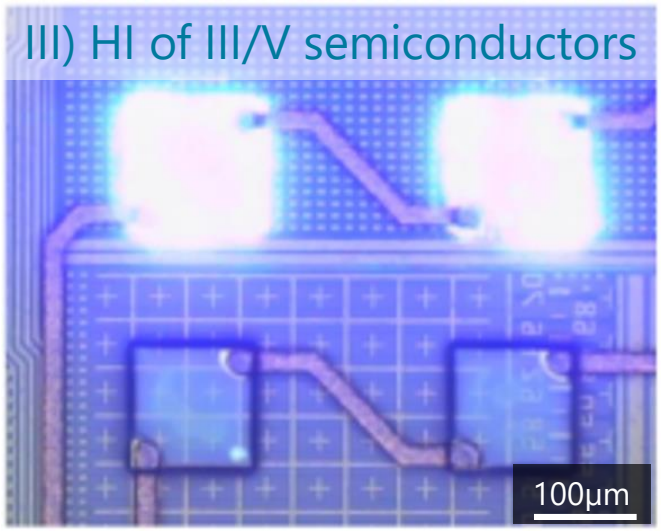
ClassOne Solstice S8
Plating Tool

µTP Roadmap

Capability	Available	2022	2023	2024	2025	>>
Micro-Transfer-Printing (µTP) Roadmap	µTP capability for Prototyping of X-FAB manufactured SOI based chiplets	XT018 Print-Ready for µTP		XT011 Print-Ready for µTP		
		Heterogeneous integration of XT018 ASICs on flexible substrates				
			µTP for RF with GaN on Si			
				heterogeneous integration of III/V devices for sensors, photonics. LED and RF applications		







Summary

- X-Fab “More than Photonics” solutions enable a wide range of photonic applications
- “More than Photonics” offering includes a range of solutions for wafer-level system integration and packaging solutions
- Micro-Transfer-Printing is a promising novel technology for heterogeneous integration of photonics and other devices
- Noble Metal and Integrated Microfluidics capabilities complement the offer, especially for bio-medical applications
- X-Fab is the **high-volume manufacturing partner** for Ligentec’s low loss SiN PIC technology

xfab

Thank you.

www.xfab.com