“More than Photonics solutions”: Enabling SiPho for high volume manufacturing: Print Ready Source wafers for Micro Transfer Printing

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Joni Mellin, X-FAB Group

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Fraunhofer IZM, Berlin June 4th , 2024

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X-FAB at a glance

A pureplay specialty foundry with six manufacturing sites in Germany, France, Malaysia and the USA – all of them automotive-qualified – we serve more than 400 customers worldwide.

Tessenderlo, Belgium (HLDG)

Lubbock, USA

Kuching, Malaysia

Corbeil-Essonnes, France

Dresden, Germany

Itzehoe, Germany

Erfurt, Germany

907m$

revenue in 2023

~4,500

employees representing 45 nationalities

400+

customers worldwide

*200mm equivalent

● Fabs/subsidiaries ● Sales offices ● Sites with photonics activities

Our fabs worldwide

	Kuching MY	**Erfurt GER**	**Dresden GER**	**Itzehoe GER**	**Corbeil FRA**	**Lubbock USA**
Process focus	CMOS BCD-on-SOI PECVD SIN Photonics	CMOS, MEMS & HI, BiCMOS, SOI, Photonics HI & MEMS, Microfluidics, TSV	CMOS, GaN-on-Si	MEMS	CMOS, BCD-on-SOI, RF-SOI, Photonics	SiC, CMOS, BiCMOS
Wafer size	8"	6" for CMOS, 6" + 8" for MEMS	8"	8"	8"	6"
Main nodes	350 nm 180 nm	1.0 µm 0.8 µm 0.6 µm	0.6 µm 350 nm	n/a	180 nm 130 nm 110 nm 90 nm	1.0 µm 0.8 µm 0.6 µm

X-FAB Photonics at a glance

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X-FAB Photonic offers innovative process technologies, professional engineering service and quality-driven manufacturing excellence to scale your product from prototypes to the volume market:

- Heterogenous integration optimized thin SOI photonics platform for datacom, telecom and sensing applications
- PECVD SiN platform on opto-CMOS for biosensing
- High volume manufacturing backbone for Ligentec's ultra low loss SiN platforms
- "More than Photonics" enhancements with micro transfer printing of III-V, LNOI, Ge, electronic chiplets, microfluidics, advanced materials and 2.5D/3D integration
- Micro transfer print ready 180nm SOI, 130nm RF SOI and 110nm SOI for driver ICs, ROICs and RF connectivity chiplets

Enabling photonics for high volume

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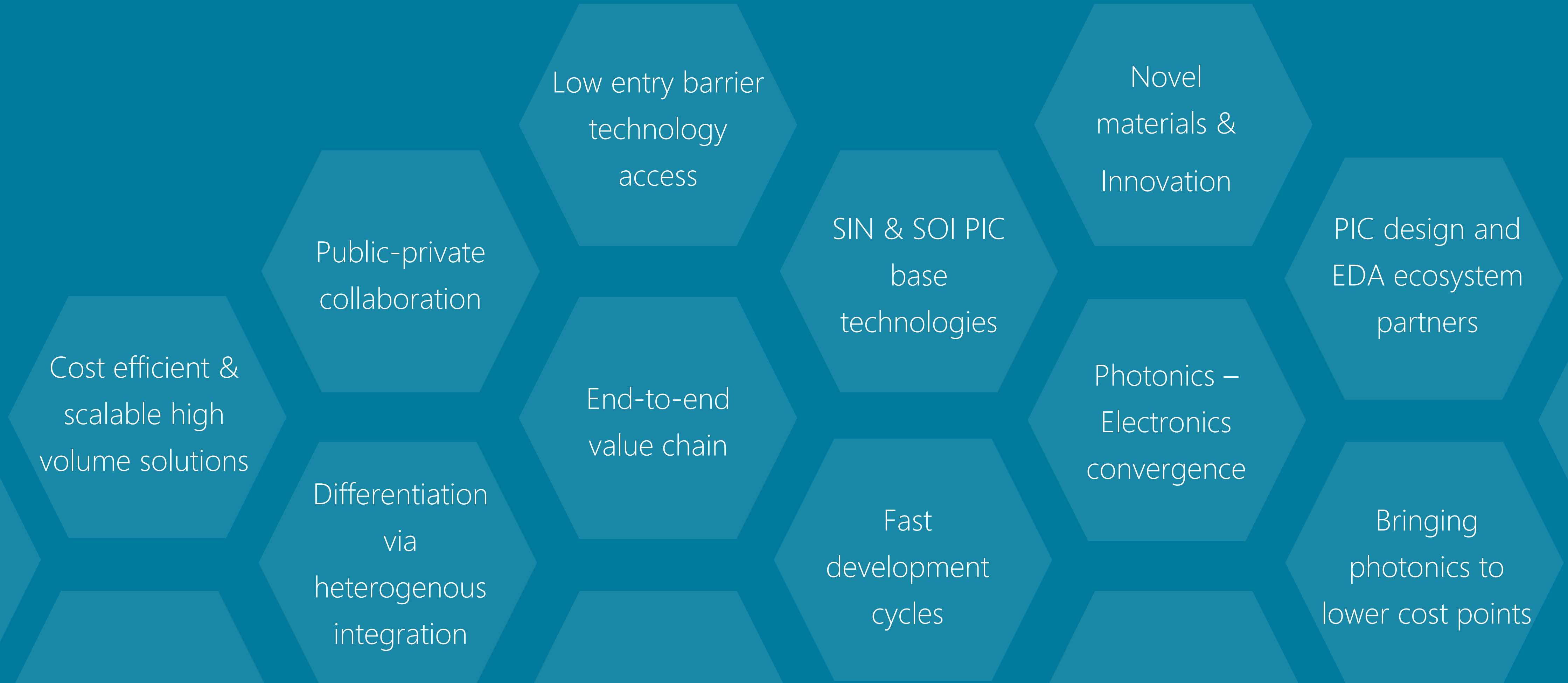

Applications enabled by silicon photonics technologies

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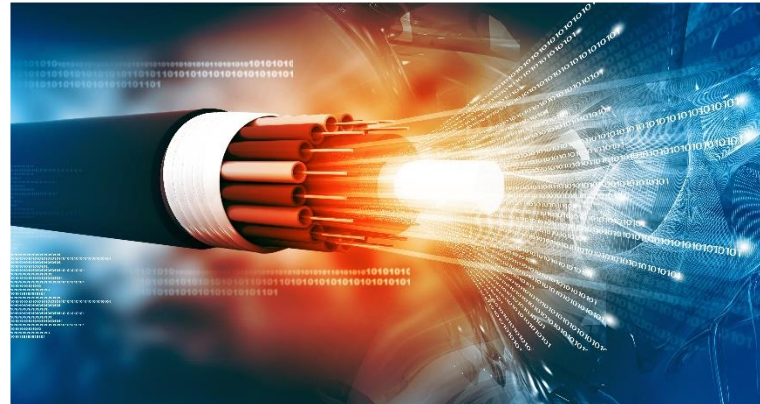
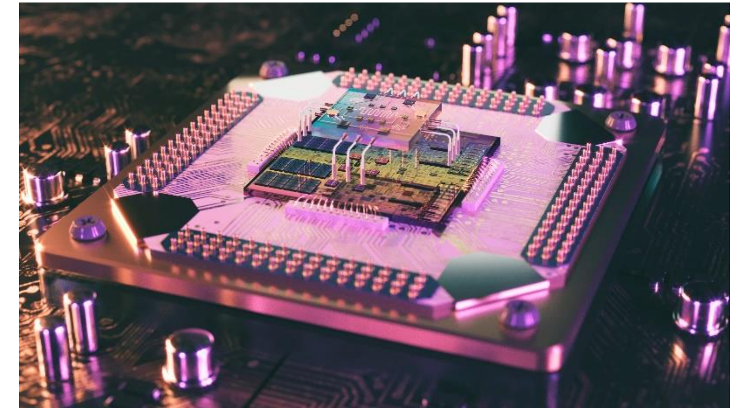
Datacom, AI and computing

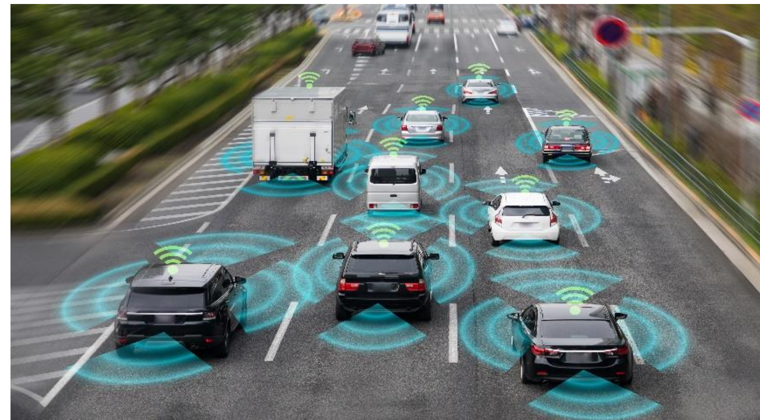


Telecom



Quantum computing & technologies

Biomedical, life sciences, lab-on-chip



Automotive, PIC enhanced LIDAR

AR/VR, industrial and environmental sensors

Silicon Photonics platforms at X-FAB

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- **Ligentec low loss SiN platform**
- Open market foundry through Ligentec
- XFAB is the high volume manufacturer
- 150nm, 350nm and 800nm LPCVD SiN
- Ultra low propagation loss (<5dB per m)
- Visible to mid-IR wavelength
- High power applications (no two photon absorption, TPA)
- Low temperature sensitivity
- X-FAB France
- **Available now via Ligentec**

High performance SiN (150nm to 800nm, passive)

Thin (220nm) SiPho (active, passive)

- **SOI based silicon photonics**
- IMEC **iSiPP200 / XPH90 HI** platform
- 220nm Si on 2um BOX, 400nm SiN,193nm litho
- Compact components
- High speed active devices
- High efficiency grating based fibre couplers
- CU BEOL (inc. MIM, resistors) with RF models up to 67GHz
- X-FAB France
- Early prototyping via IMEC. High vol. at X-FAB
- **Early access: Q2'25**
- **Risk production & MPW prgm: Q4' 25**

- **Photonic Biosensor on CMOS**
- Monolithic CMOS integration
- Passive disposable biosensors
- PECVD nitride on 180nm/110nm 248nm litho
- Thin and thick waveguides
- Visible wavelength
- Low temperature sensitivity
- Integrated CIS, photodiodes, SPAD
- X-FAB Malaysia (Kuching)
- **Early access for custom programs**

Biosensing PECVD SiN (150nm/400nm active/passive)

More than Photonics

- **Photonics microsystems solutions**
- Heterogeneous integration with e.g. microtransfer printing and die-to-wafer of e.g. InP, LNOI, GaAs, Ge, **Si chiplets**. Also for alien PIC wafers
- 2.5/3D integration (TSV)
- Microfluifidic layers
- Biofunctionalization layers with noble metals (Au, Pt)
- XFAB BU Microsystems (Erfurt)
- **Available now for custom programs**

*: photonixFAB project

XPH90 220nm SOI passive/active HI optimized platform

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XFAB Passive SOI Photonics Platform – HI capabilities

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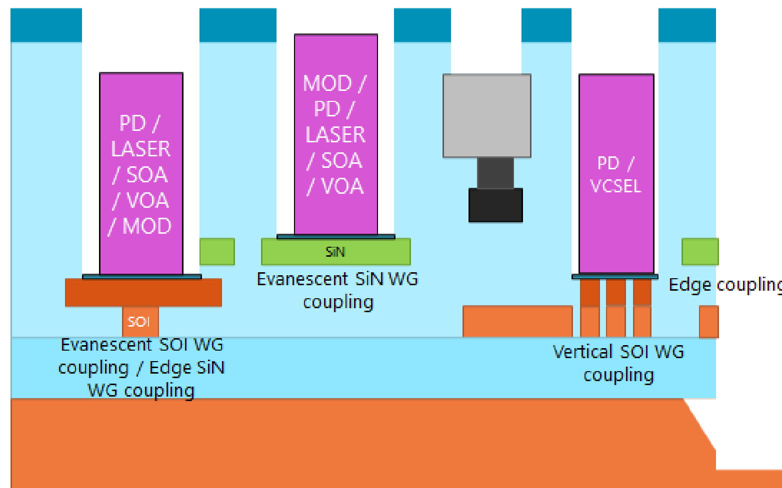
- Supported HI coupling:
  - Evanescent (high efficiency)
  - Vertical (high density)
  - Edge (external, exotic)
  - Others (incl. combination)
- Integration of passive and active devices:
  - Photonic chiplets
  - Couplers / lenses
  - Electronics



X-FAB Group Company Confidential 6

Key features

- HI platform for III-V, LNOI and Ge-PD chiplets
- 193nm litho (90nm process node) for CD
- WGSOI and WGSIN waveguides
- WGSOI with 3 etching levels: full and RIB
- SOI / SiN WGs – options for components n_r matching
- WGPOLY for selective etch and GC / EC / HI improvement
- OPTWIN for optical window
- 3 + 3 implant layers for Si pin-modulators
- Metal heater
- MTP – Al thick metal

- Cu BEOL (2 to 4 layers – RF characterized up to 67GHz)- Optional
- CS – deep etching for edge coupling and singulation
- UCUT – optional
- Ge-PD - Optional

Gained benefits

- High performance materials via HI
- Possibility of waveguides annealing – lower losses for both SOI and SiN
- Combination of Si and SiN high-performance waveguides – more options for coupling, design flexibility

Timeline

- Early prototyping (photonics) @ IMEC: Today
- Early technology access @ X-FAB: Q2 2025
- Risk production release: Q4 2025
- Production: Q4 2026

Micro Transfer-Printing

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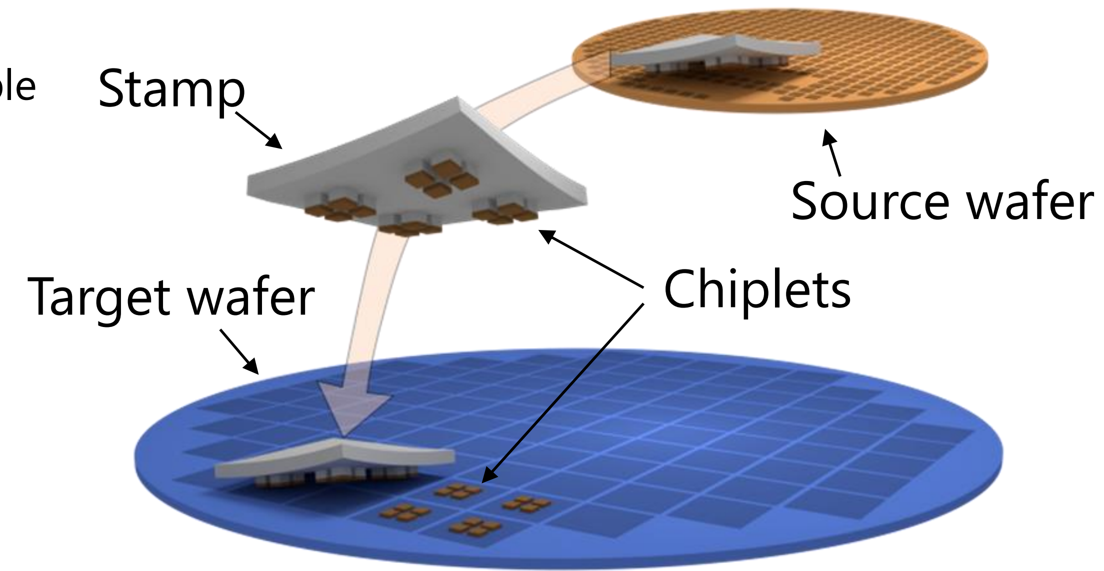
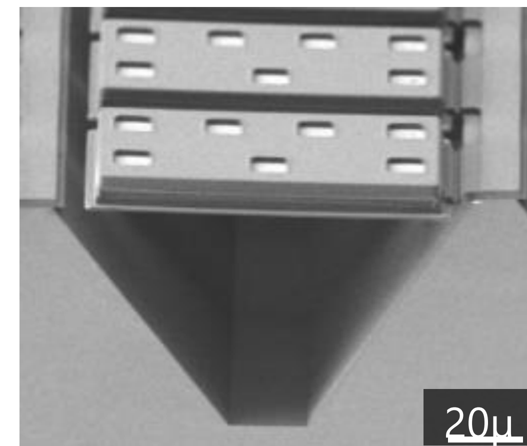
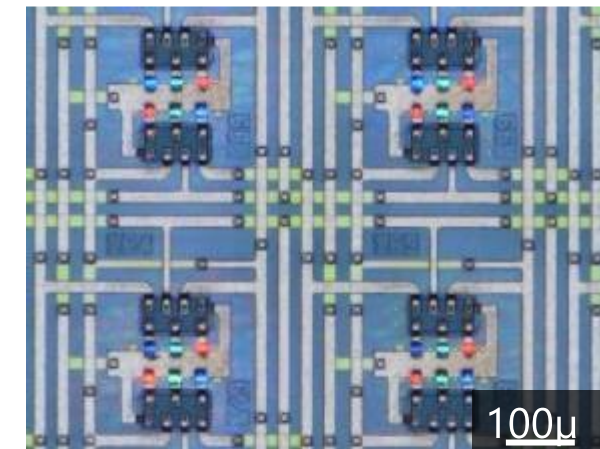
- Massively-parallel pick-and-place wafer-level technology
  - Heterogeneous integration – multiple source wafer materials possible
  - Effective use of source material
  - High yield and alignment precision (below ±1.2um) with capability upgrade to photonics requirements on-going
- Different source / 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







Benefits of Micro-Transfer Printing

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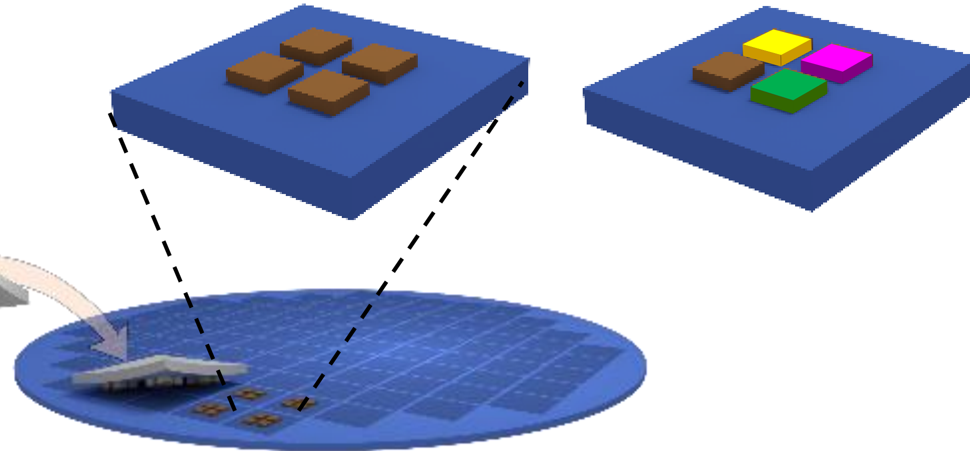
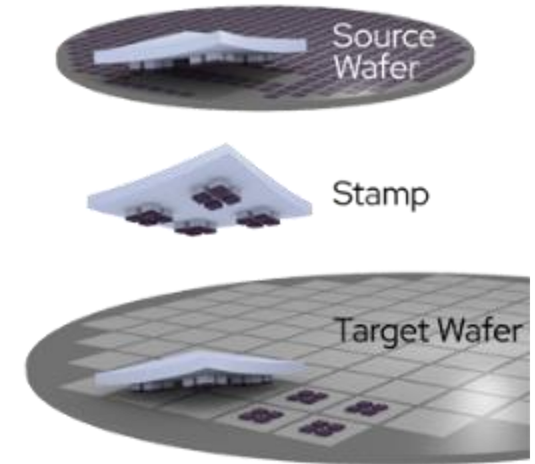
› **Mass-Transfer**

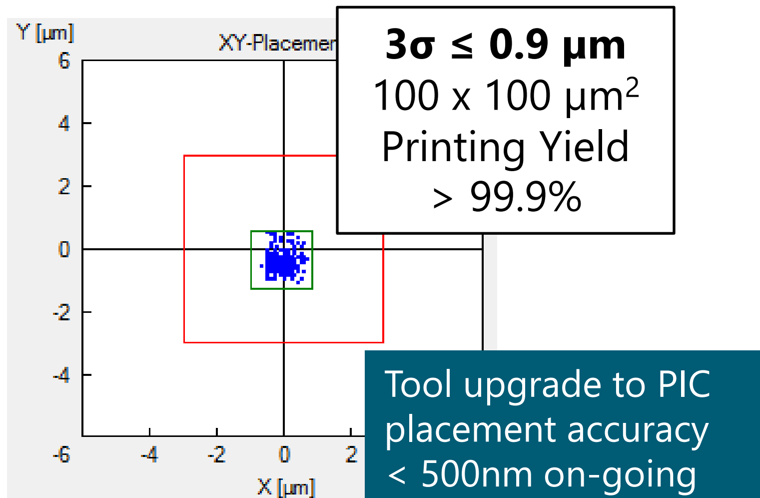
› **Heterogeneous Integration**



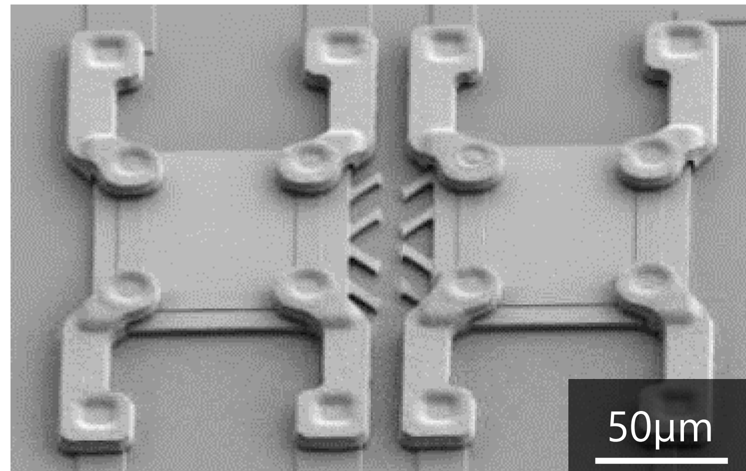
› **Effective Source Utilization**



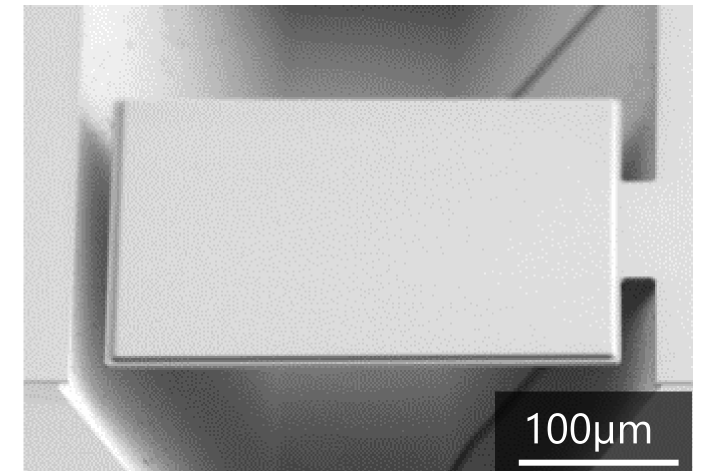
› **High Placement Accuracy**



› **Short Metallization Tracks**



› **Small & thin Devices**



Print-ready Source Wafer Preparation

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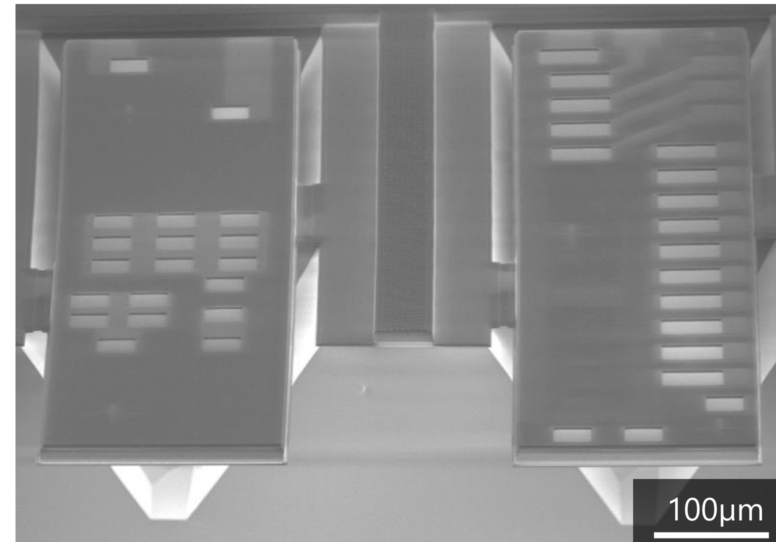
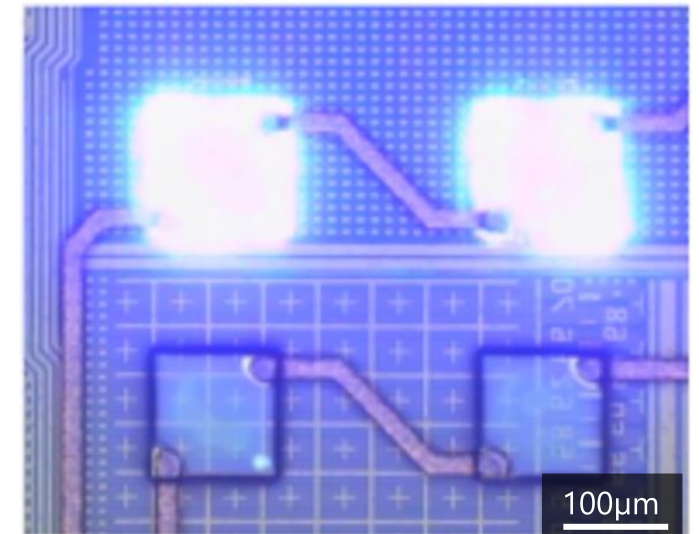
1. **Print-ready Source Wafer Preparation**
2. Printing Process
3. Post-Processing: RDL & Passivation

Print-ready SOI CMOS



Print-ready ASICs from 110 nm and 180 nm X-FAB SOI CMOS Technologies available

Print-ready III/V SCs



Improve the functionality or sensitivity by printing compound Semiconductors on CMOS Wafers.
→ Heterogeneous Integration

Micro-Transfer-Printing: Printing Process

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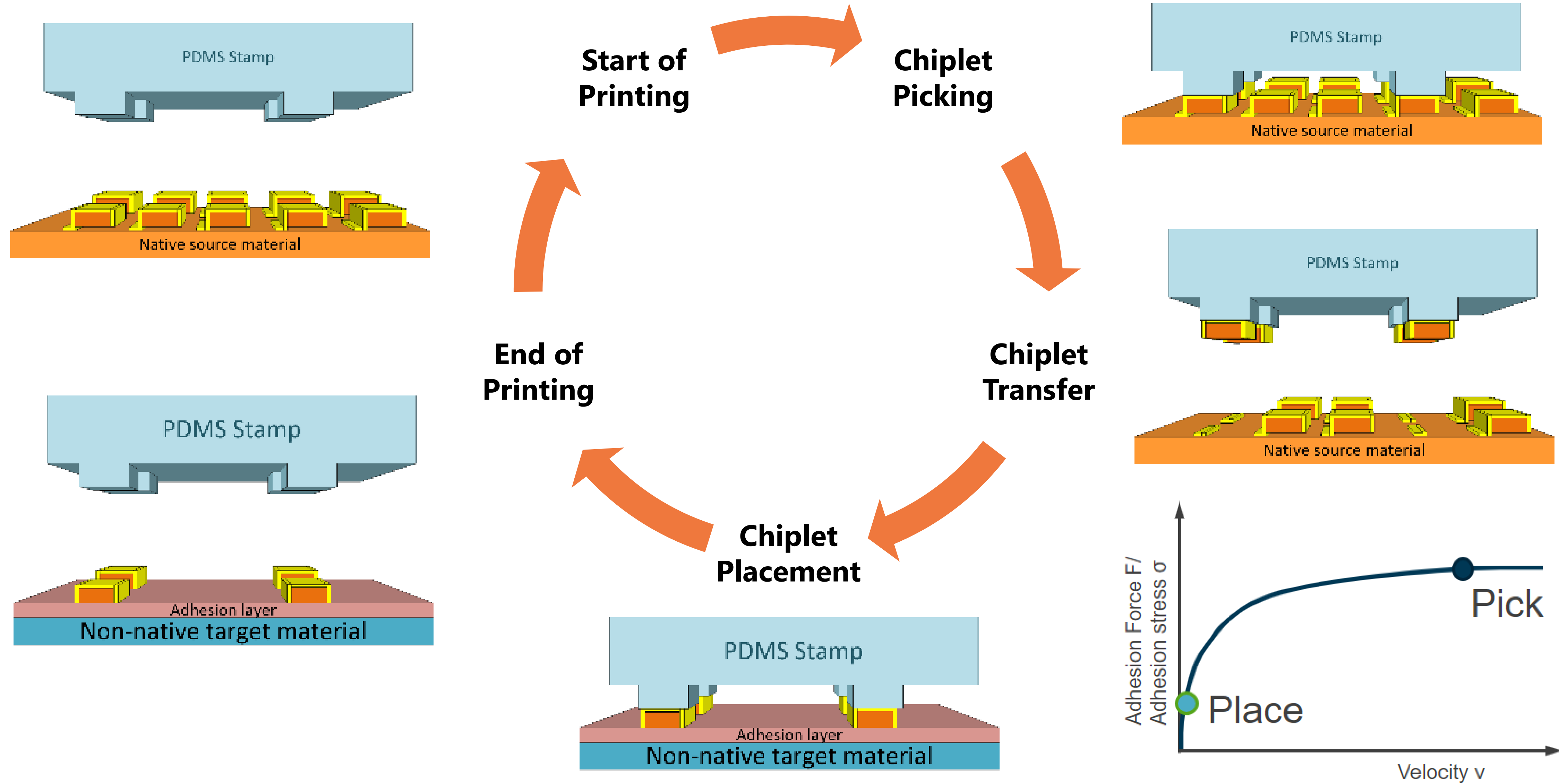

Source Wafer Fabrication

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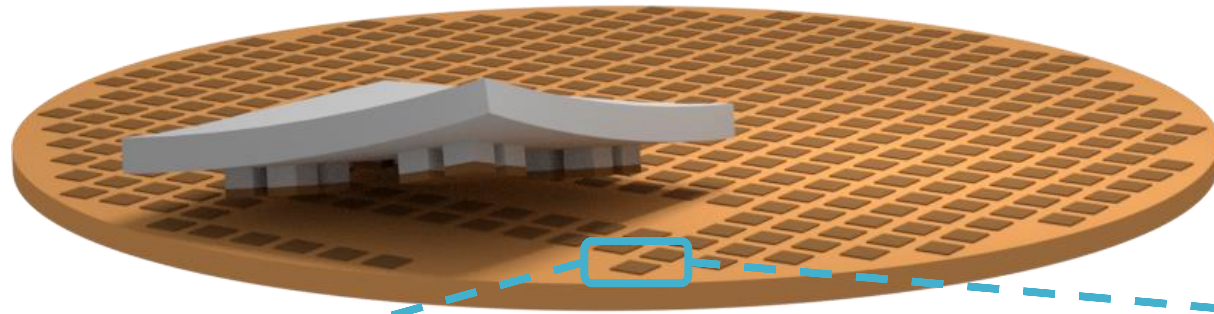
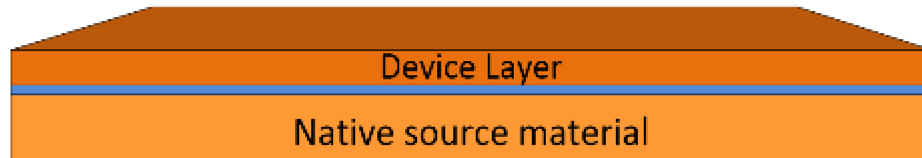
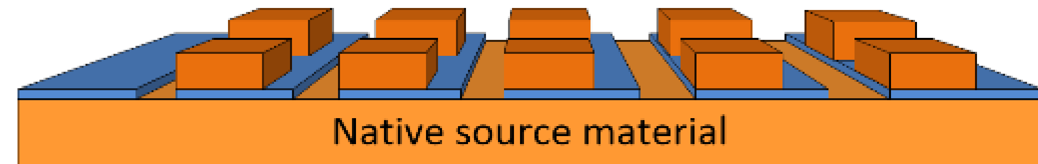


print-ready Source Wafer

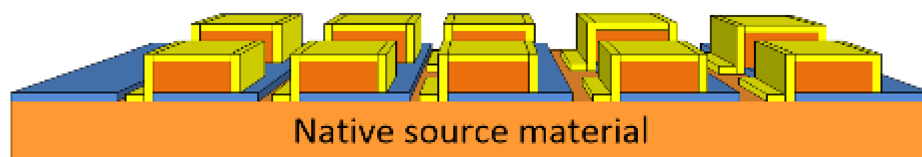
1. Source Wafer



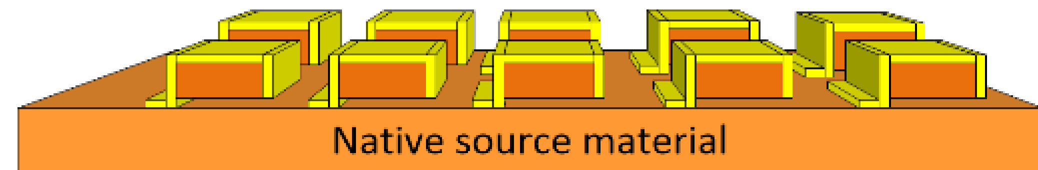
2. Device Formation



3. Tether Formation



4. Release Etch



Source Wafer Fabrication: SOI CMOS (part I)

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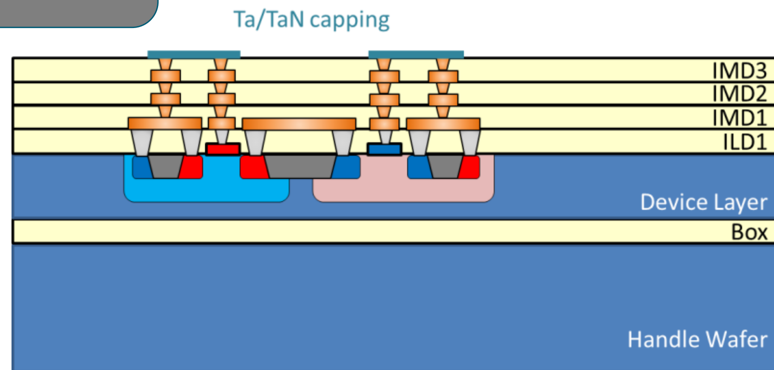
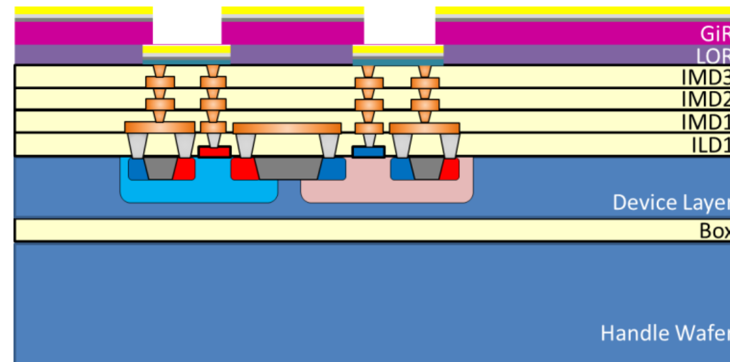
Pad Protection

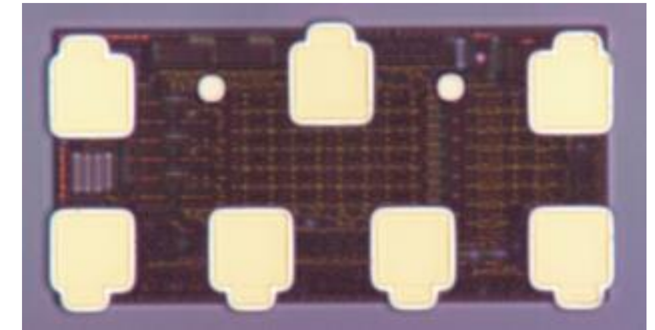
CMOS Wafer
110/180 nm X-FAB



Pad protection:
reliable CMOS protection

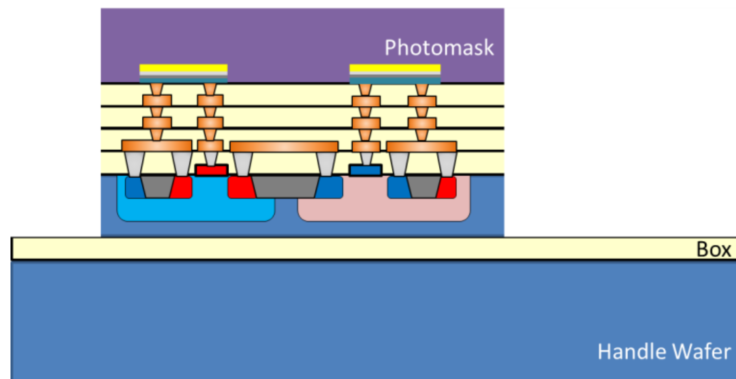


Noble Metal Deposition:
TaPtAu & lift-off

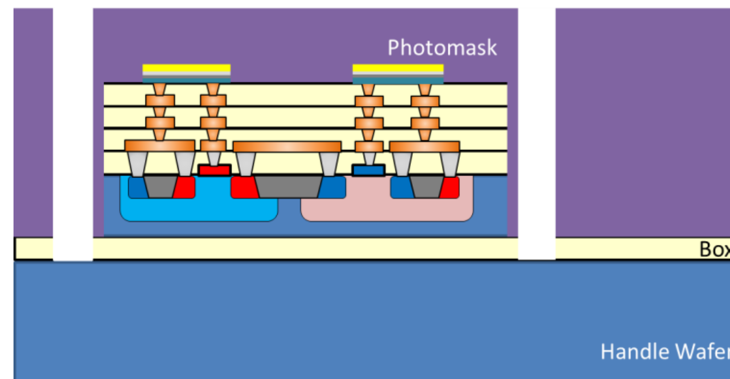


Chiplet Singulation

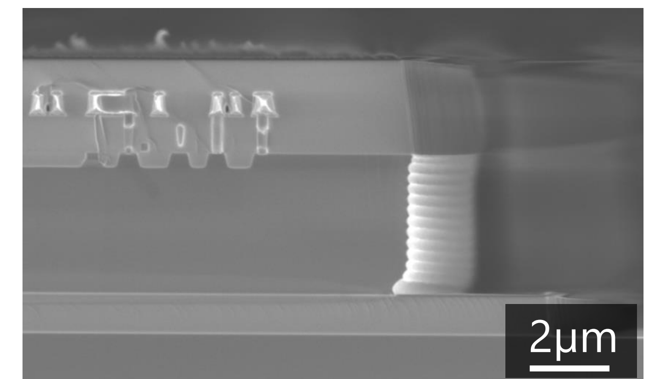
RIE BEOL & Si



RIE BOX



Dry Etching of Si and Dielectrics



Source Wafer Fabrication: SOI CMOS (part II)

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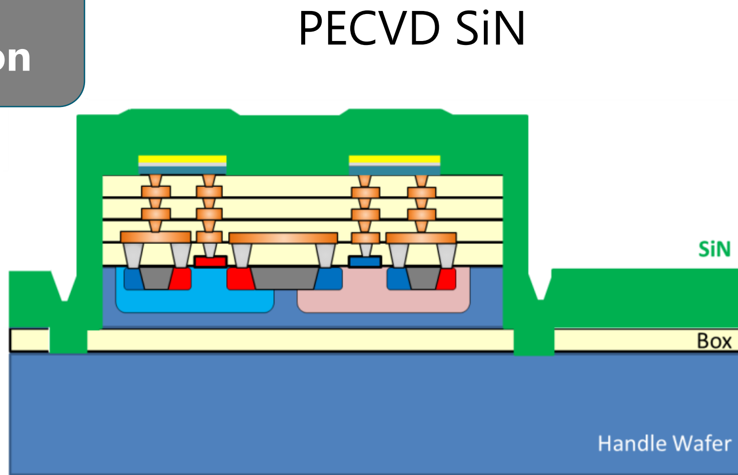
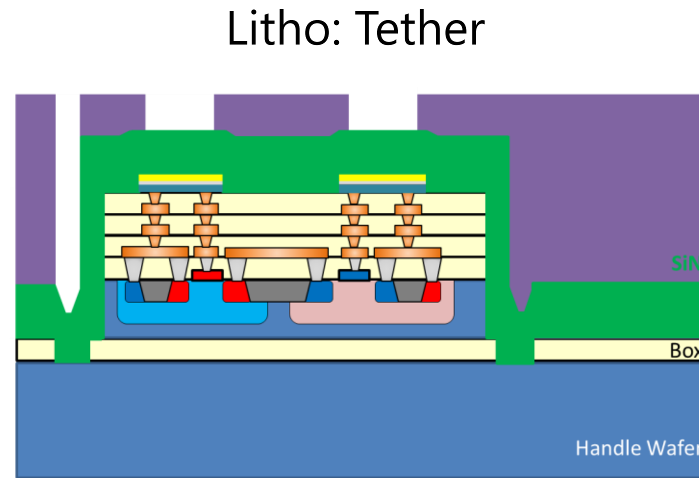
Tether Formation

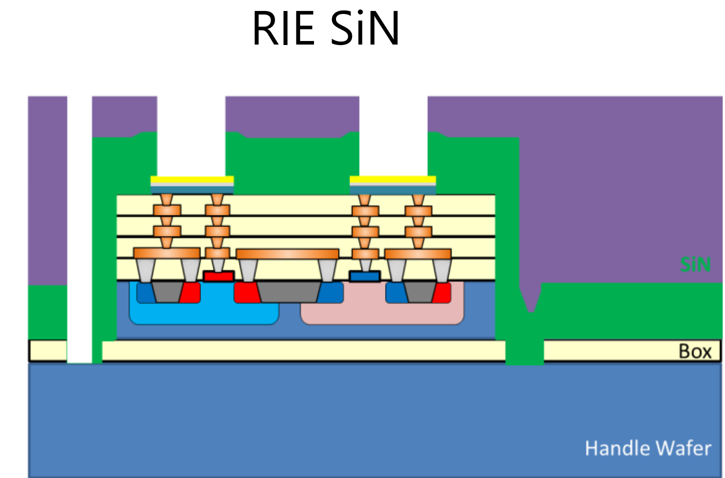
PECVD SiN



Litho: Tether

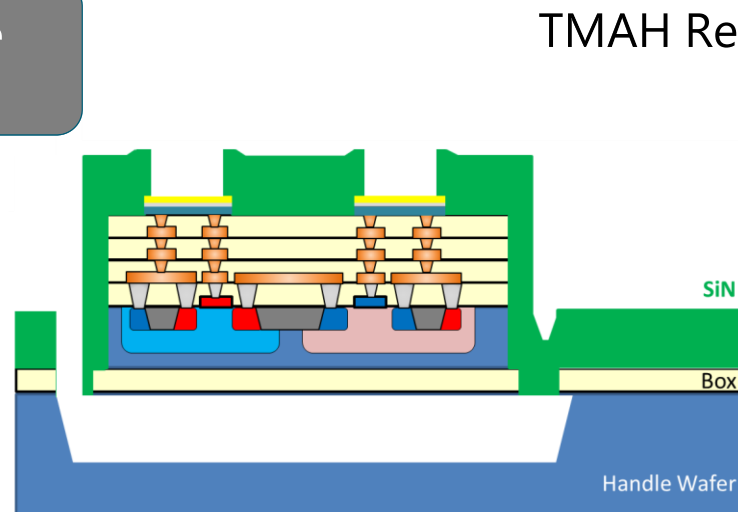


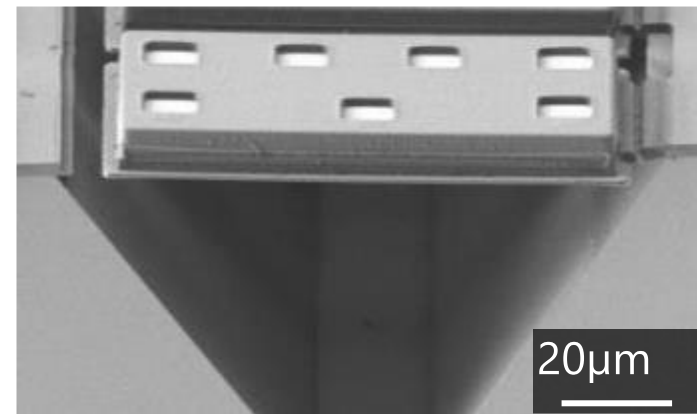
RIE SiN



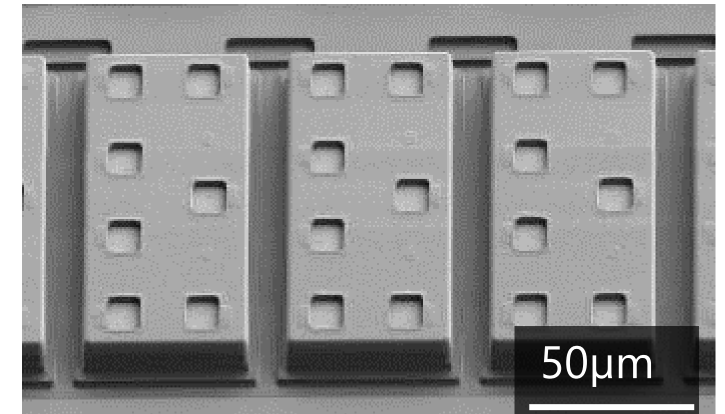
Release Etch

TMAH Release Etch.





Dielectric Deposition & Patterning



Micro Transfer Print - Ready / Compatible Silicon Technologies

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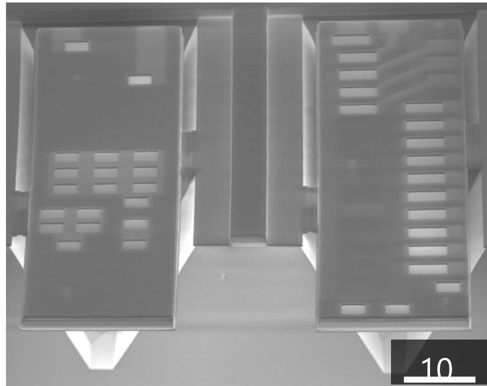
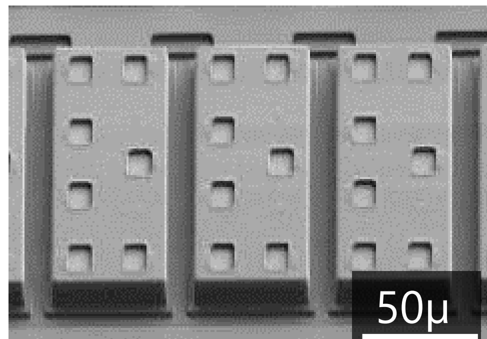


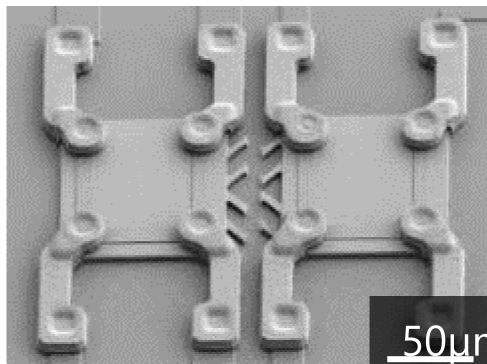
Micro Transfer Print ready chiplets

- ASIC source wafer enablement for micro transfer printing
- Formation of release trenches and tether structures
- Release etch
- Die sizes from 30µm x 30µm up-wards and heights (2-20µm)



ASIC technologies ready / compatible for Micro Transfer Printing

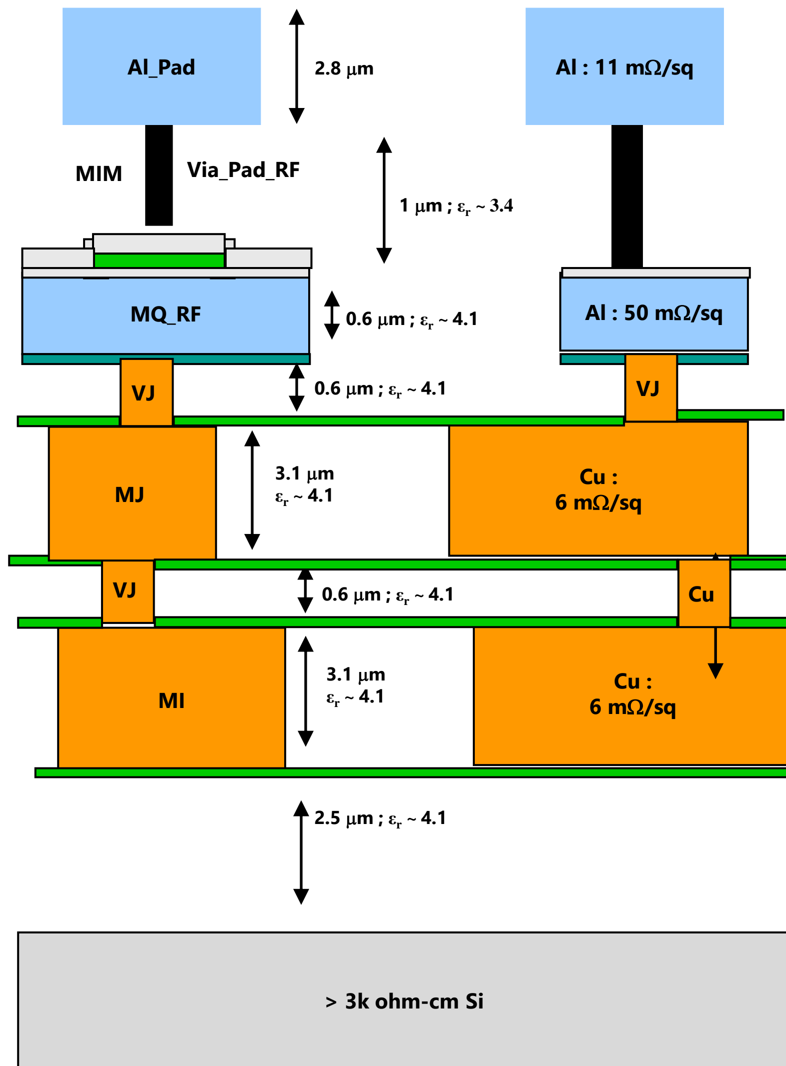
- XT018 180nm BCD-on-SOI 1.8V / 5V / 10V … 375V / max. 6 Al BEOL
- XT011 110nm BCD-on-SOI 1.5V / 5V / 12V … 85V / max. 8 Cu BEOL
- XR013 130nm RF SOI 1.2V/2.5V / max. 8 Cu BEOL (inc. 2 thick Cu layers), RF passives
- XIPD RF integrated passive device platform characterized up to 67GHz



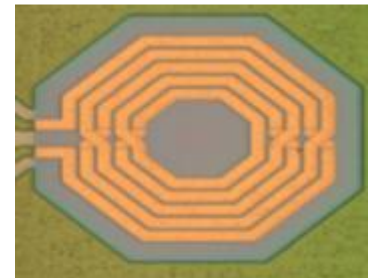
Target Applications

- Light source driver / control ICs and read-out ICs for photonics applications
- RF connectivity and LNA chiplets on top of photonics ICs
- Read-out / driver IC's for sensors or sensor arrays on non-silicon substrates (medical sensors, imaging sensors)
- ASIC stacking for power applications
- Gate driver integrated for compound semiconductor devices (e.g., Power GaN)

Micro transfer print compatible Integrated Passive Device technology



- **X-FAB Integrated passive technology (XIPD) is a cost-effective solution for RF integration of basic functions like:**
  - Filtering
  - Baluns
  - Impedance matching
- **XIPD is a BEOL only technology** based on HR-Si engineered substrate:
  - > 3kOhm-cm substrate → SOI substrate for micro transfer print enablement
  - Up to 4 metal layers including 2 thick Cu (3um thickness)
  - High-Q Inductors
  - Low Voltage (2.1fF per μm^2, 20V) MIM Capacitor
  - Wire-bond, bump and Cu-Pillar Chip package interface supported
- **XIPD enablement for micro transfer printing**
  - Available on request
  - XIPD is in mass production



Micro transfer print @ X-FAB

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Electronic applications

- Available today for risk production
- Microtranfer print CMOS source wafer technologies available for production

Silicon Photonics applications

- Placement accuracy improvement to meet photonics ***3σ < 500nm*** requirements on-going within photonixFAB
  - MTP tool upgrade done. Process set-up on-going
  - Early technology access (TRL6):   Mid-2025

- ***Existing*** Source wafer preparation technology is ***compatible*** for e.g. ***Thin Film LNO chiplets*** for microtransfer printing on top Silicon Photonics wafers

Enabling photonics product innovation with a path to high-volume manufacturing (photonixFAB)

Photonic design/EDA
LUCEDA PHOTONICS

PIC foundry and testing
xfab
LIGENTEC

Heterogeneous integration
xfab

Active material III-V chiplets
SMART PHOTONICS

Packaging & testing
phix

Systems and applications
NOKIA
NVIDIA
aryballe
PHOTONFIRST

R&D support
cea leti
imec

- Demonstrate platform capability through application partners
  - → telecom
  - → datacom/data-center
  - → sensing (olfaction sensor)
  - → fiber-interrogators

Co-funded by the European Union

ChipsJU

Customer Engagement Portal // photonixFAB.eu

- New portal enables early technology access
  - Description of available technologies & capabilities
- Contact form to get in touch with the respective partner
- Explore here: https://www.photonixfab.eu/technologies-services

Summary

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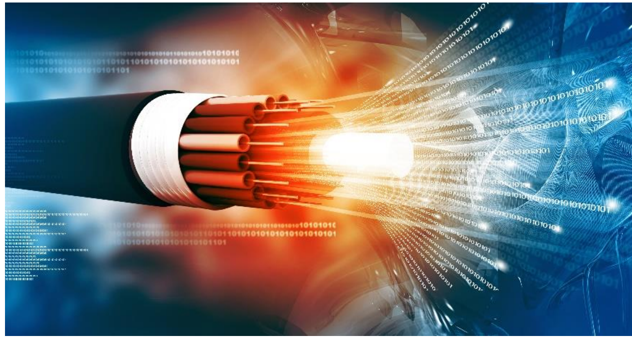

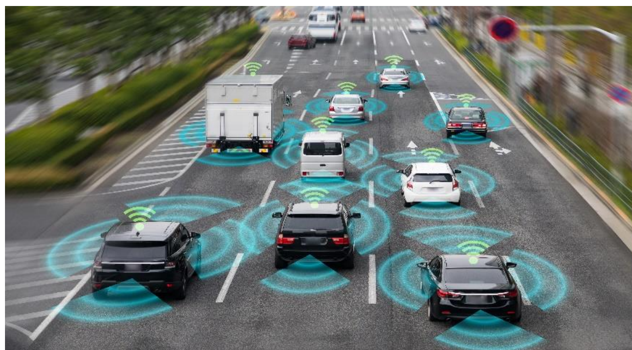

- X-Fab “More than Photonics” solutions enable a wide range of photonic applications
- X-FAB is the **high-volume manufacturing partner** for Ligentec’s low loss SiN PIC technology @ www.ligentec.com
- “More than Photonics” offering includes a range of solutions for wafer-level system integration and packaging solutions
- Micro-Transfer-Printing is a promising novel technology for heterogeneous integration of photonics and other devices – Electronic micro transfer print ready chiplet technologies already available for production. Same technology can be used for e.g. TFLNO chiplet source wafers.
- Visit the photonixFAB Consortium Customer Engagement Portal @ www.photonixFAB.eu

photonixFAB project overview and acknowledgements

Key facts

- Industry driven initiative with 12 partners from 9 countries
- € 47.6 m public + private funding
  - co-funded by the EU under grant agreement no. 101111896
  - top-up funding by Belgium, Germany, France, Israel, Italy, The Netherlands and Switzerland
- Start: May 2023
- Duration: 3.5 years

Consortium partners:

Technology & Manufacturing

Research & Technology

Applications

Key technologies

- Ultra-low loss SiN platform
- SOI platform for datacom/telecom
- InP platform enablement for MTP
- EDA tools
- Photonics Assembly and packaging
- Micro transfer printing for InP and LNOI

Acknowledgements

photonixFAB is co-funded by the European Union under grant agreement no. 101111896. The project is supported by the Chips Joint Undertaking and its members, including top-up funding by Belgium, Germany, France, Israel, Italy and the Netherlands. The project is also supported by Switzerland separately.

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Thank you.

www.xfab.com