MICROPRINCE:

Open access pilot line for Micro-Transfer-Printing of functional components on wafer level

Sebastian Wicht*, Uwe Krieger, Daniela Guenther, Niclas Heise

X-FAB MEMS Foundry GmbH

Matthias Krojer, Gabriel Kittler

X-FAB Semiconductor Foundries GmbH

Falk Naumann, Frank Altmann

Fraunhofer IMWS

David Gomez, Alin Fecioru

X-Celeprint US/ Ireland

Smart Systems Integration 2019, 10th April 2019, Barcelona

This project has received funding from the ECSEL Joint Undertaking under grant agreement No 737465. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Germany, Belgium, Ireland.

List of contents

1) Introduction of the Funded Project
2) Motivation for Micro-Transfer-Printing (µTP)
3) General µTP process
4) Introduction of the investigated target applications
5) Results of process characterization
6) Summary

List of contents

1) Introduction of the Funded Project
2) Motivation for Micro-Transfer-Printing (µTP)
3) General µTP process
4) Introduction of the investigated target applications
5) Results of process characterization
6) Summary

1) MICROPRINCE- Funded project for µTP

- MICROPRINCE is funded by **ECSEL JU** within the HORIZON 2020 call.

ECSEL Joint Undertaking
Electronic Components and Systems for European Leadership

- The project is focused on creating the worldwide first open access **pilot line for heterogeneous integration** of smart systems by **micro-transfer-printing (µTP)** in a semiconductor foundry manufacturing environment.
- The project duration is planned with 3 years (04/2017-03/2020).
- Consortium consists of **13 partners** from industry and research.

- MEMS Foundry GmbH
- Semiconductor Foundry GmbH

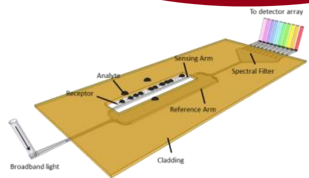
supported by TECHNIKON

- Melexis Technologies
- Melexis Technologies SA
- Melexis NV
- Melexis GmbH

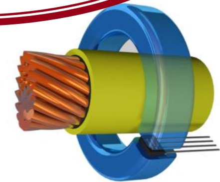
1) Introduction of the funded project

- Project goals:

Devices for Si–photonics

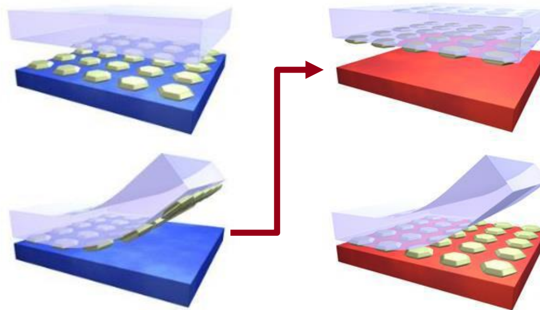


Printed GaAs Hall plates

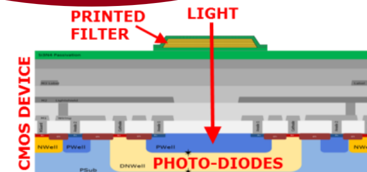


Installation of a µTP Pilot line for an open access platform

Printing LEDs



Printed optical filters

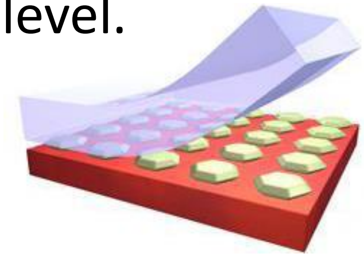


List of contents

1) Introduction of the Funded Project
2) Motivation for Micro-Transfer-Printing (µTP)
3) General µTP process
4) Introduction of the investigated target applications
5) Results of process characterization
6) Summary

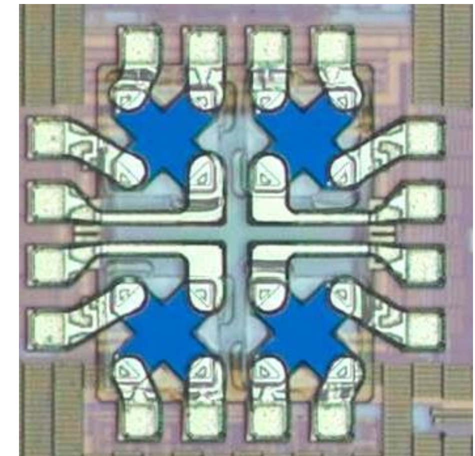
2) Motivation for µTP

- Technology for **heterogeneous integration** on wafer level.
- Pronounced potential for **parallel placement**.



- High **placement accuracy** is achievable→ ±1.5µm (3σ).
- Very **short metallization tracks** accessible→ low impedance.
- Reduced package sizes accessible.
- Transfer/ packaging of **small & thin devices**.
  - Height of down to 2-3µm.
  - Lateral dimensions below 50x50µm^2 possible.
- Placement in small cavities achievable.

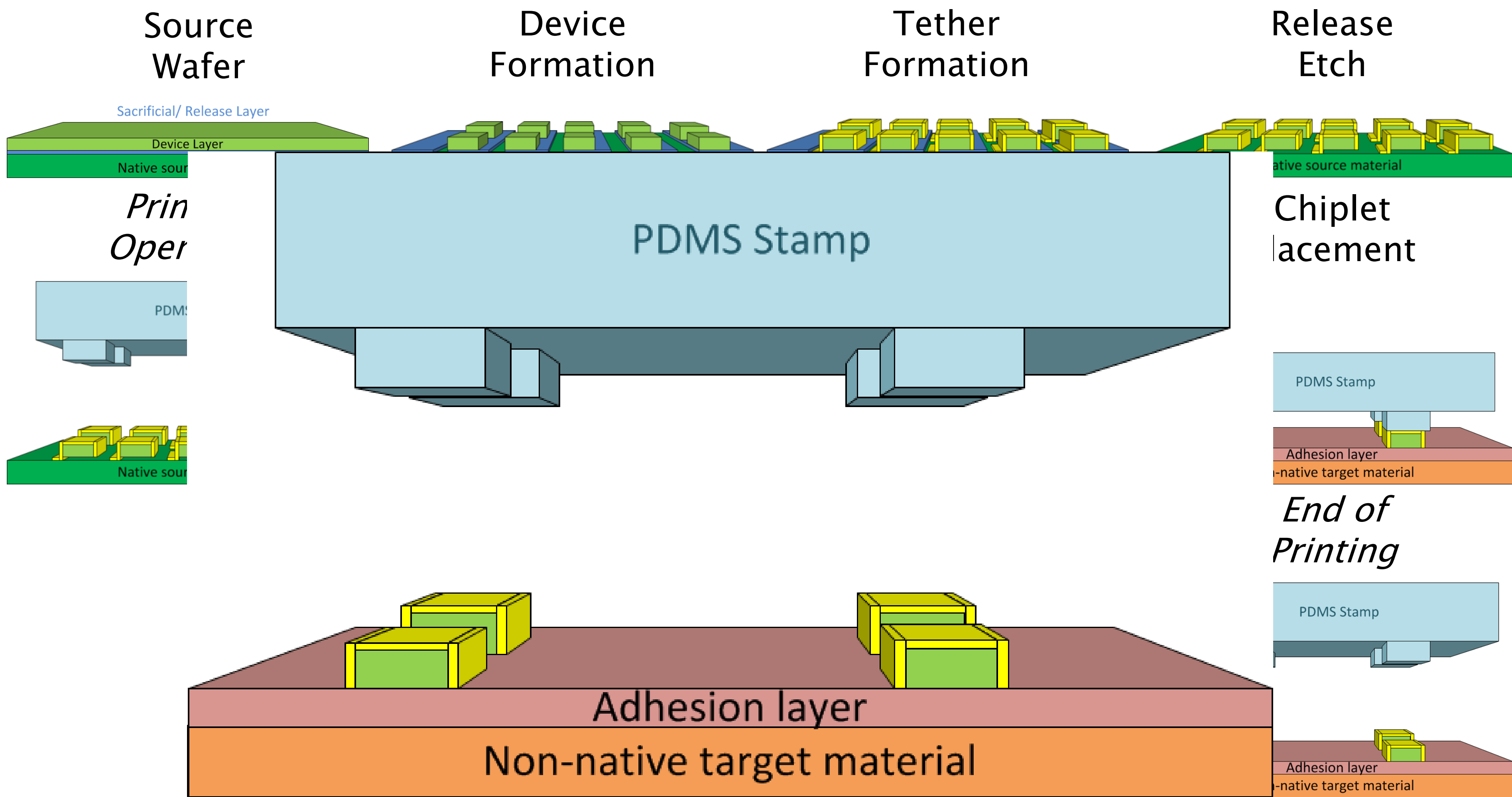
• • •



List of contents

1) Introduction of the Funded Project
2) Motivation for Micro-Transfer-Printing (µTP)
3) General µTP process
4) Introduction of the investigated target applications
5) Results of process characterization
6) Summary

3. General µTP process- Printing



3. General µTP process- Printing

Source Wafer

Sacrificial/ Release Layer
Device Layer
Native source material

Device Formation

Native source material

Tether Formation

Native source material

Release Etch

Native source material

Printing Operation

PDMS Stamp

Native source material

Chiplet Picking

PDMS Stamp

Native source material

Chiplet Transfer

PDMS Stamp

Native source material

Chiplet Placement

PDMS Stamp

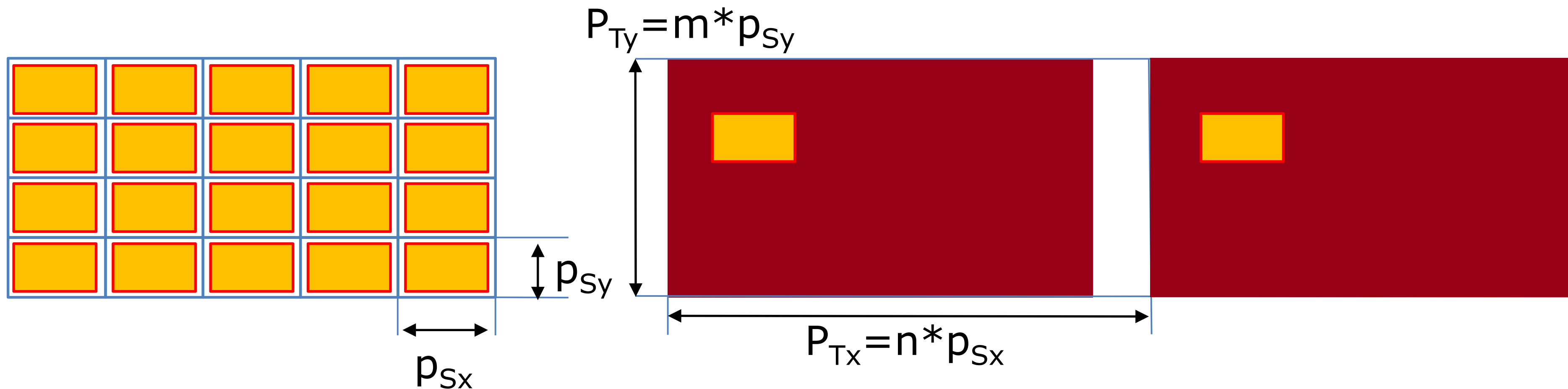
Adhesion layer
Non-native target material

End of Printing

PDMS Stamp

Adhesion layer
Non-native target material

3. General µTP process- Design restrictions

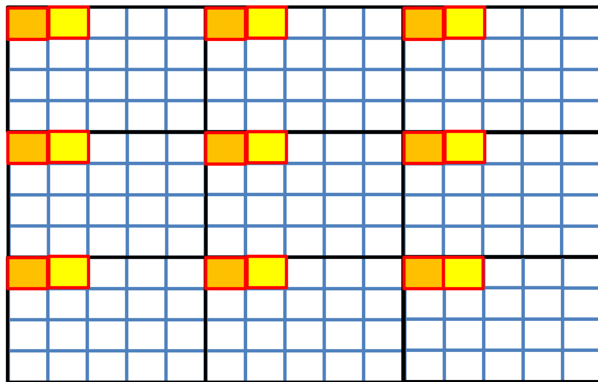


- Correlation between target and source die pitches are required:

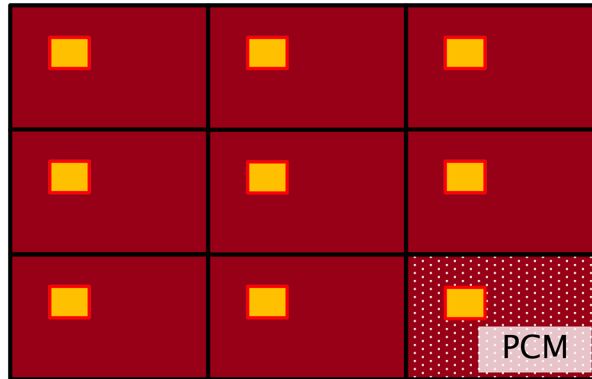
$$P_{Tx} = n \cdot p_{Sx} \; \& \; P_{Ty} = m \cdot p_{Sy}$$

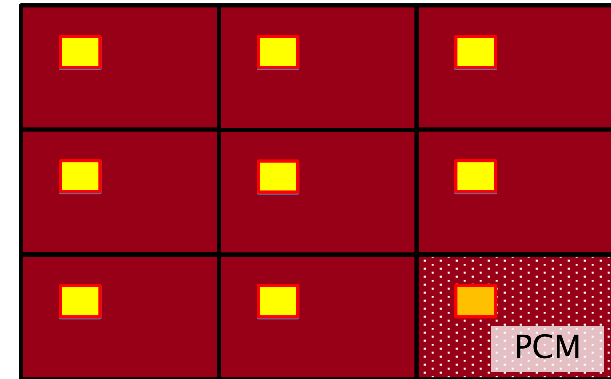
  - **Target die pitches** must be **multiples of the source die pitches**.
  - m, n are integer.
  - Target chip grid includes dicing lines, source chip grid includes area for tethers and anchor structures.

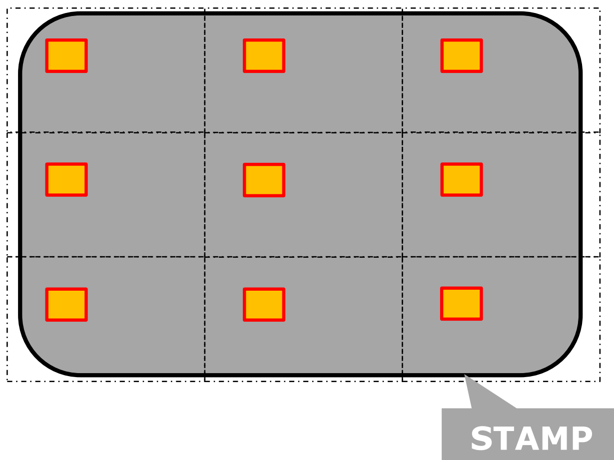
3. General µTP process- Design restrictions



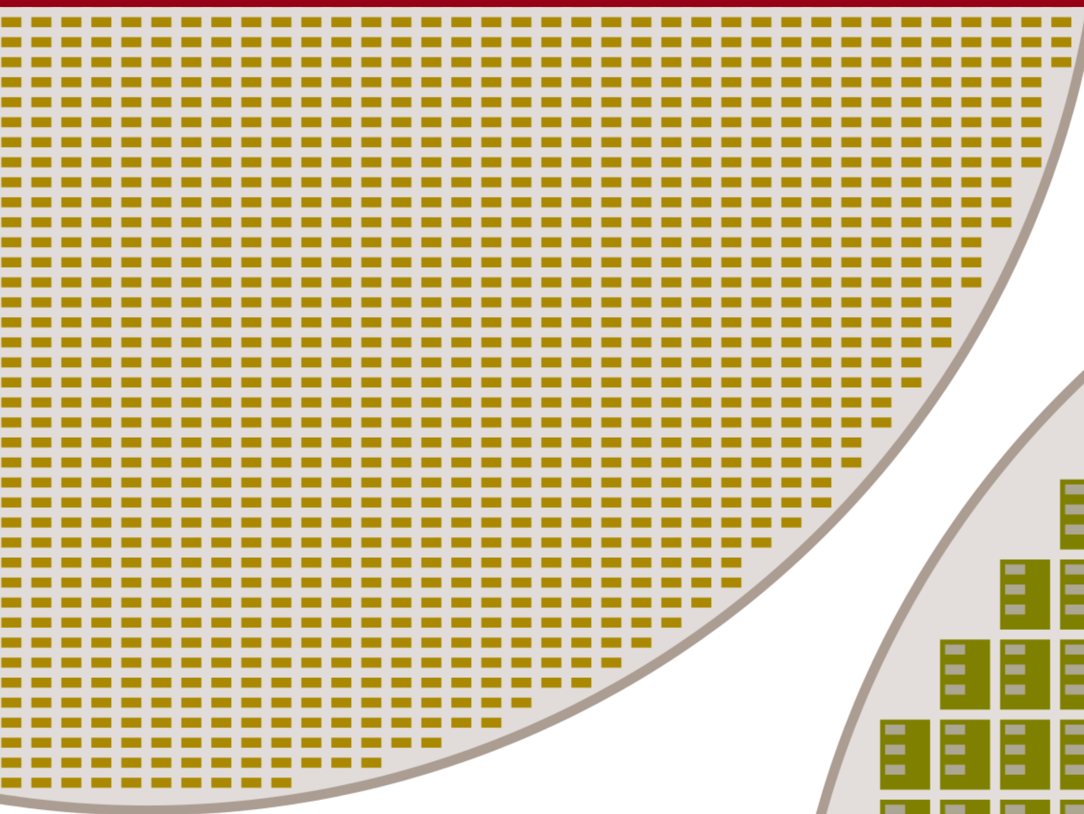
Printfield Soure wafer





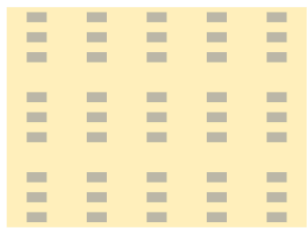


- Requirements of array printing:
  - Stamp populates equivalent areas along the wafer.
  - PCM layout is pre-defined by chip design→ one chip per reticle PCM test fields .
  - PCM test has to be designed individually per application.



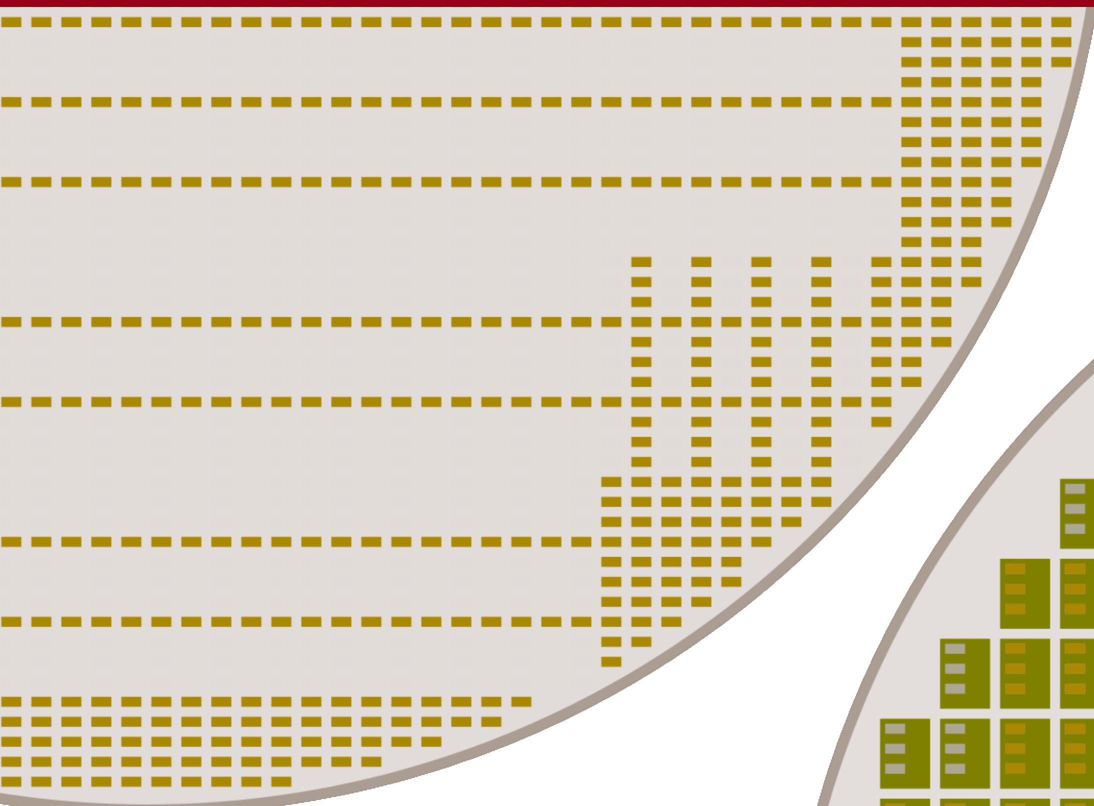
Source wafer

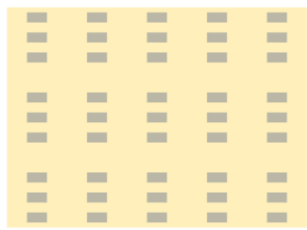
Target wafer



Stamp

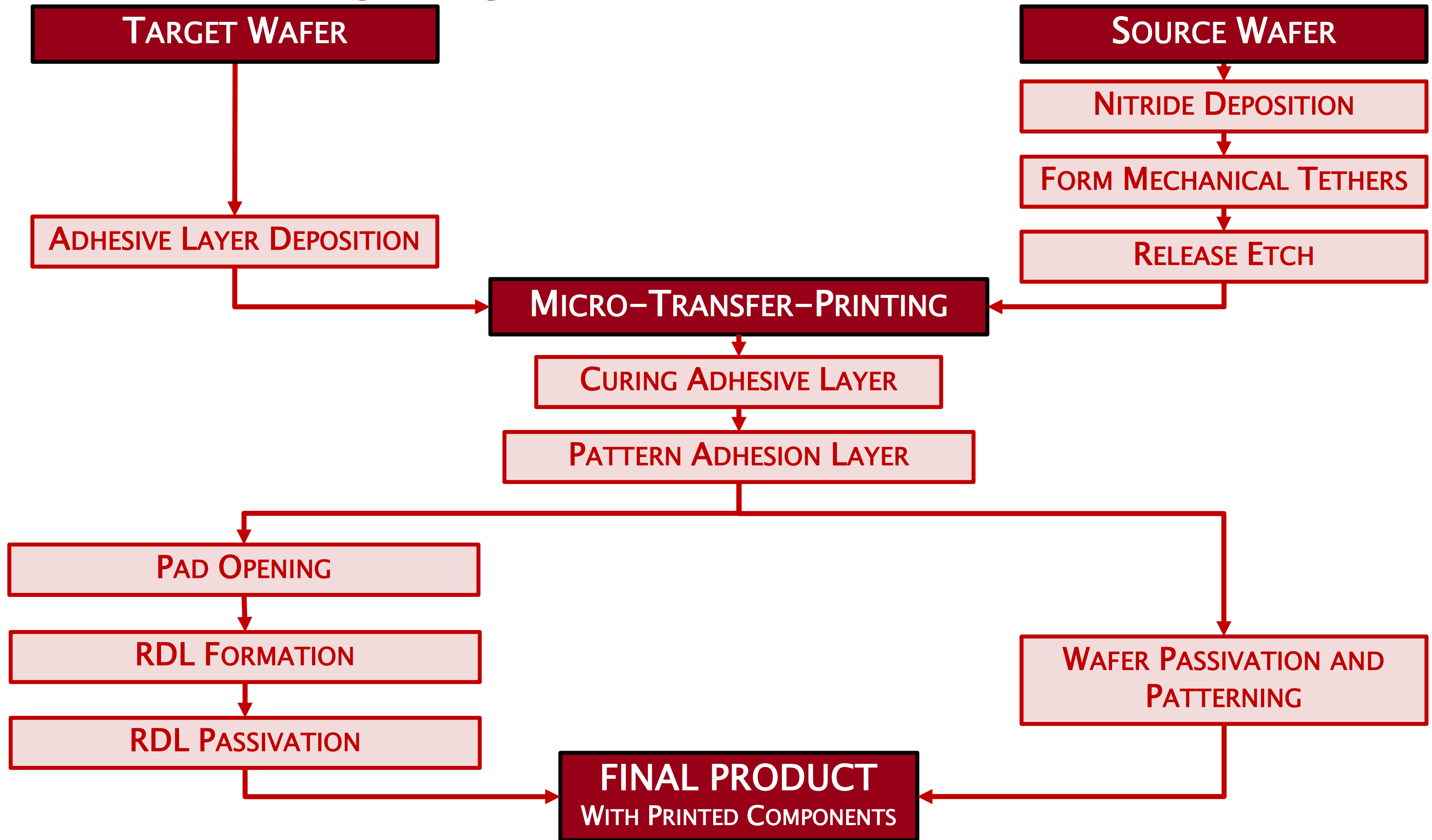
TECHNISCHE UNIVERSITÄT DRESDEN





TECHNISCHE UNIVERSITÄT DRESDEN

3. General µTP process- Flow Chart

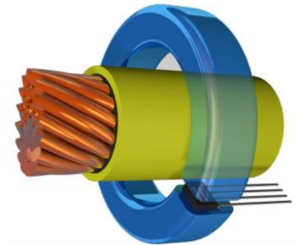


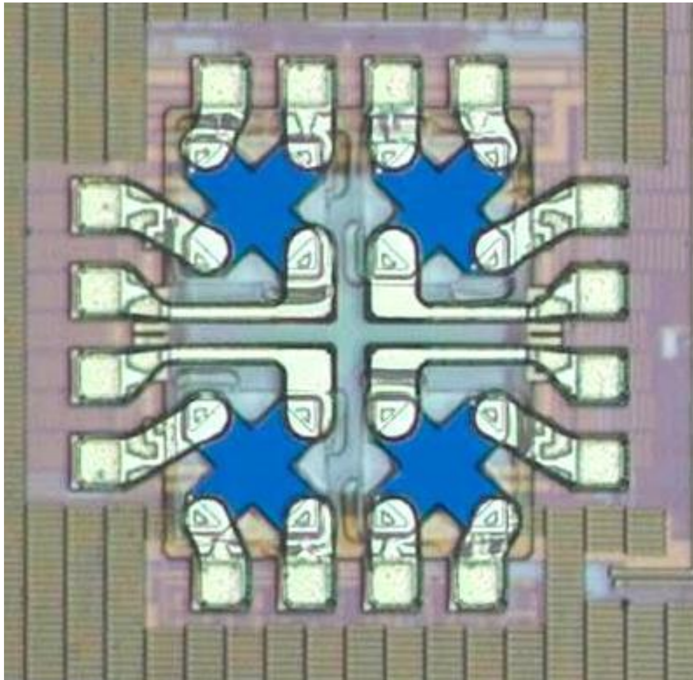
List of contents

1) Introduction of the Funded Project
2) Motivation for Micro-Transfer-Printing (µTP)
3) General µTP process
4) Introduction of the investigated target applications
5) Results of process characterization
6) Summary

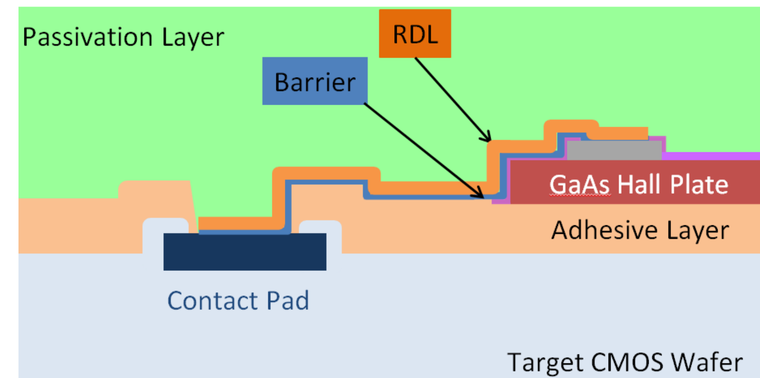
4) Target applications- GaAs Hall Plates

- µTP for highly sensitive magnetic sensors.



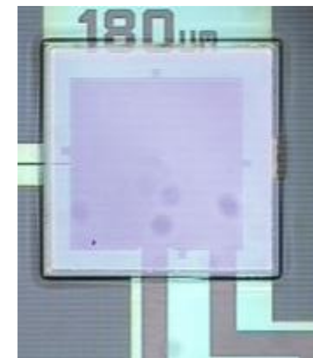


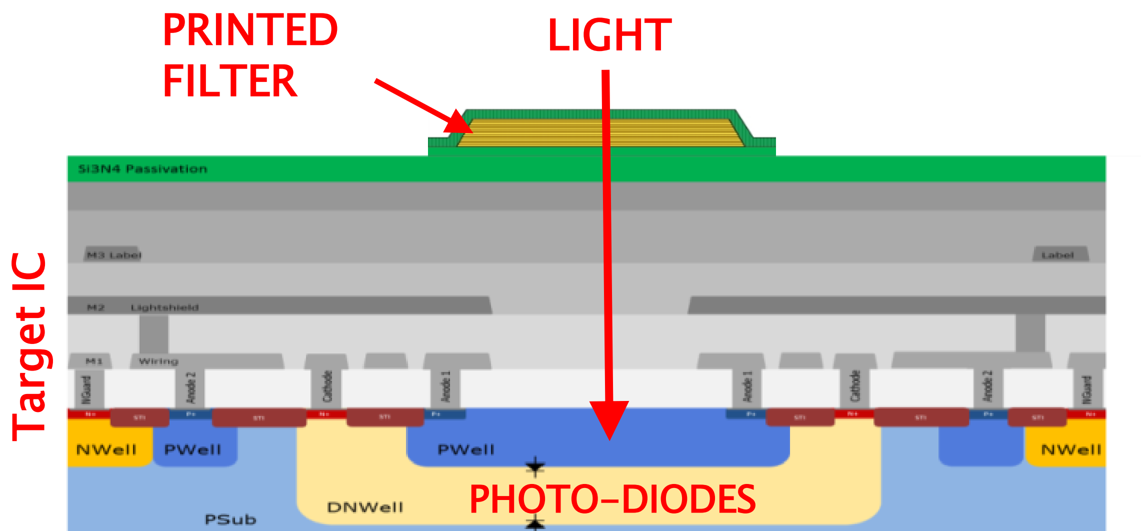
- Integration of GaAs Hall plates shall overcome the limitations of Si devices.
- GaAs offers a higher electron mobility and allows therefore a higher sensitivity to magnetic fields.

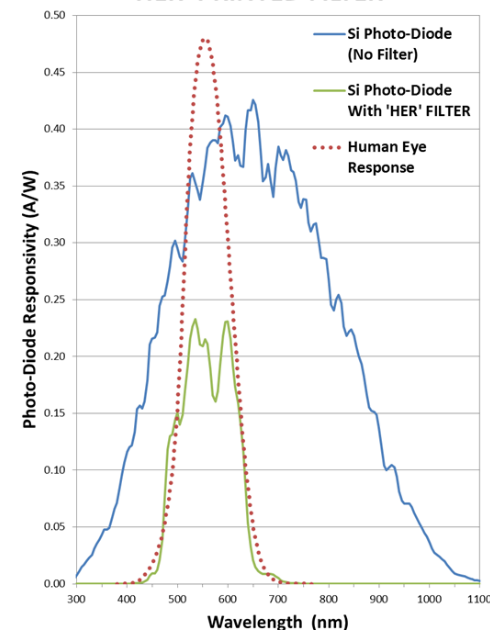


4) Target applications- Printed Filter

- µTP of filters for Human Eye Response sensors.
- More efficient utilization of expensive filter material.
- Furthermore, µTP could be applied for the integration of different filter materials on one chip.

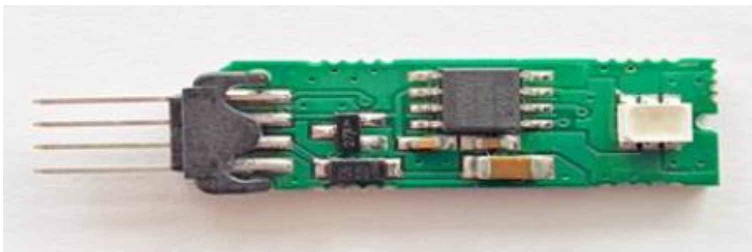




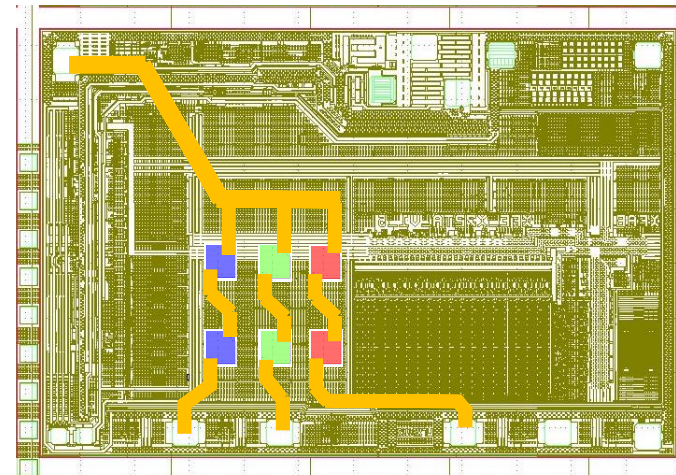


4) Target applications- LEDs for ambient lighting

- Transfer printing of RGB µLEDs for ambient lighting in cars.

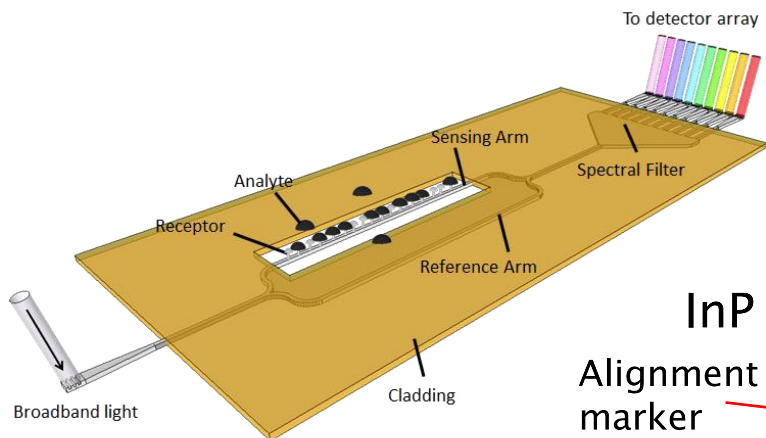


- By printing directly on the driver IC: cost efficient, more flexible and smaller packages shall be achieved.
- Special requirements on LED design.



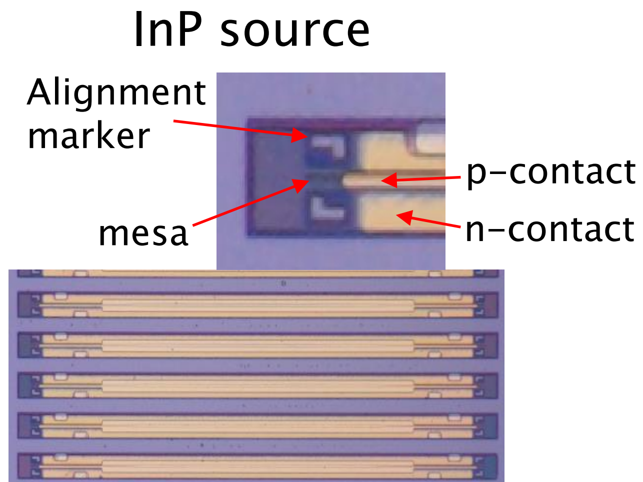
4) Target applications- Si-Photonic devices

- Transfer printing of III/V active devices for Si-photonics biomedical application.

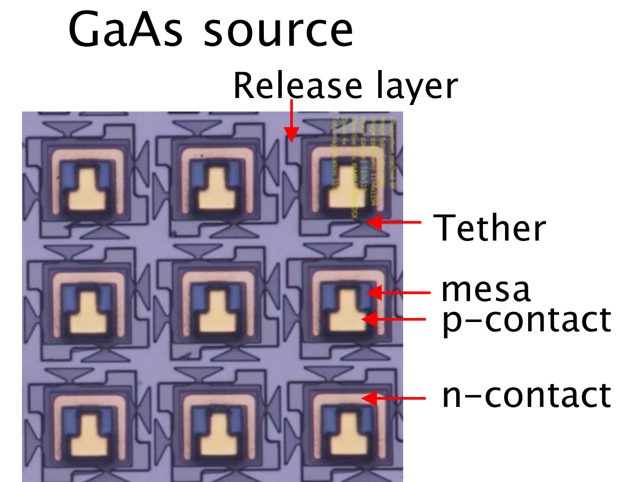


- Cost efficient setup of spectroscopic sensing applications by including GaAs & InP photodiodes and LEDs in passive Si & SiN photonic circuits.

InP source



GaAs source



List of contents

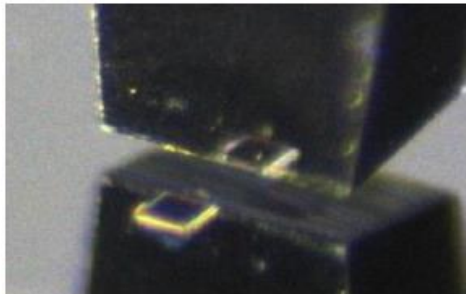
1) Introduction of the Funded Project
2) Motivation for Micro-Transfer-Printing (µTP)
3) General µTP process
4) Introduction of the investigated target applications
5) Results of process characterization
6) Summary

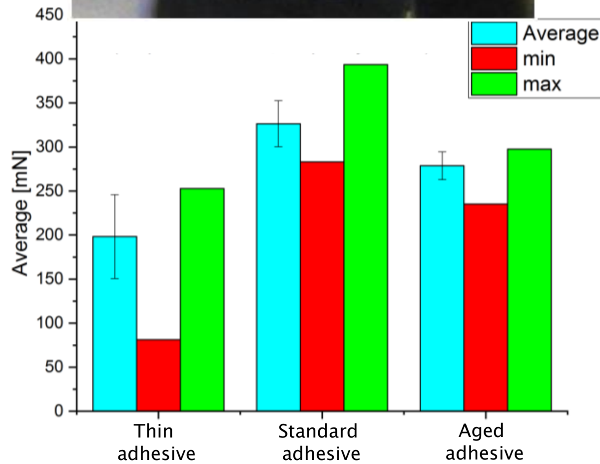
5) Process characterization

Fraunhofer IMWS

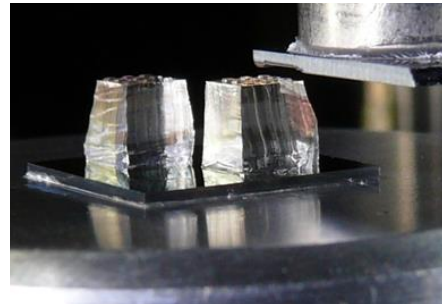
- Various process and device characterizations as well as simulation are performed:

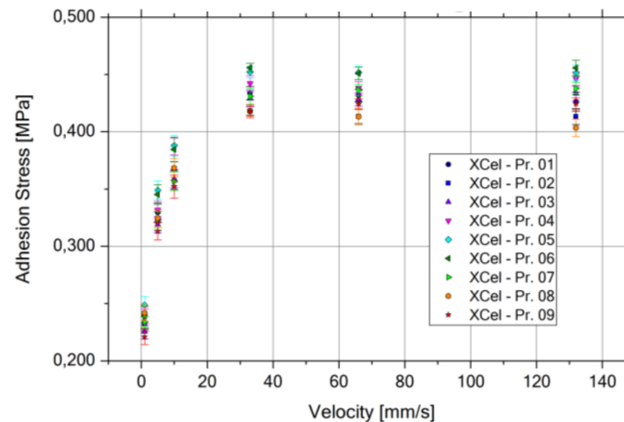
Adhesion tests



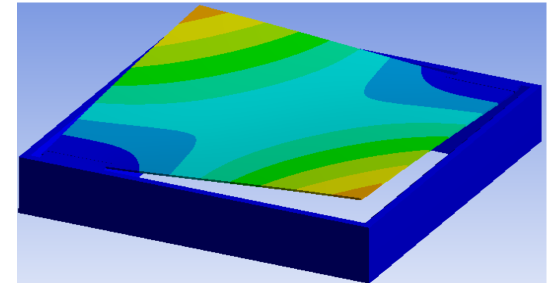


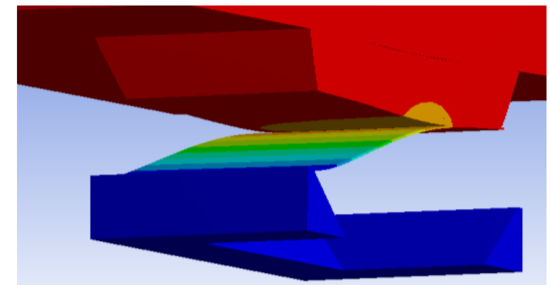
Stamp characterization





FEA Modeling



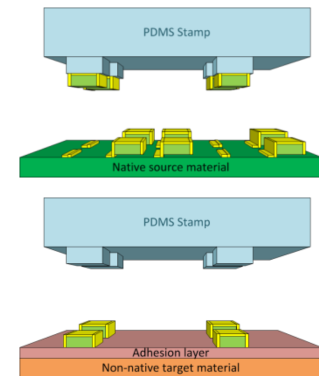


List of contents

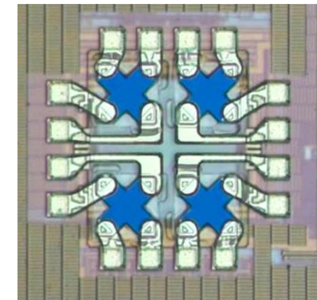
1) Introduction of the Funded Project
2) Motivation for Micro-Transfer-Printing (µTP)
3) General µTP process
4) Introduction of the investigated target applications
5) Results of process characterization
6) Summary

6) Summary

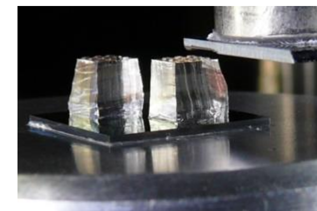
- The MICROPRINCE project aims on the **installation of a pilot line for Micro-Transfer-Printing** (µTP).
- µTP is a versatile technology for **parallel heterogeneous integration on wafer level**.



- Within the project the capabilities of this technology will be demonstrated for several target applications: **GaAs Hall Plates**, **filters**, **LEDs** and **Si-photonics**.



- Furthermore, the process and material characteristics are extensively investigated within the project.



Aknowledgement

- "The **Microprince** project has received funding from the European Union's H2020 Programme (ECSEL JU) under grant agreement number 737465"

- Thanks to all the project partners and involved team members for their contribution, the provided data and the collaboration.

- MEMS Foundry GmbH
- Semiconductor Foundry GmbH

supported by TECHNIKON

- Melexis Technologies
- Melexis Technologies SA
- Melexis NV
- Melexis GmbH

Thank you for your kind attention.

MICROPRINCE- Goals

- Transfer of the µTP-technology for microelectronics application from **research to an industrial environment**.
- **Creation, installation and demonstration of a µTP pilot line** in a manufacturing environment for open access.
- Technology demonstration for **five defined target applications:** Hall plates for **current sensors**; filter for **optical sensors**; µLEDs for **car ambient lighting**; LEDs, sensors and modulators for **communication** and **bio-medical Si-photonics** applications.
- Realization of printing processes from and on different wafer sizes (3, 4, 6 & 8 inch) mm silicon wafers.
- Development of µTP as platform technology including **design rules** and their implementation in **Process Design Kits (PDK)**.

MICROPRINCE- Project structure

WP 8: Project- and Innovation Management

WP7: Dissemination, Communication, Exploitation and Standardization (Lead: IMWS)

WP2: Micro-Transfer-Printing for High Sensitivity Magnetic Sensors (Lead: MLX TLO)	**WP3:** Micro-Transfer-Printing for Optical Sensors (Lead: XFAB)	**WP4:** Micro-Transfer-Printing for Silicon Photonics (Lead: HUA)	**WP5:** Micro-Transfer-Printing of LED Devices (Lead: MLX DE)	**WP6:** Micro-Transfer-Printing for Biomedical Implant Applications (Lead: IMEC)

WP1: Design and installation of the µTP pilot line (Lead: XMF)

- Specification, set-up and installation of the pilot line for high volume production in a MEMS foundry environment
- Development and providing of general process for manufacturing

X FAB

MICRO PRINCE

MICROPRINCE Grant Agreement No. 737465

"The **Microprince** project has received funding from the European Union's H2020 Programme (ECSEL) under grant agreement number 737465”

If you need further information, please contact the coordinator:

X-FAB MEMS Foundry GmbH
Haarbergstrasse 67, 99097 Erfurt, GERMANY
Tel: +49 361 427 6508 Fax: +49 361 427 6171
E-Mail: sebastian.wicht@xfab.com

The information in this document is provided “as is”, and no guarantee or warranty is given that the information is fit for any particular purpose. The users thereof use the information at their sole risk and liability.