

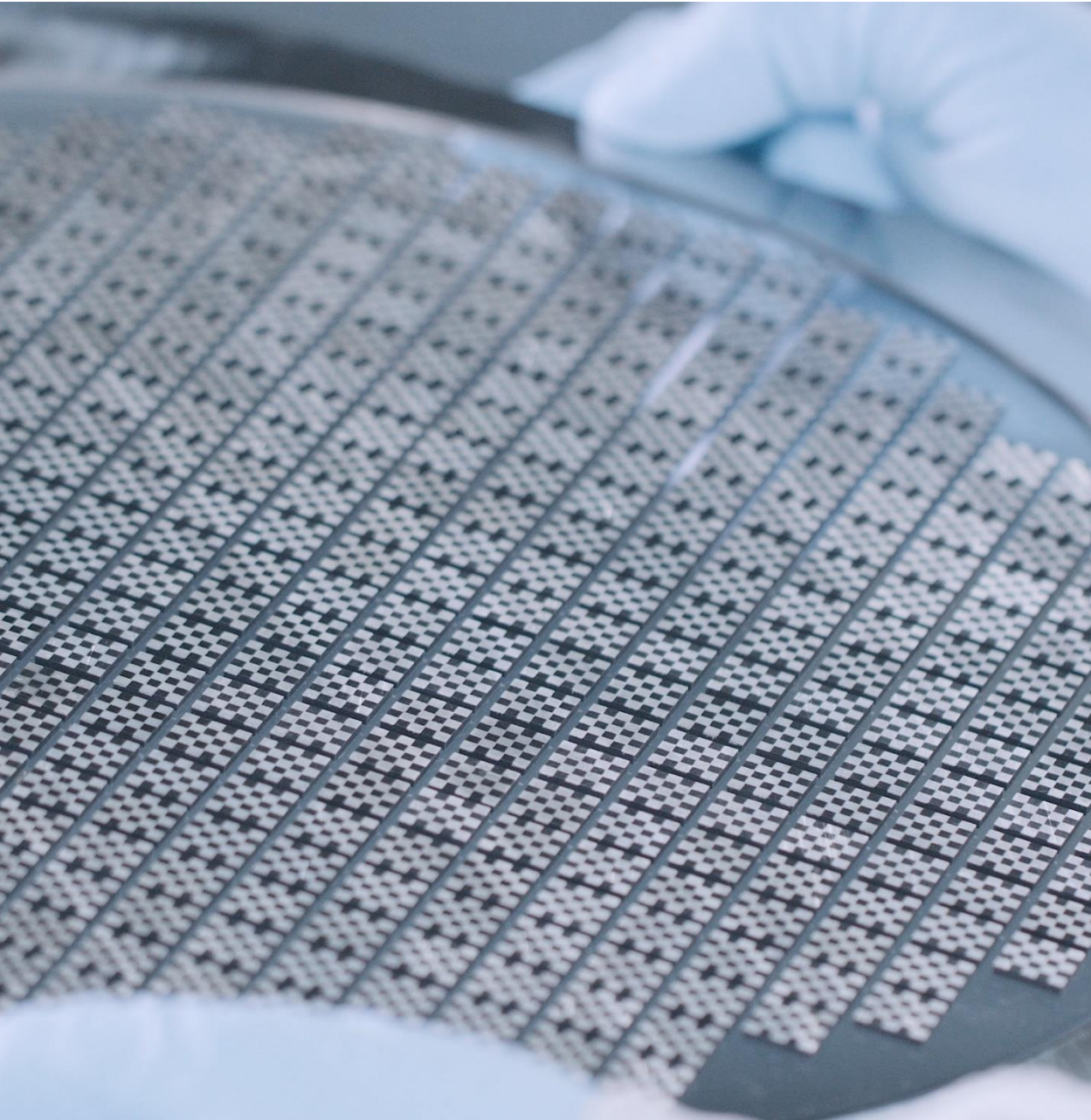
HERAEUS PREXONICS®  
SYSTEM SOLUTION

TURNKEY DIGITAL PRODUCTION  
PROCESS FOR SELECTIVE  
METALLIC COATINGS

TechBlick conference, 17<sup>th</sup> October 2023, Franz Vollmann

The Heraeus logo is centered within a white diamond shape. This diamond is surrounded by a thick, dark grey border that has a slight 3D effect, appearing to float above a dark grey shadow. The background of the slide is a dark gradient.

Heraeus



1

MAJOR CHALLENGES & MASS PRODUCTION

2

HERAEUS PARTICLE FREE INK

3

HERAEUS INKJET PRINTING SYSTEM

4

TECHNICAL AND COMMERCIAL DATA

5

ADVANTAGES OF INKJET PRINTING

## MAJOR CHALLENGES IN SEMICON IN THE NEXT 5 YEARS



**Space & Weight** reduction to enable further miniaturization



**Thermal challenge** arising from higher density packages



**Full design flexibility** without compromising on cost efficiency and output



Rapid succession of device generations requires **rapid design change**



Innovative solutions require **scaling up in shortest times and at lowest cost**



Use of **additive technologies** to minimize waste, process time and improve ESG

MAJOR CHALLENGES IN SEMICON IN THE NEXT 5 YEARS

All those topics must be resolved  
with new technologies

Full  
Automation

Lights-Out  
Capability

meeting **Mass Production Requirements**

Material Reliability in  
24/7 Production

Sustainability &  
CO<sub>2</sub> Footprint

In-line  
Process Control

Process Stability  
(R&R)

SCALABILITY

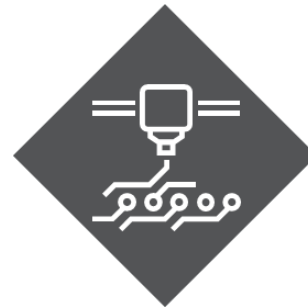
Lab-scale results are by no means indicators  
for  
**meeting Mass Production Readiness**

## HERAEUS PREXONICS® SYSTEM SOLUTION

### Process Expert

#### **In-depth understanding**

of the entire process impact of ink and machine specifications with a high level of expertise in curing technology systems



### Printer Manufacturer

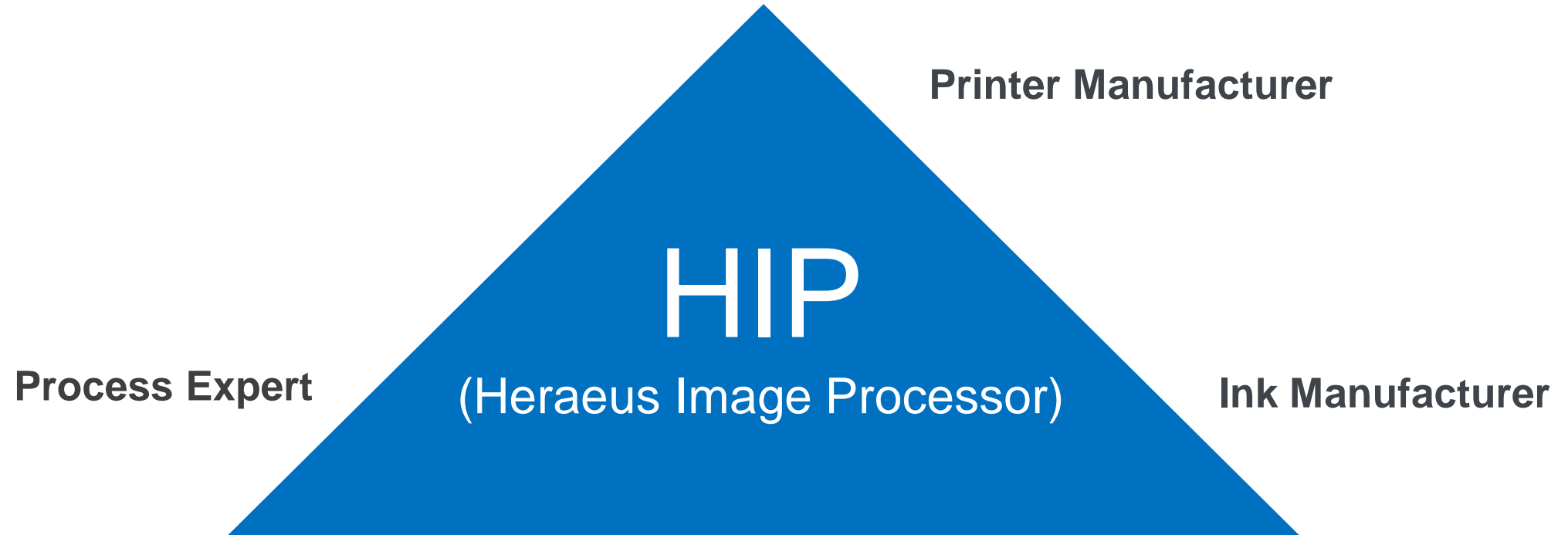
Expertise in **inkjet printing** systems & process know-how



### Ink Manufacturer

Expertise in formulation & mass production of **particle free Metal Organic Decomposition (MOD) inks**

HERAEUS PREXONICS® SYSTEM SOLUTION

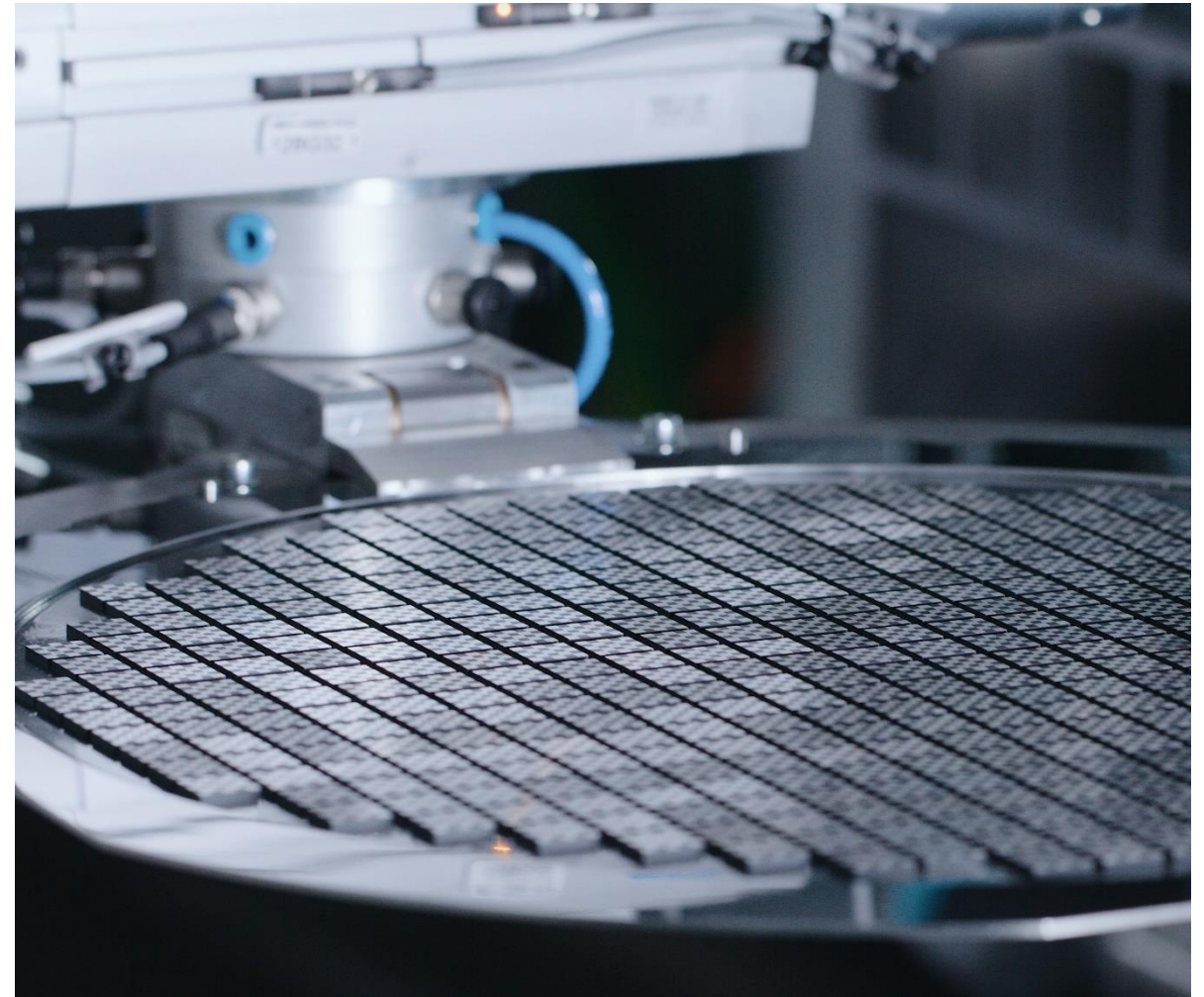


**System components to be aligned and fine-tuned for mass production**



# INKJET PRINTING - OPENING THE WORLD OF DIGITAL, SELECTIVE PRINTING

- Mask free
- 99% material efficiency
- Reduced process time & cost
- Digital process enables rapid design change
- Unprecedented design freedom
- Improved "ESG/EHS footprint" by avoiding environmentally harmful processes







- 1 | HERAEUS PREXONICS® EMI SHIELDING SOLUTION
- 2 | HERAEUS PARTICLE FREE MOD INK
- 3 | HERAEUS INKJET PRINTING SYSTEM
- 4 | HERAEUS PROCESS CAPABILITY
- 5 | ADVANTAGES OF INKJET PRINTING

## PREXONICS® MOD SILVER INK FOR EMI COATING



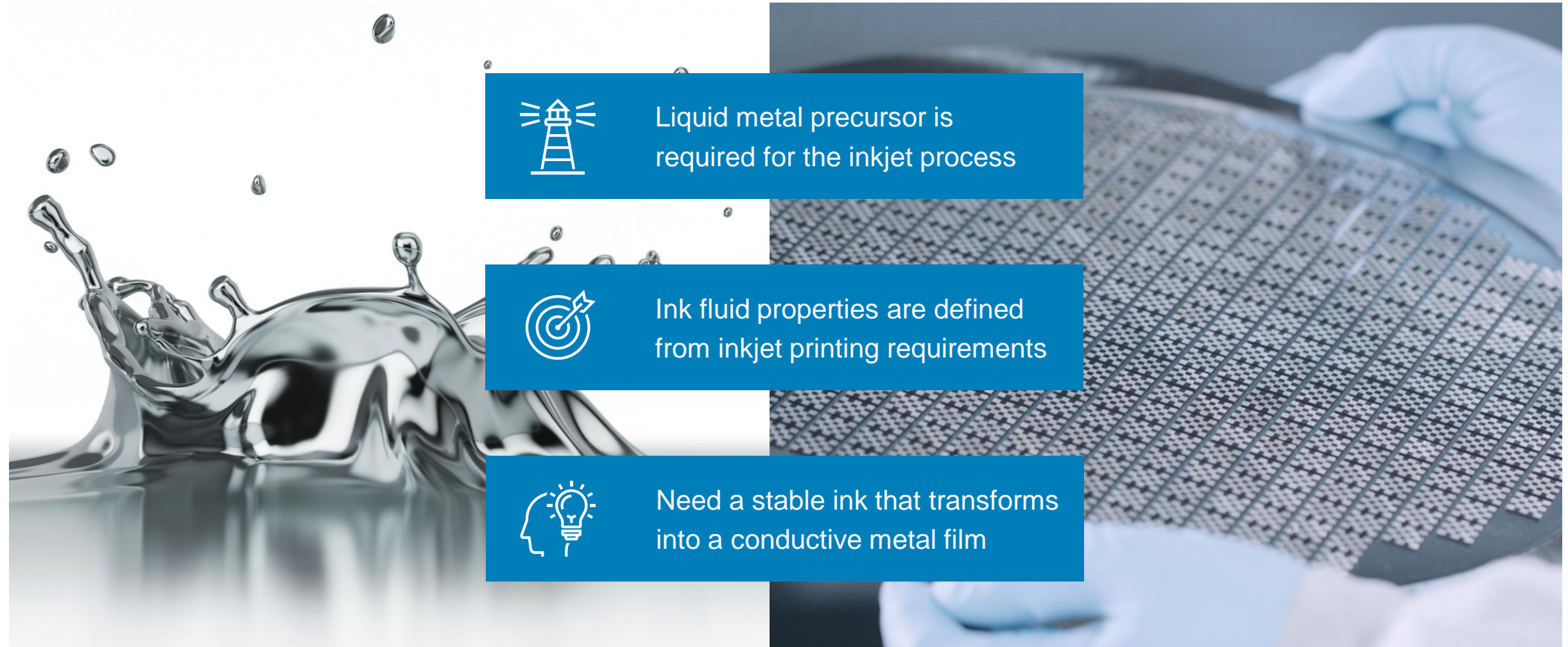
Liquid metal precursor is required for the inkjet process



Ink fluid properties are defined from inkjet printing requirements



Need a stable ink that transforms into a conductive metal film



## GENERIC COMPOSITION OF PREXONICS® MOD INK



### Fluid dynamics

#### **Solvent**

Fluid dynamics, evaporation and flash point



### Curing properties

#### **Ag precursor**

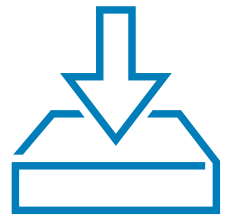
Solubility, decomposition and volatile side products



### Reliability performance

#### **Adhesion promotor**

Interaction with the substrate surface, robust against heat and moisture



### Shelf life

#### **Stability additive**

Further fluid mechanical adjustments and long term stability of the ink





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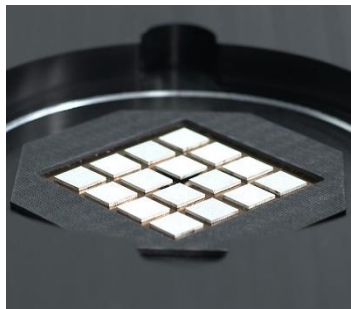
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## EQUIPMENT TAILORED TO YOUR NEEDS



### Prexonics® PES 1120

- Equipment for lab use / technology validation
- Multi-unit feasibility tests
- Proof of reproducibility



### Prexonics® PES 2110

- Equipment for production on populated wafer frame
- Pre-treatment included
- Automated loading and unloading

## EQUIPMENT PORTFOLIO

PES 1120



Purpose

Feasibility studies & customer trials

Output

0.5 WPH (\*)

Features

4 printheads  
Rectangular panel  
No automation

Availability

1x Hsinchu/TWN  
1x Shanghai/CH  
4x Hanau/GER

PES 2110



Production machine for low-mid size quantities

2-3 WPH (\*)

24 printheads  
12" wafer  
Automation  
In-line processes

2x Hanau/GER

PES 31XX  
Next GEN



High volume production machine

12-15 WPH (\*)

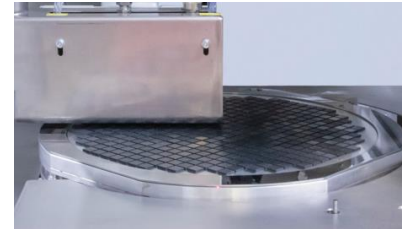
Wafer/tray  
Full automation

In design phase

(\*) for 2 μm coating thickness, 180°C process

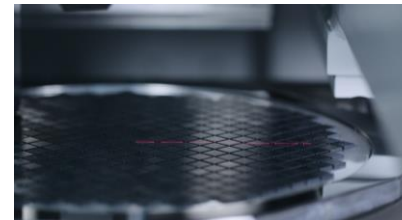


### PREXONICS® PES 2110



#### Pre-Treatment

- Atmospheric plasma
- Different process gases possible
- Ensures adhesion of Ag coating on various EMC substrates



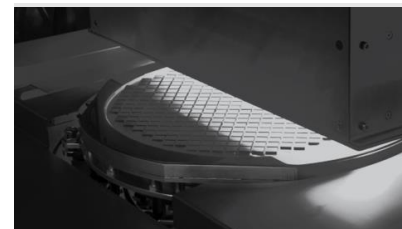
#### AOI Scan

- Fast and efficient localization of objects on chuck
- Optical 3D scan to apply transformation to print
- Flexible recognition of wide range of objects



#### Inkjet Printing

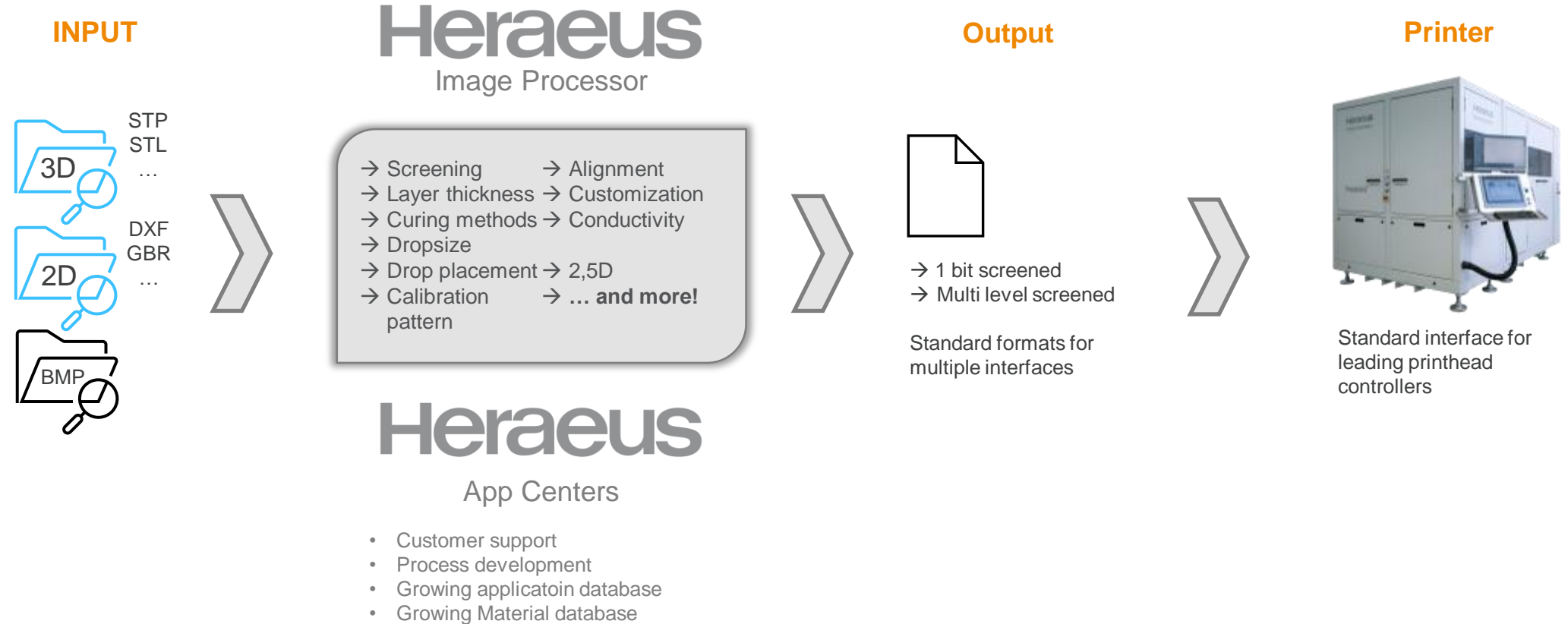
- Standard carrier: 12 inch wafer frame
- Single pass printing of populated wafer frame
- Selective printing capability without masking/etching or additional tools



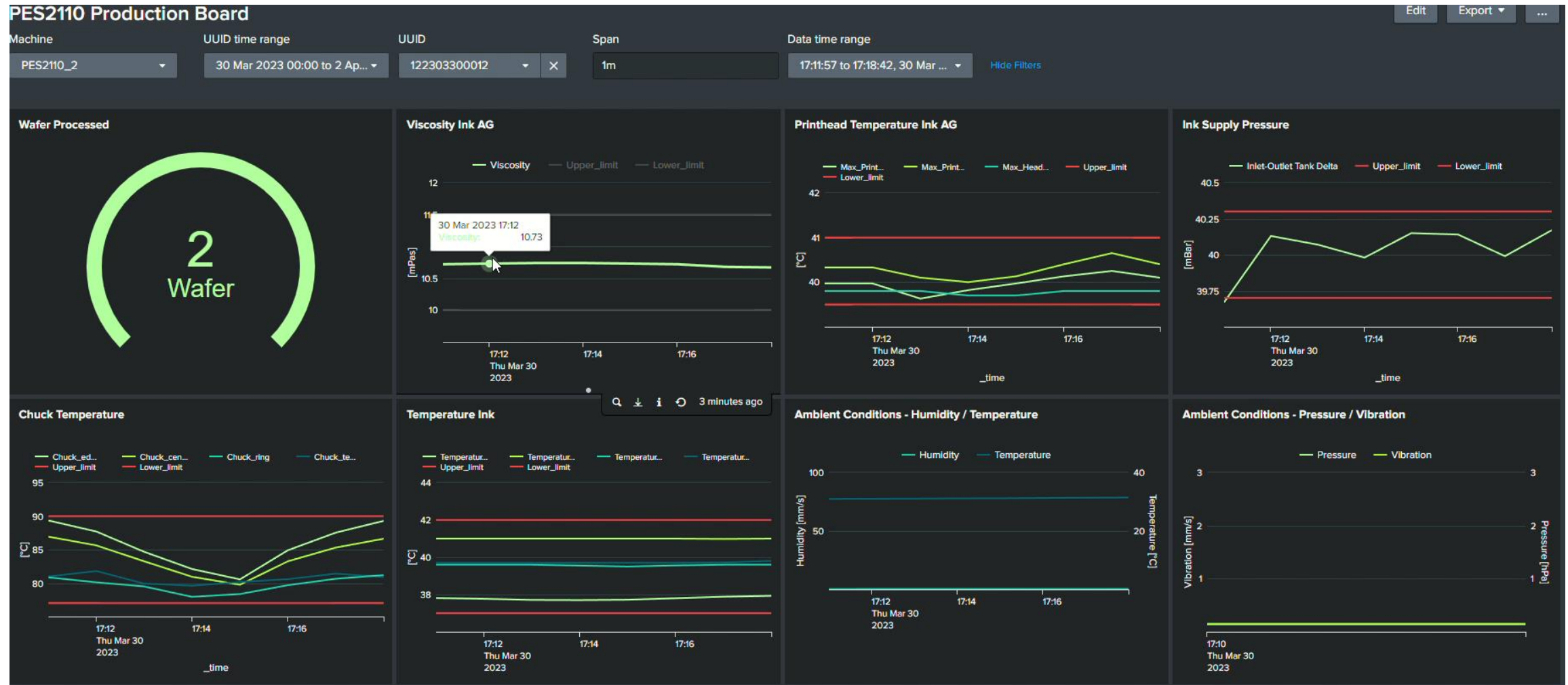
#### Curing

- Single pass curing of populated wafer frame
- Tailored curing for excellent silver formation on packages

## FROM LAB → INDUSTRIAL PRODUCTION



## PES 2110 CONTROL DATA





1 | HERAEUS PREXONICS® EMI SHIELDING SOLUTION

2 | HERAEUS PARTICLE FREE MOD INK

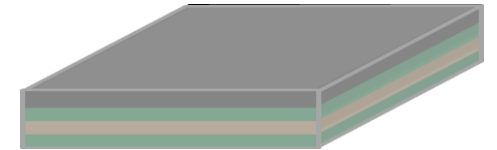
3 | HERAEUS INKJET PRINTING SYSTEM

4 | HERAEUS PROCESS CAPABILITY

5 | ADVANTAGES OF INKJET PRINTING

## ADHESION AFTER RELIABILITY

- Topside adhesion 5B is achieved for all tests
- Sidewall adhesion ≥ 4B is achieved after uHAST, TCT and HTS (500h)  
3B after 1,000h HTS



Dummy packages			Measurement setup			Judgement			
Item	Condition	Sample size	Judgement	Tape	SPEC	Readout	Adhesion topside	Adhesion sidewall	Result
t <sub>0</sub>	after production	30	ASTM D3359	3M600	≥ 4B	t <sub>0</sub>	5B	5B	Pass
MSL3 + uHAST(B)	MSL3 30°C / 60%RH, 192 h uHAST 110°C / 85%RH, 264 h	30	ASTM D3359	3M600	≥ 4B	264 h	5B	4B	Pass
MSL3 + TCT(N)	MSL3 30°C/60%RH, 192 h TCT -40°C/85°C, 1,000 cy	30	ASTM D3359	3M600	≥ 4B	500 cy ; 1,000 cy	5B	5B	Pass
HTST	HTST 125°C, 1000 h	30	ASTM D3359	3M600	≥ 4B	500 h ; 1,000 h	5B	4B (500h); 3B (1,000h)	Improving

t <sub>0</sub>				MSL3 + uHAST		MSL3 + TCT		HTS	
-				110°C / 85%RH / 264h		-40/+85°C / 1,000 cycles		125°C / 1,000h	
Topside	Sidewall	Topside: 5B	Sidewall: 5B	Topside: 5B	Sidewall: 4B	Topside: 5B	Sidewall: 5B	Topside: 5B	Sidewall
									4B (500h) 3B (1,000h)



## COATING APPEARANCE, LASER MARK READABILITY

- Coating appearance
  - Color is consistent over the produced units
  - Color at  $t_0$  is within one Pantone range
  - Color after reflow is within one Pantone range

Dummy packages		Measurement setup		Judgement
Item	Sample size	Light source	Judgement distance	Range no.
$t_0$	100	D65 (6,500K)	30 cm	7528U
Reflow	100	D65 (6,500K)	30 cm	4685U



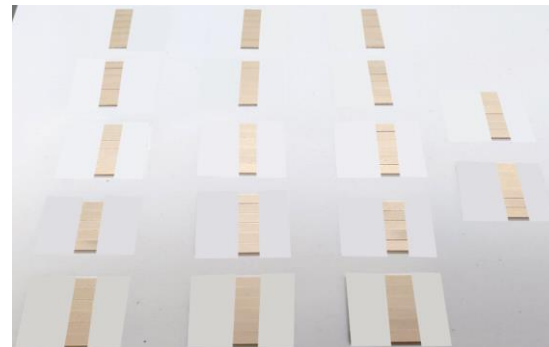
- Laser mark readability
  - Coated letters and figures are machine readable
  - Coated QR codes are machine readable

QR code types		Measurement setup	Judgement
Cell size	Depth	Equipment	Machine readable
200 $\mu\text{m}$	25 $\mu\text{m}$ 50 $\mu\text{m}$	Cognex barcode reader	Yes
150 $\mu\text{m}$			Yes
120 $\mu\text{m}$			Yes
75 $\mu\text{m}$			Yes

Color appearance at  $t_0$



Color appearance after reflow



Color reference



QR code at  $t_0$



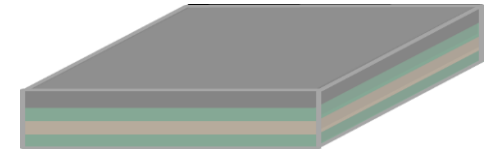
QR code after uHAST



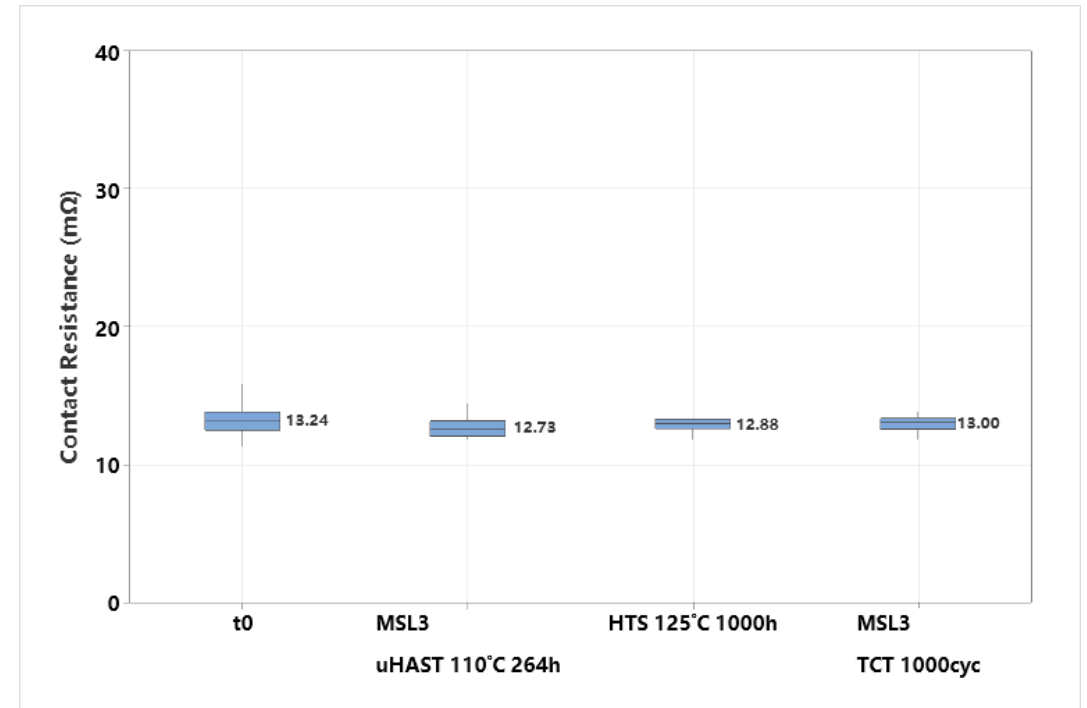
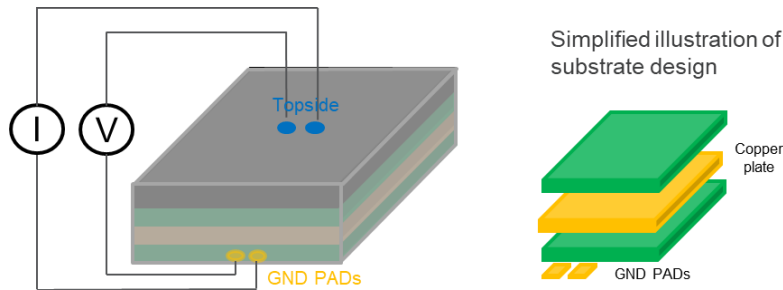


# ELECTRICAL CONDUCTIVITY AFTER RELIABILITY

- No degradation of conductivity after reliability
- Contact resistance measurement
  - Keysight 34465A DMM (4-point probe)
  - From coating topside to contact pads

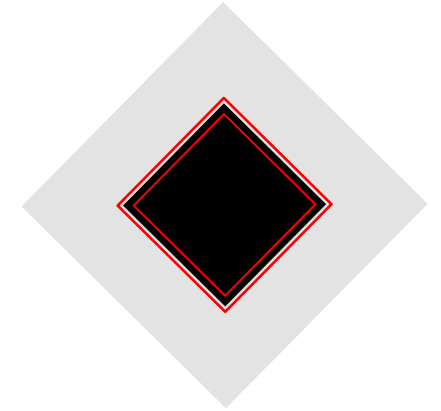


Dummy packages			Judgement	
Item	Condition	Sample size	Readout	Contact resistance
t <sub>0</sub>	after production	30	t <sub>0</sub>	13 mΩ
MSL3 + uHAST(B)	MSL3 30°C / 60%RH, 192 h uHAST 110°C / 85%RH, 264 h	30	264 h	13 mΩ
MSL3 + TCT(N)	MSL3 30°C/60%RH, 192 h TCT -40°C/85°C, 1,000 cy	30	1,000 cy	13 mΩ
HTST	HTST 125°C, 1000 h	30	1,000 h	13 mΩ



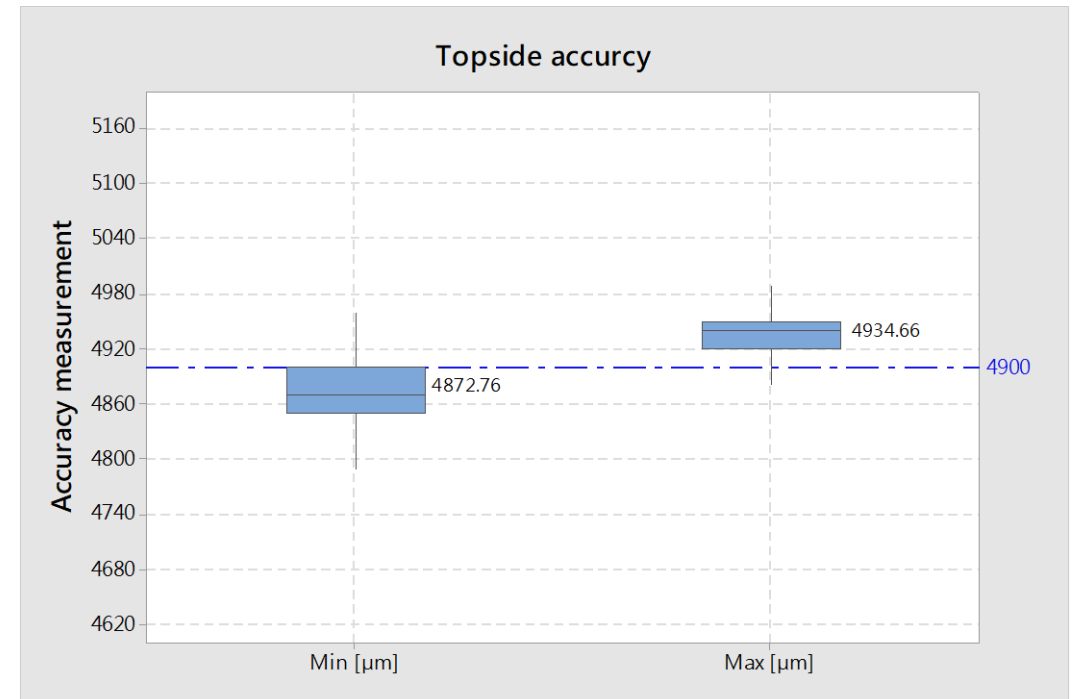
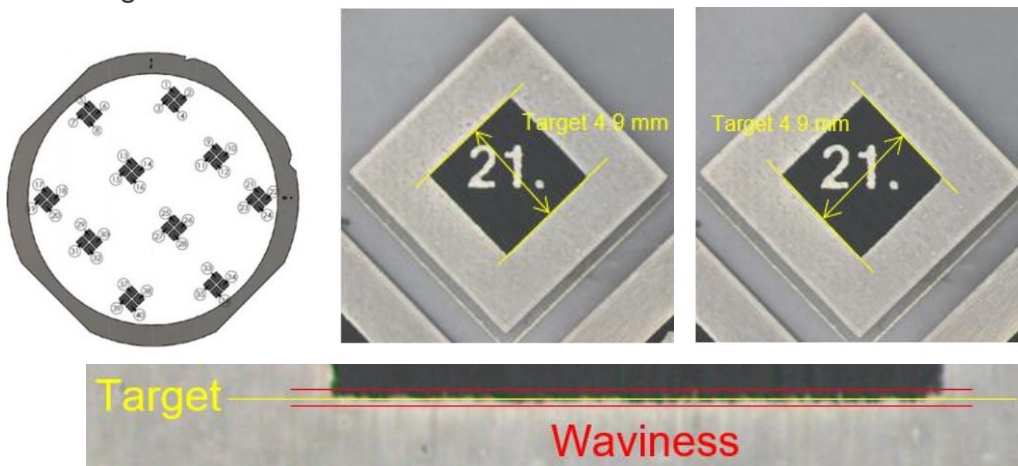
## PES 2110 PRINT ACCURACY AT TOPSIDE

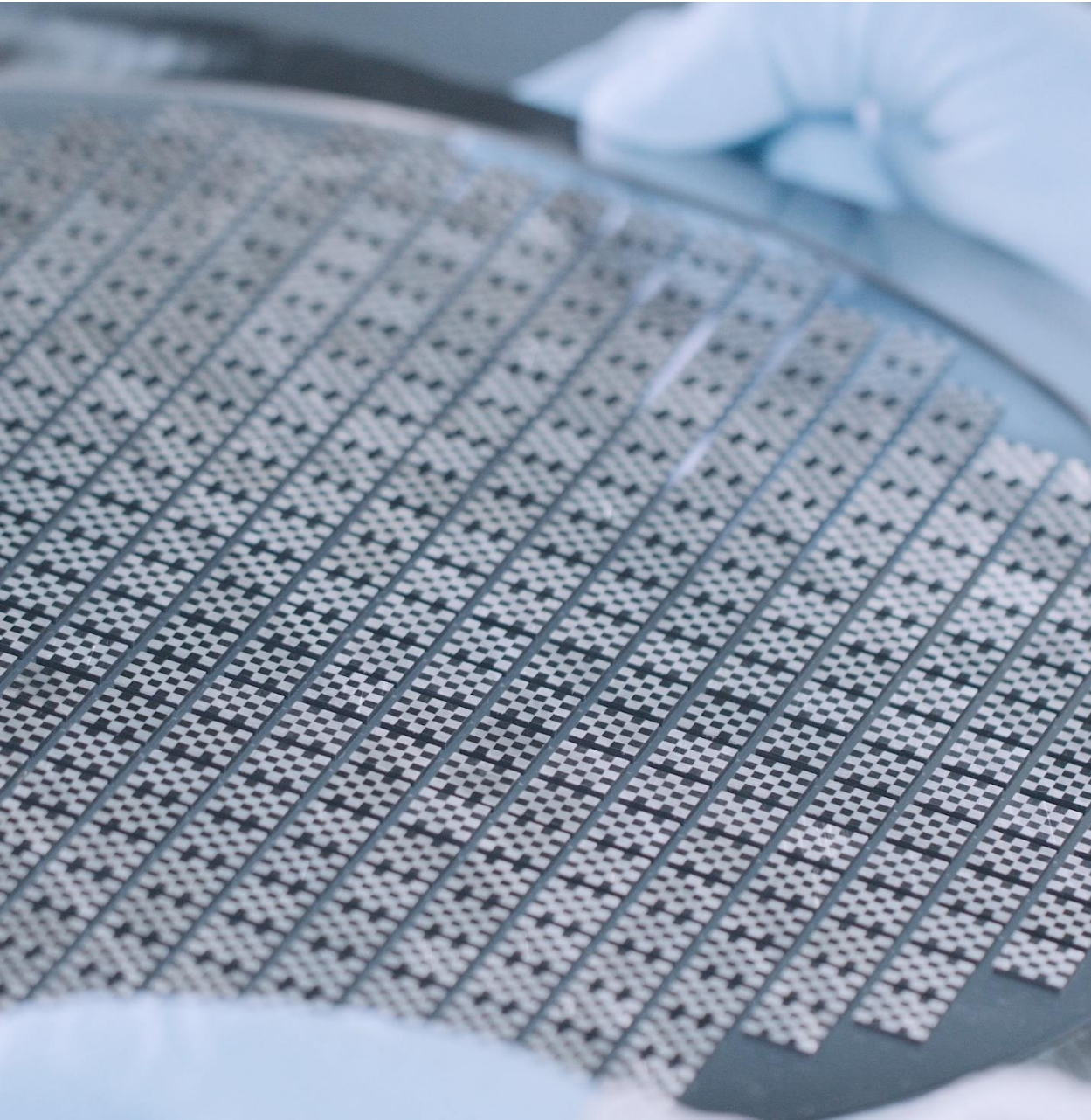
Dummy packages		Measurement setup		Accuracy	
Item	Sample size	Printer	Measurement tool	Overall AVG	Overall STD
Topside accuracy	1,000	PES 2110	Zeiss microscope	4,904 $\mu\text{m}$	41.2 $\mu\text{m}$



### Measurement setup

- Evaluation on continuous production
- 4 packages per group; 10 groups per wafer ring, 25 rings in total
- Evaluation on printing accuracy of whole printhead set onto 12" wafer ring area





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## PACKAGE DESIGN FREEDOM

**With Heraeus Prexonics® selective printing capability, package designers don't have to be constrained by the limitation of PVD sputtering.**

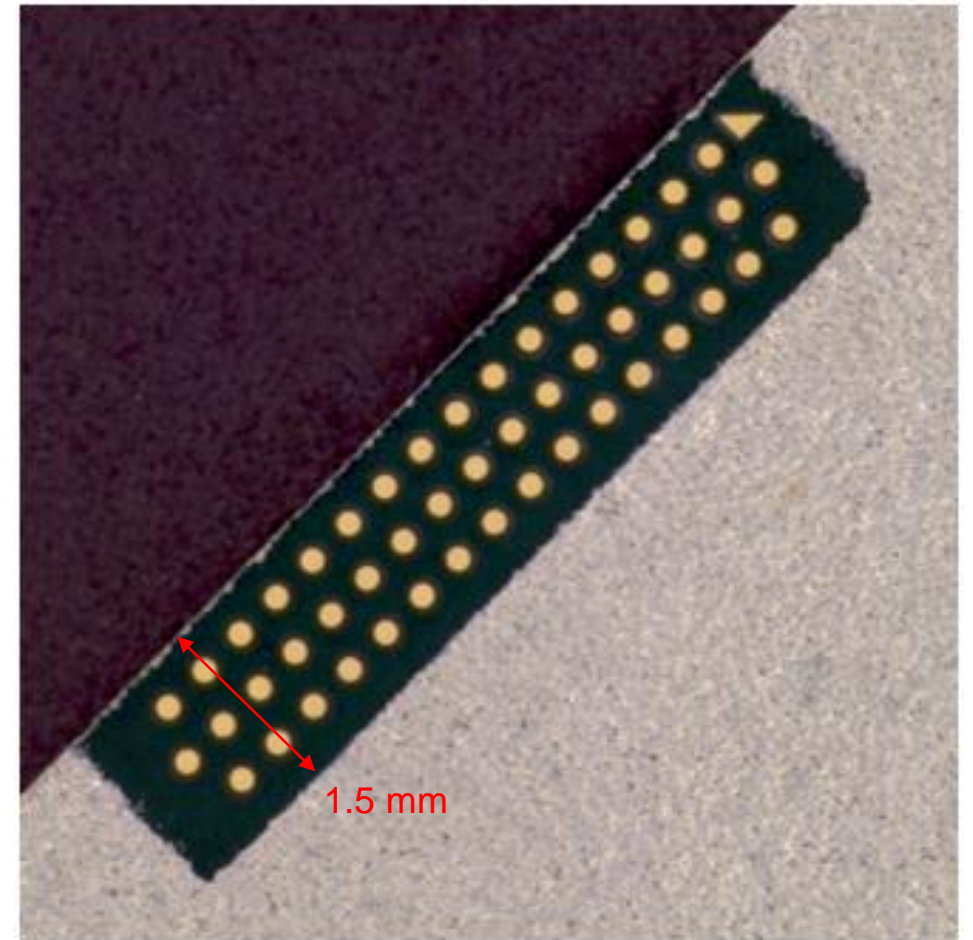
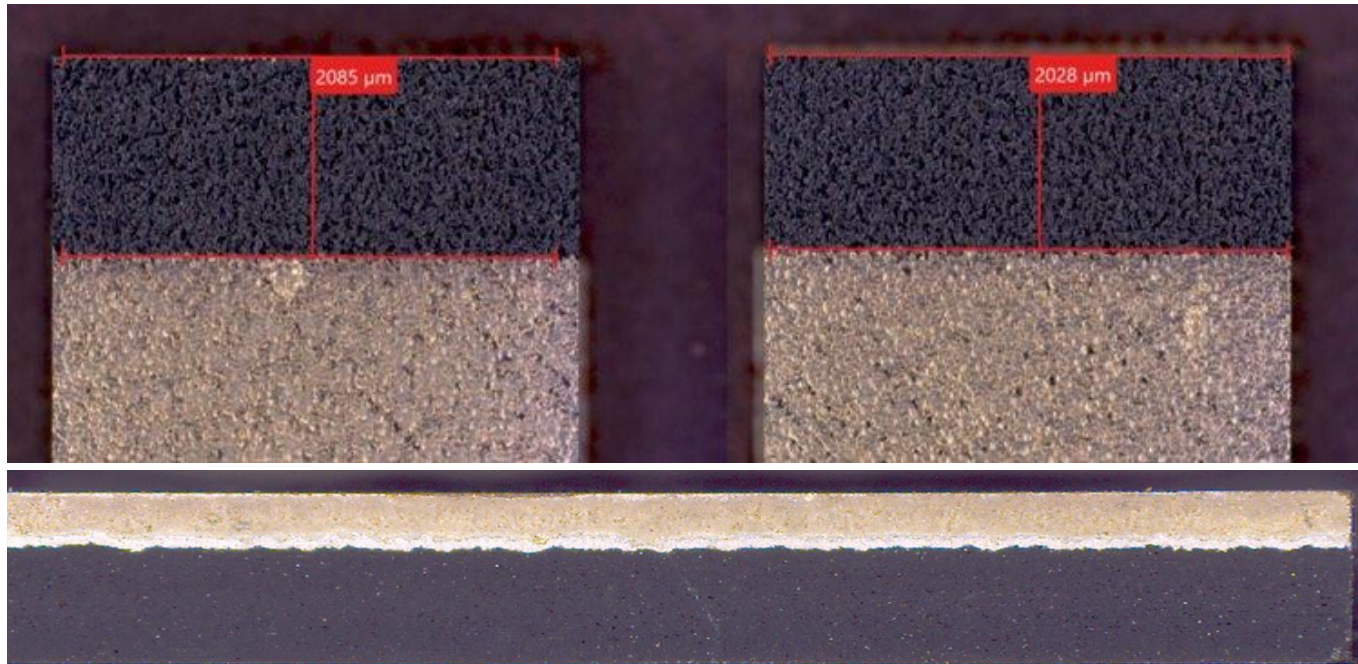
### **You have the possibility to:**

- redesign package layout, such as grounding pins shape and size
- adopt new grounding technology, such as grounding position and height of sidewall stand-off, hence flexibility in substrate design and requirement
- develop roadmap to improve thermal management: selective printing for SiP multi-chip area for heat dissipation

Heraeus

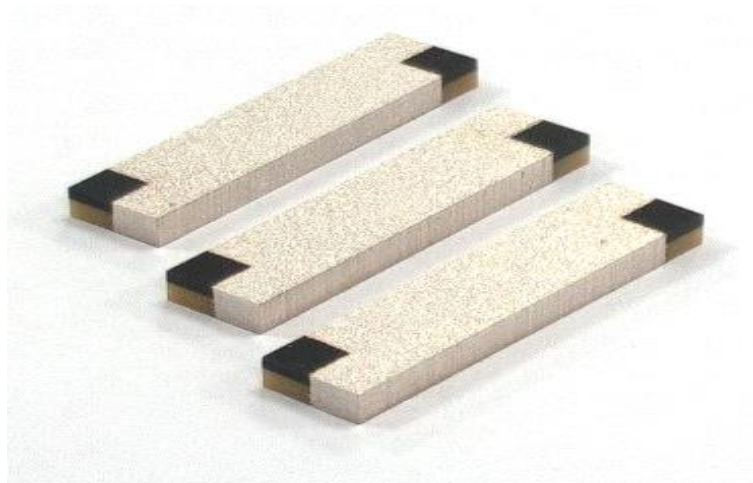


# PICTURES OF SELECTIVE COATING

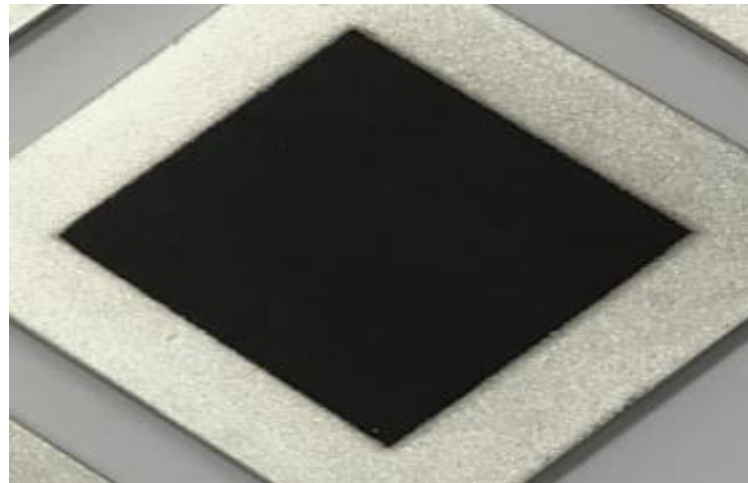


## HERAEUS INKJET PRINTING ENABLES SELECTIVE PRINTING

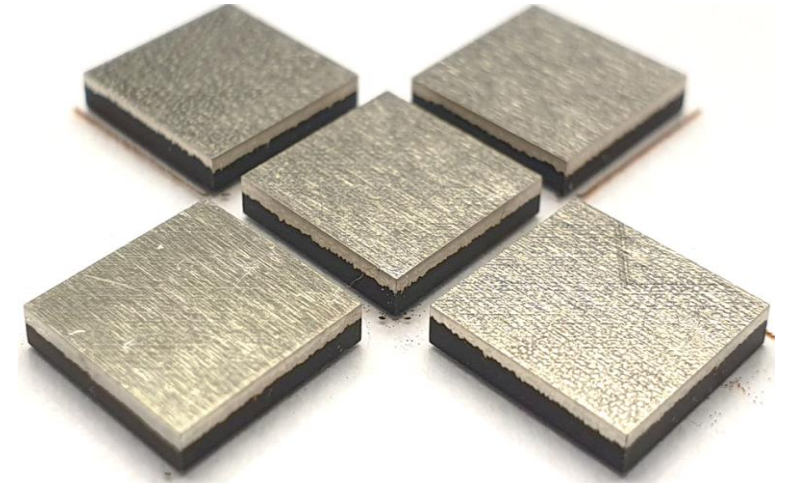
### Selective Printing



### Example 1



### Example 2



- Selective printing without additional masking or etching process
- Different stand-offs possible by tailored print data generation

- Selective printing on topside

- Sidewall stand-off printing

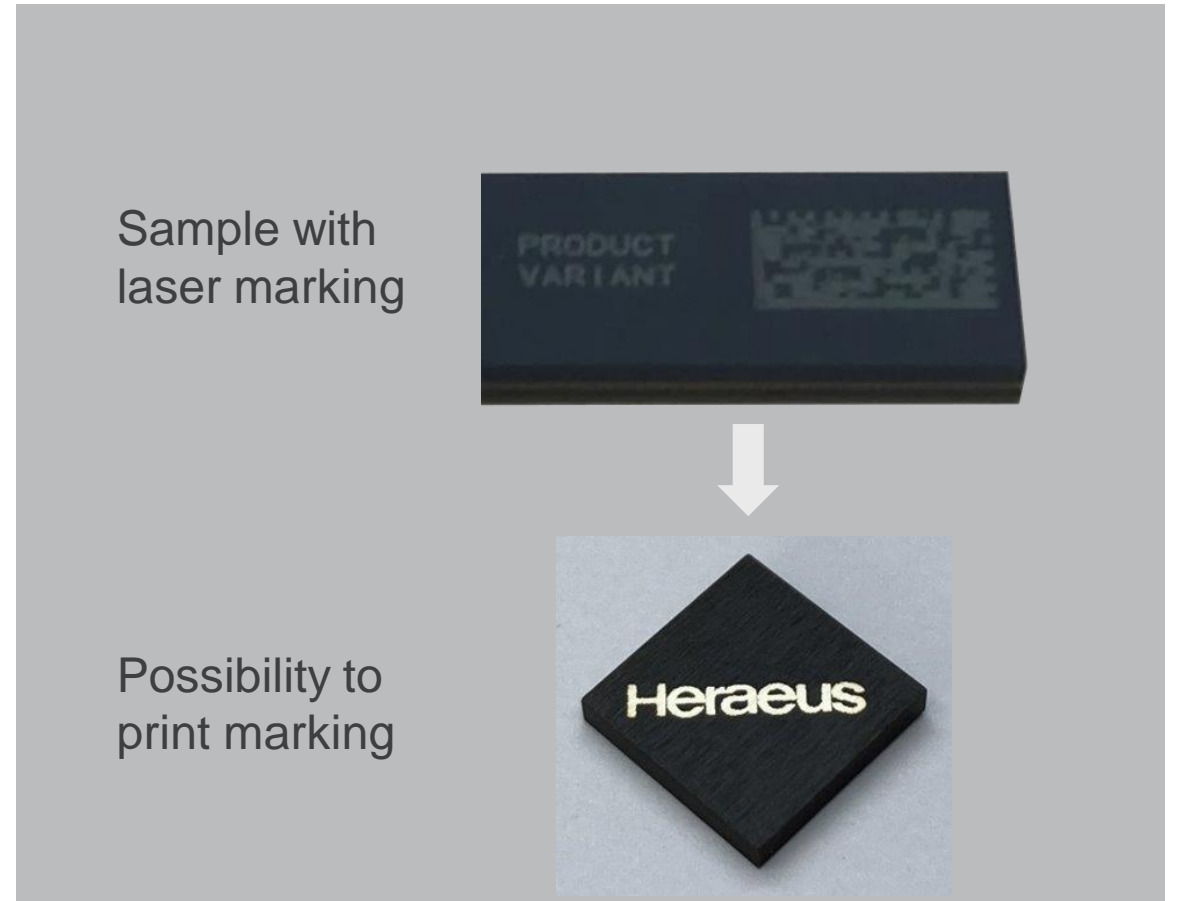


## POSSIBLE FUTURE APPLICATIONS



**Evaluate Heraeus Prexonics® selective printing capability for 2D barcode printing as an alternative for laser marking.**

- possibility to simplify the backend process post-molding by combining 2D barcode with EMI Shielding coating
- possibility for package height reduction in line with miniaturization roadmap



## PREXONICS® - A WIDE RANGE OF POTENTIAL APPLICATIONS

### EMI shielding package-level

Including selectively coating (maskless)  
on EMC and other substrates

### Exposed-die design packages

Direct coating with Ag-ink on both Si  
surface and EMC

### TIM (Thermal Interface Material)

Use of Ag-ink structures to provide  
superior heat dissipation due to high  
thermal conductivity of Ag

### BSM (Back-Side Metallization)

Improving performance by better  
electrical and thermal connection to  
circuit components



### Fine-line printing

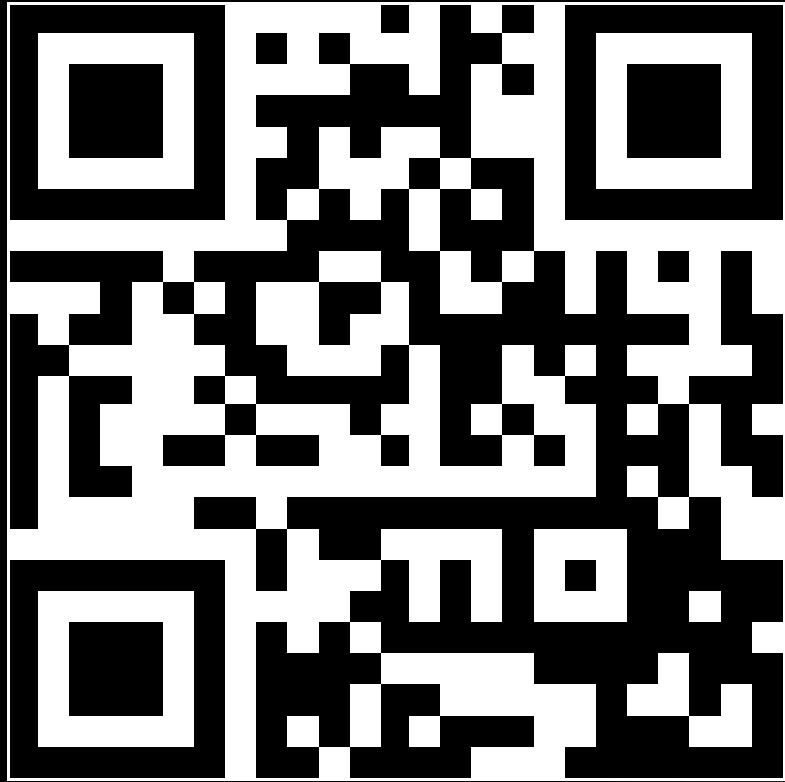
Printing of conductive traces on various  
substrates (EMC, glass, ceramic, PI,..)

### Antenna printing

Printing of antenna structures on  
different shaped EMC's

### Replacement for Electroplating

Selective printing of Ag-ink on contact  
areas of interconnect devices



THANKS FOR YOUR ATTENTION!