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INKJET PRINTING FOR SEMICONDUCTOR PACKAGING

IMAPS, Device Packaging Conference
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Author: Joost Hermans



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WHY SHOULD WE USE INKJET PRINTING?



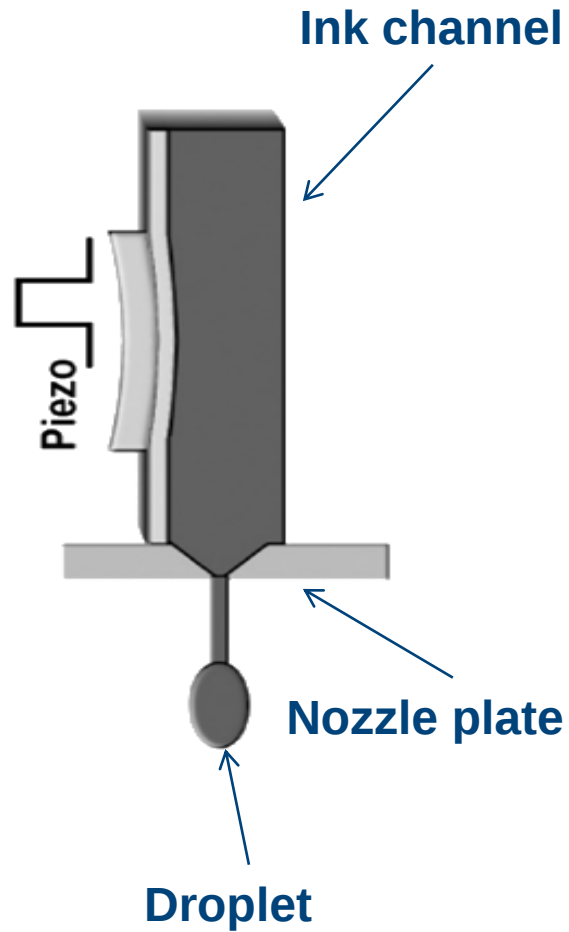
WHY SHOULD WE USE INKJET PRINTING

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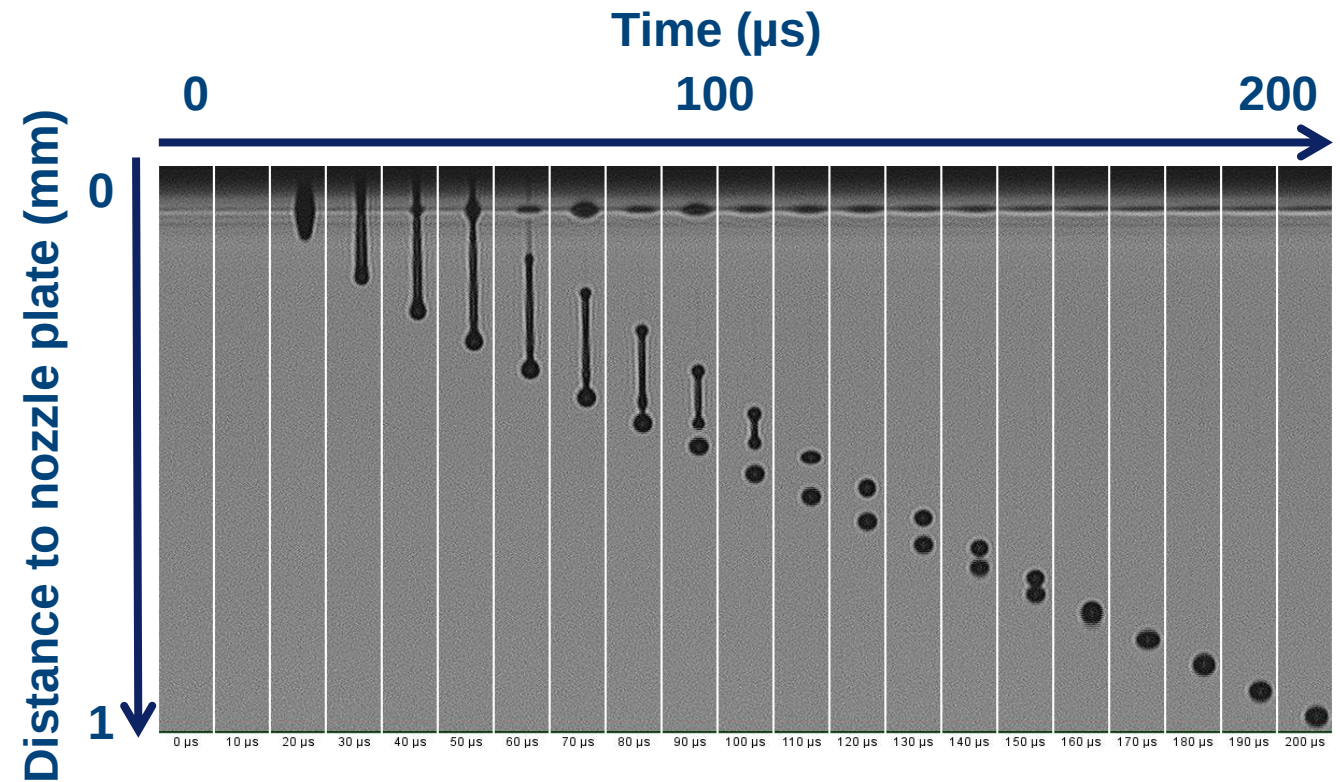
- + What is inkjet printing?
- + What are the advantages of inkjet printing?
- + What materials can be inkjet printed?
- + Which application can be addressed with inkjet printing?

WHAT IS INKJET PRINTING?

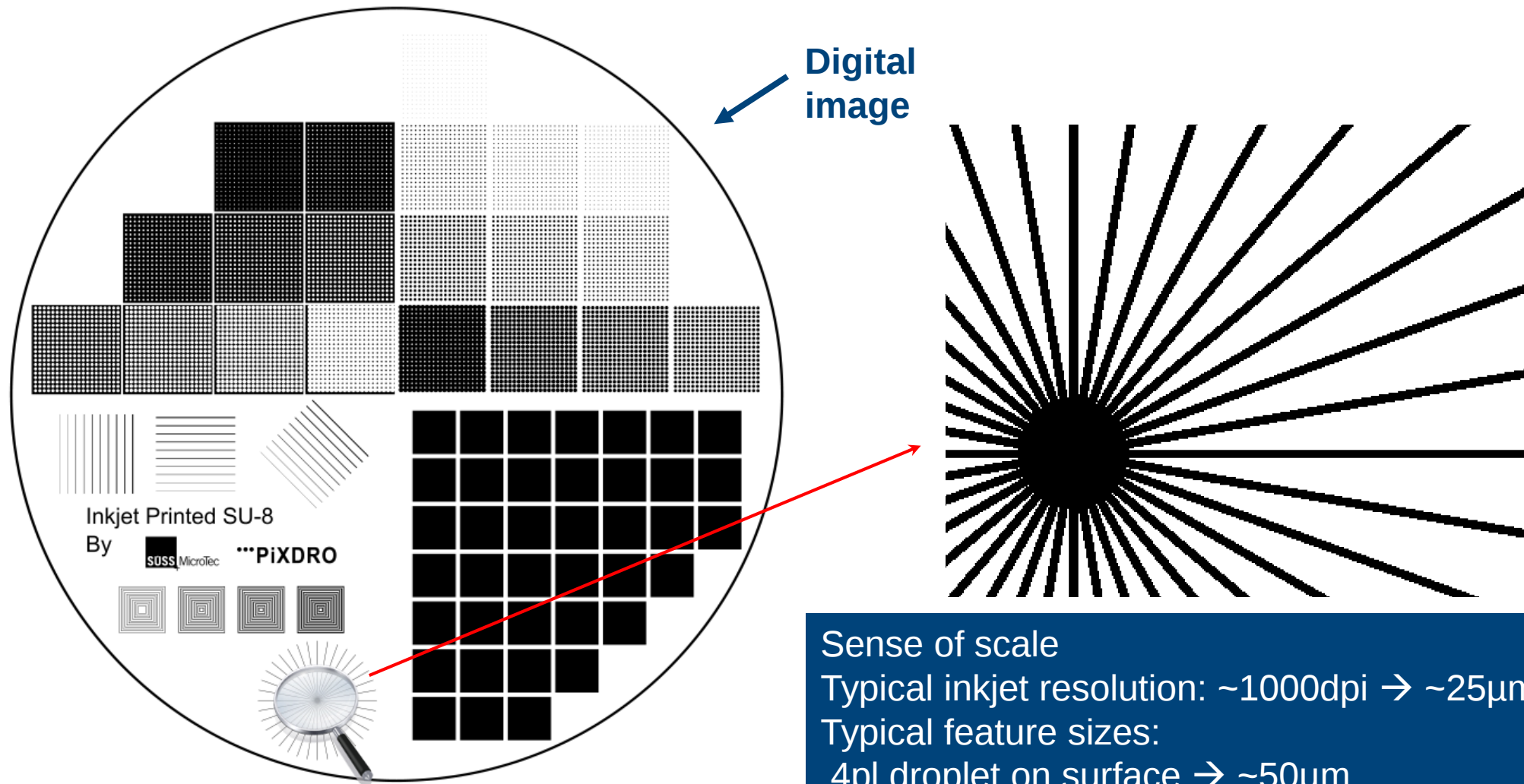
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Sense of scale

4 pL droplet = $\sim 20\text{ }\mu\text{m}$ diameter30 pL droplet = $\sim 40\text{ }\mu\text{m}$ diameter

WHAT IS INKJET PRINTING?



Sense of scale

Typical inkjet resolution: $\sim 1000\text{dpi} \rightarrow \sim 25\mu\text{m}$ per pixel

Typical feature sizes:

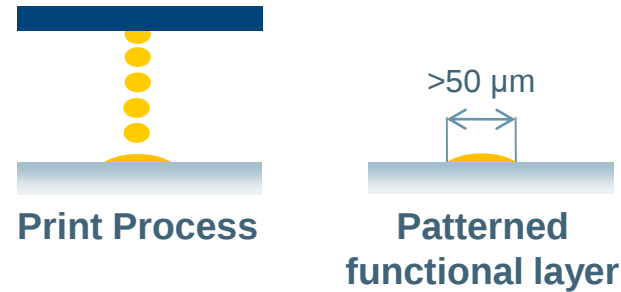
4pl droplet on surface $\rightarrow \sim 50\mu\text{m}$

30pl droplet on surface $\rightarrow \sim 100\mu\text{m}$

WHAT IS INKJET PRINTING?

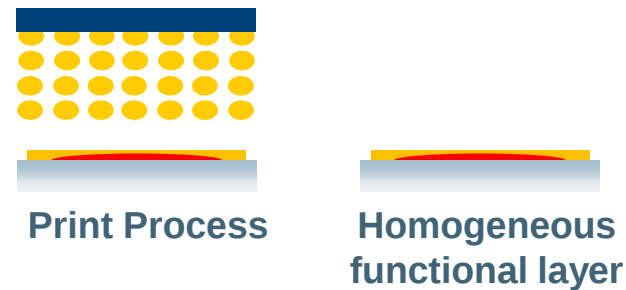
Direct patterning

- Functional materials



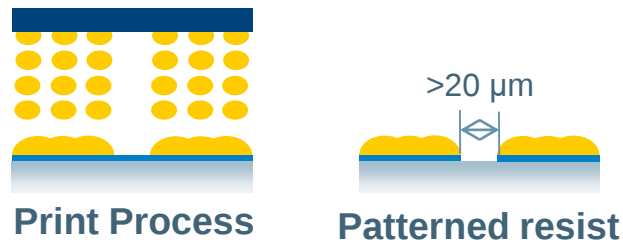
Homogeneous layers

- Passivation coatings
- Encapsulation



Resist

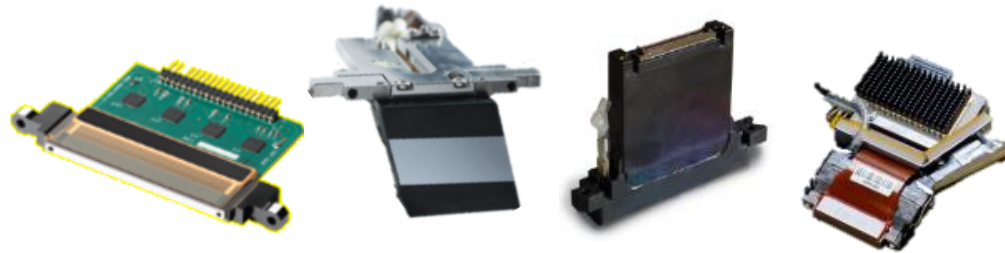
- Solder resist
- Etching
- Plating



Sense of scale: Feature sizes:
Positive features $\rightarrow >50\mu\text{m}^*$
Negative features $\rightarrow >20\mu\text{m}^*$

* Highly depends on interaction of ink with substrate

WHAT IS INKJET PRINTING?



Supplier	Fujifilm Dimatix		Konica Minolta	Canon	
Series	Q-Class	Samba	KM1024i	C29	
Nozzles	256	2048	1024	256	#
Nozzle density	100	1200	360	150	DPI
Maximum frequency	50	100	50	18.7	kHz
Native drop volume	10 – 80	2.5	6 – 30	29	pL
Maximum temperature	90	60	55	145	°C



NOTE: Other printheads may also be integrated

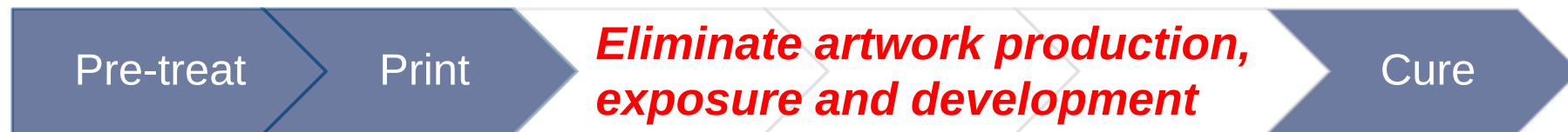
Sense of scale
 Typical print time for 8 or 12 inch wafer → ~ 1 minute*
 * Highly depending on specific process requirements

WHAT ARE THE ADVANTAGES OF INKJET PRINTING?

Traditional process flow



Inkjet printing process flow



- + Reducing handling, floor space, maintenance and cleaning
- + Efficient material usage
- + Green process, less chemistry and less waste disposal
- + No more need for mask production, storage and logistics

WHAT ARE THE ADVANTAGES OF INKJET PRINTING?

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Digital patterning:

- + Individual scaling per product → to correct for deformation in upstream processes
- + Different image per product → with information from upstream processes
- + Quick turnaround, e.g. high mix
- + Variable layer thickness

Direct patterning:

- + No need for removal of materials

Non-contact deposition:

- + Printing on delicate surfaces
- + Compatible with non-flat topography

WHAT MATERIALS CAN BE INKJET PRINTED?

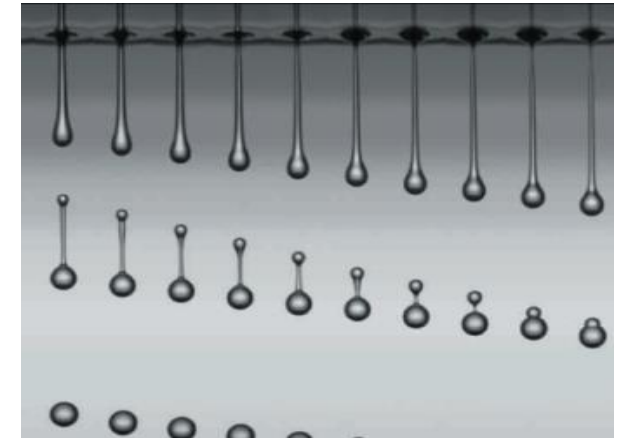
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Ink types	Polymers based on acrylate, epoxy and polyimide 100% solid or solvent based Nanoparticle dispersion Phase change (hotmelt)
Viscosity*	2 – 20 cPoise (mPa s)
Surface tension	24 – 36 Dyne/cm (mN/m)
Post treatments	Temperature curing UV curing Sintering (photonic, laser, heating)

Temporary materials	Permanent materials		
Resists	Dielectric	Adhesives	Conductive
Hotmelt	Polyimide	Adhesive	Ag nanoparticle
UV-curable resists	SU-8		Cu nanoparticle
Photo resist	Solder Mask		PEDOT:PSS

*Sense of scale,
viscosities:

Water:	1cP
Olive oil:	80cP
AZ P4620:	563cP

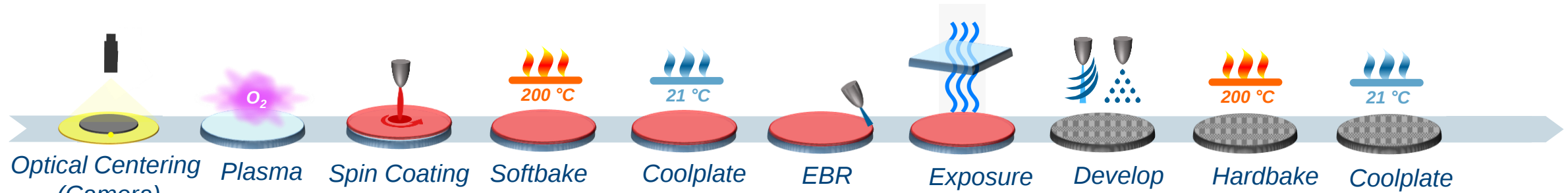


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INKJET PRINTING OF RESISTS

INKJET PRINTABLE PHOTORESIST

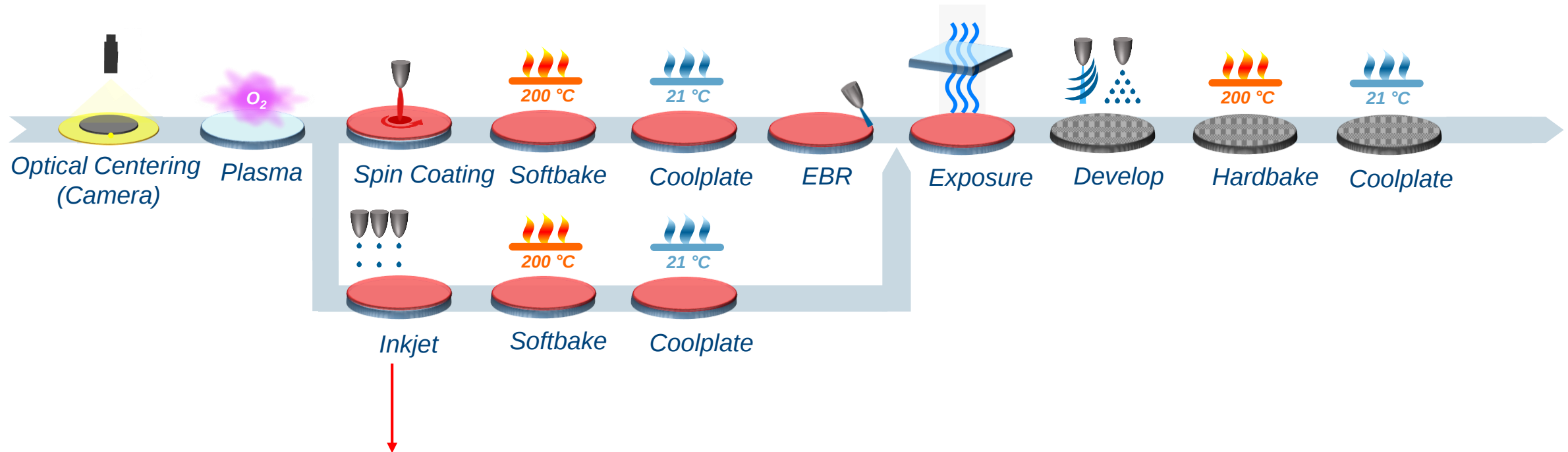
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~85% of photoresist wasted

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INKJET PRINTABLE PHOTORESIST

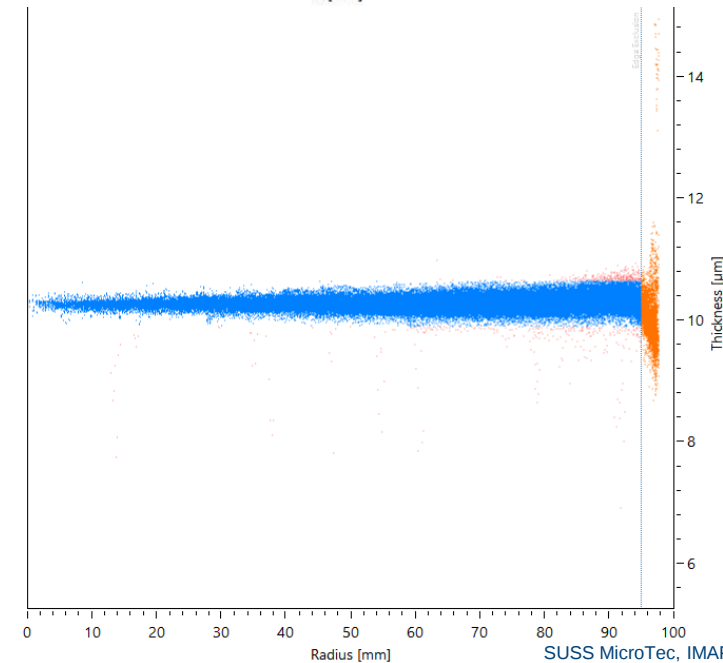
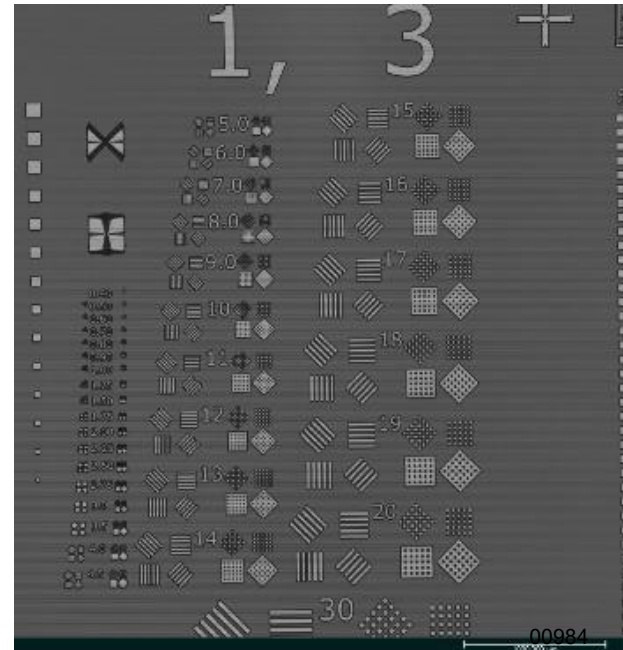
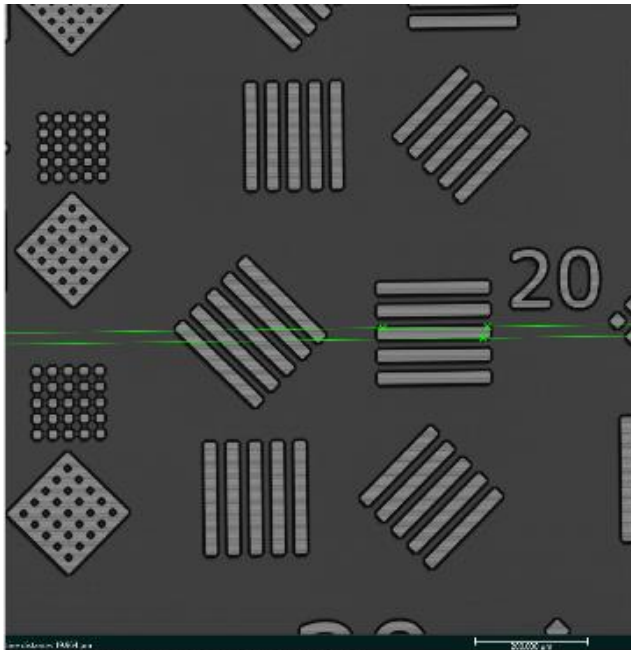
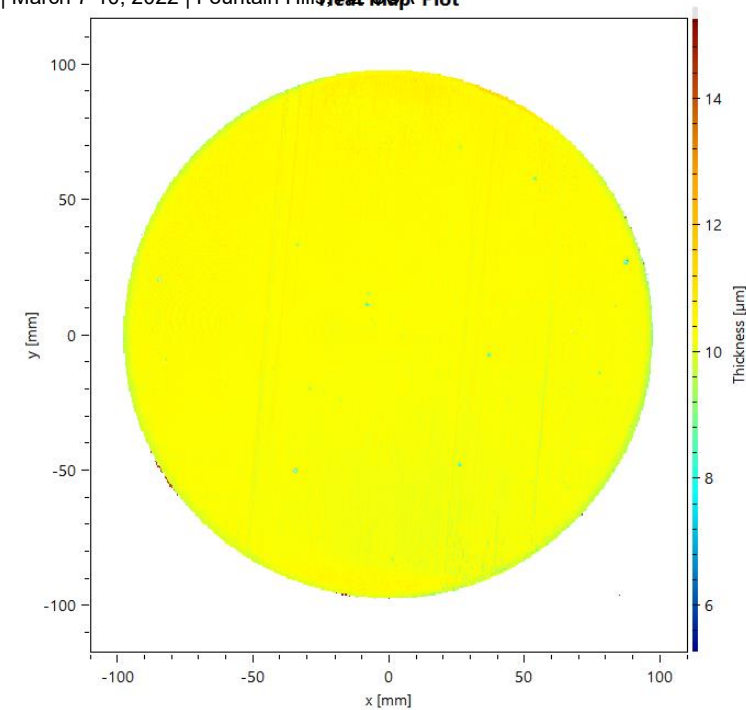


Inkjet printing deposits material
only where it is needed
→ no wasted photoresist

INKJET PRINTABLE PHOTORESIST

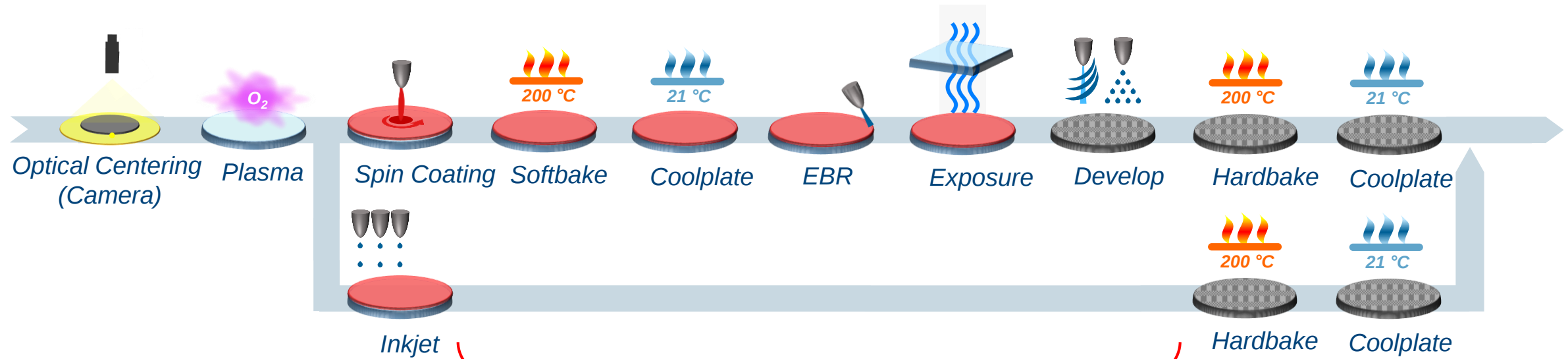
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- + AZ P4000 series resist adjusted for inkjet printing
- + Printed with 2.5mm edge exclusion
- + Layer thickness (after softbake):
 - Average: 10.3 μ m
 - StDev: 0.1 μ m (5mm edge exclusion)



PHOTORESIST

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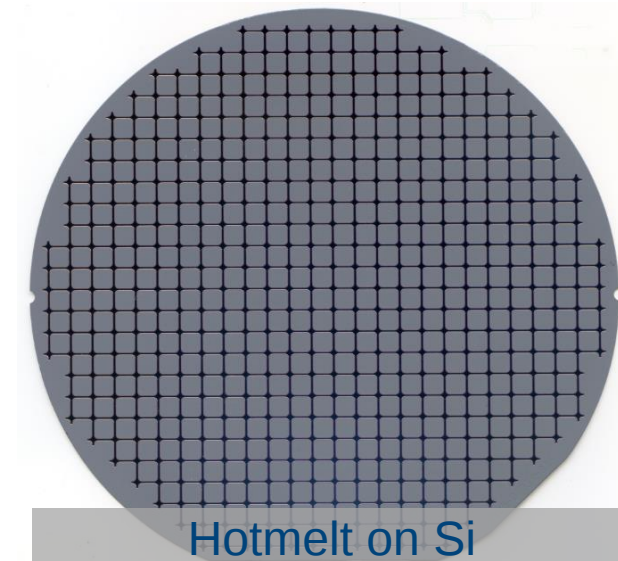
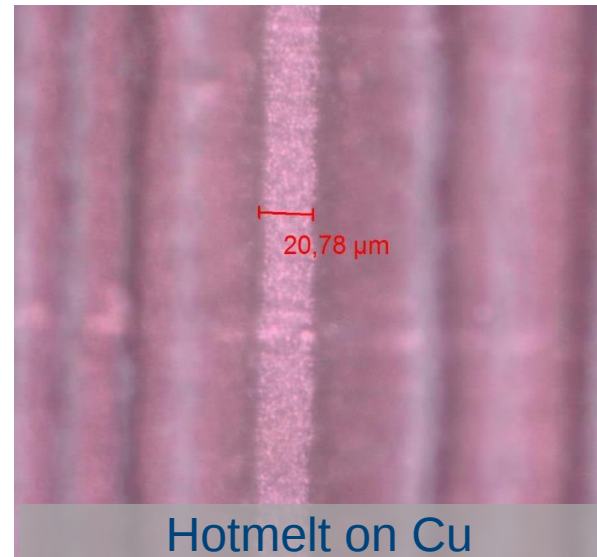
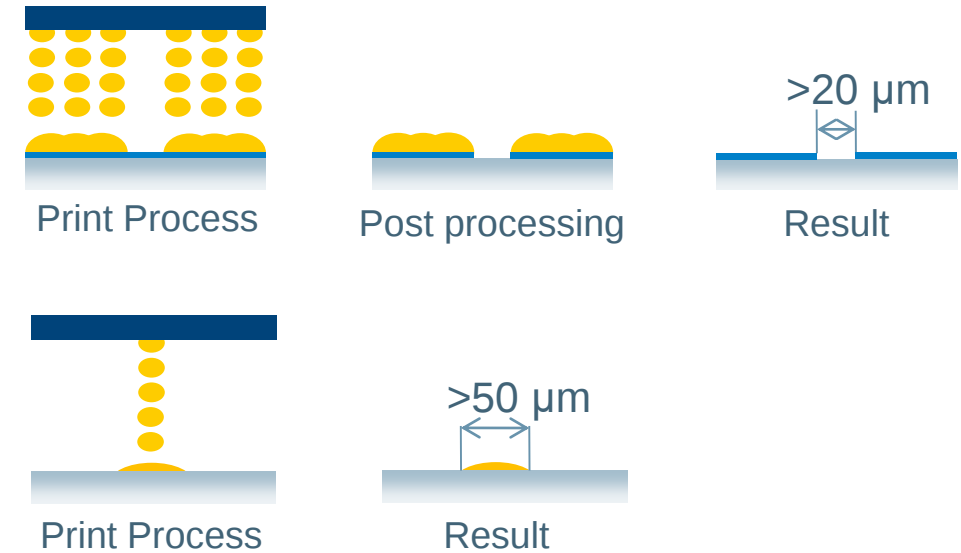
Why not skip the whole exposure & development step
→ directly patterned photoresist for feature size >100µm

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INKJET PRINTABLE RESISTS

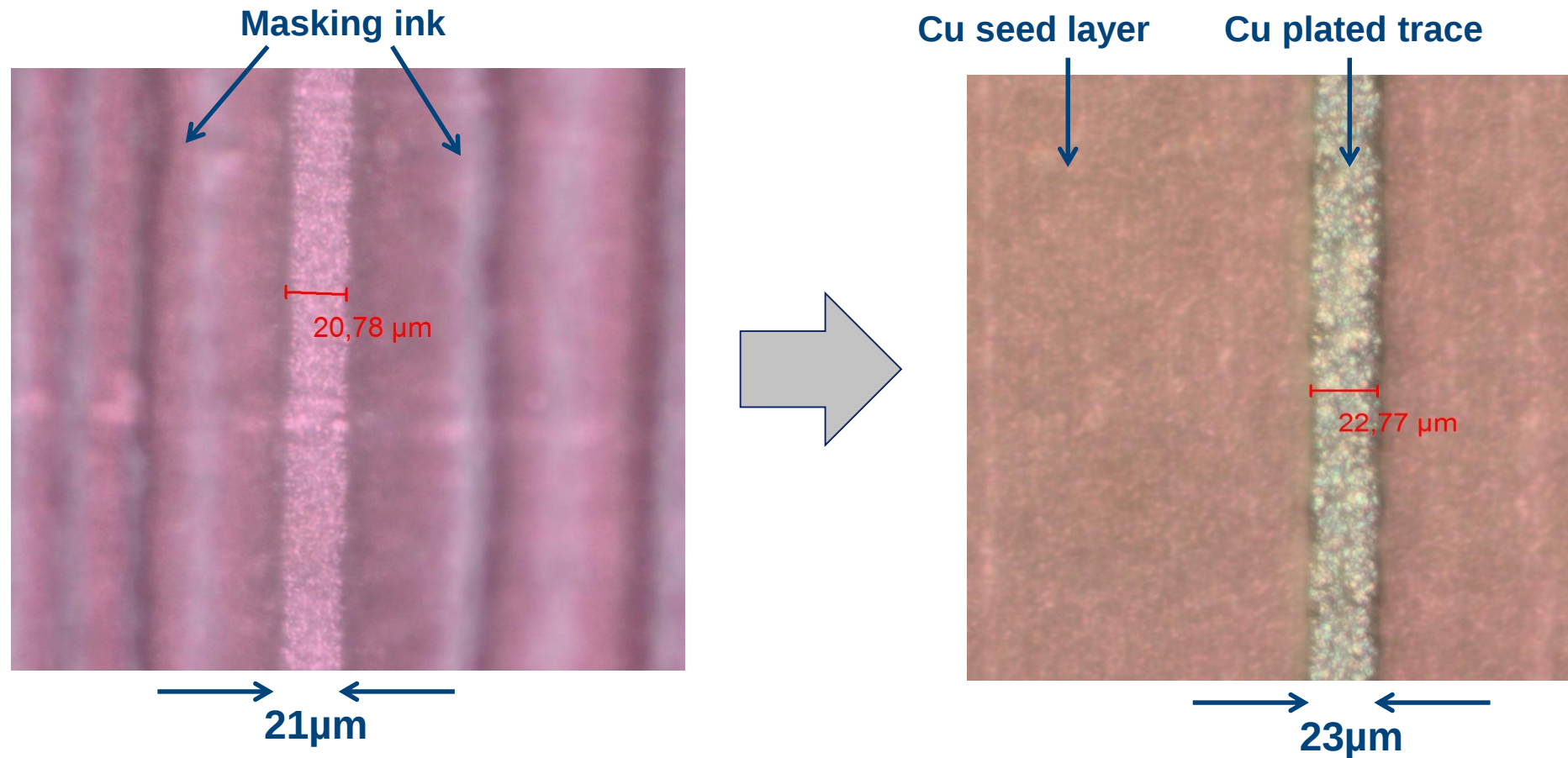
Ink types	Hotmelt, UV curable
Minimum feature size*	> 50/20 μm L/S
Layer thickness*	10 – 100 μm
Applications	Wet-chemical etching and plating
Properties	Acid resistant

**Actual performance depending on ink, process and substrate*



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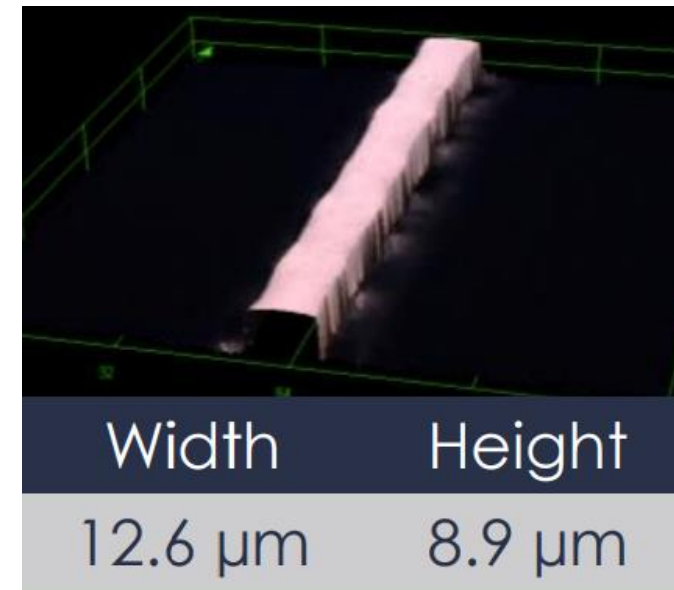
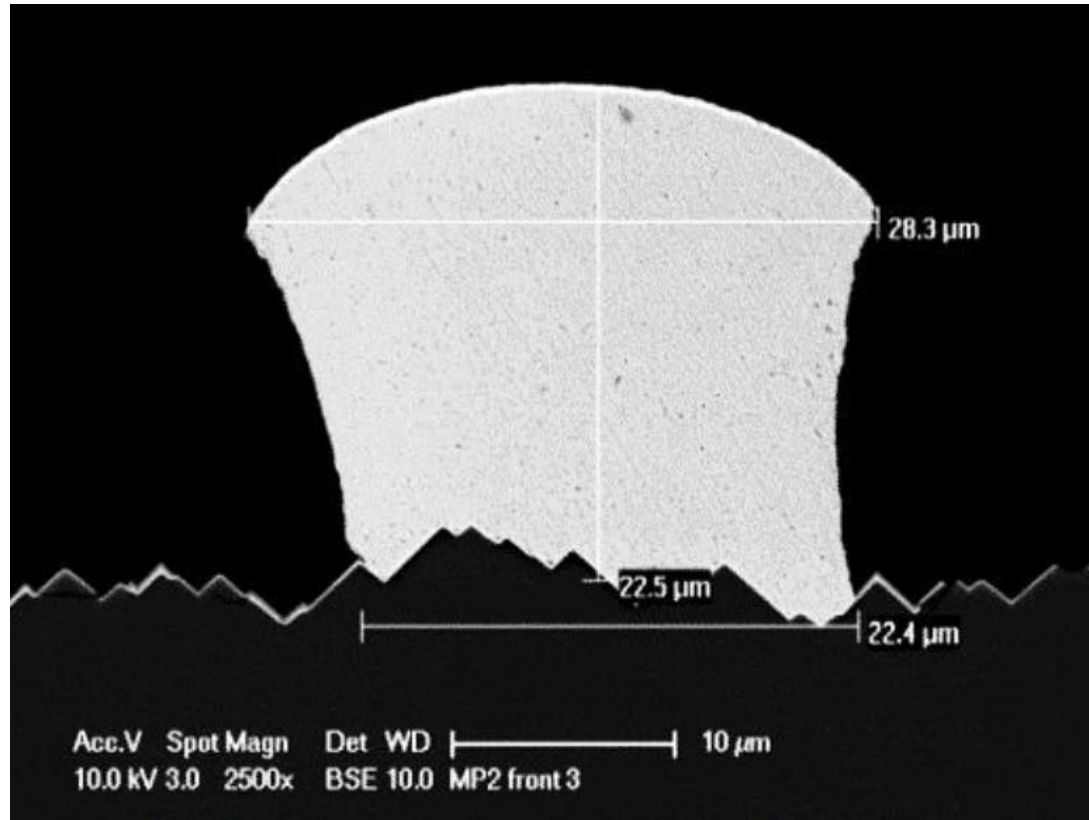
INKJET PRINTABLE RESISTS



- + Typical masking thickness of 1 layer: $\sim 40\ \mu\text{m}$ $\rightarrow$ multiple layers created thicker masks
- + Edge angle: $\sim 80^\circ$

INKJET PRINTABLE RESISTS

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Cu plated trace on Cu seed layer with inkjet printed plating resist
Courtesy CSEM, Switzerland

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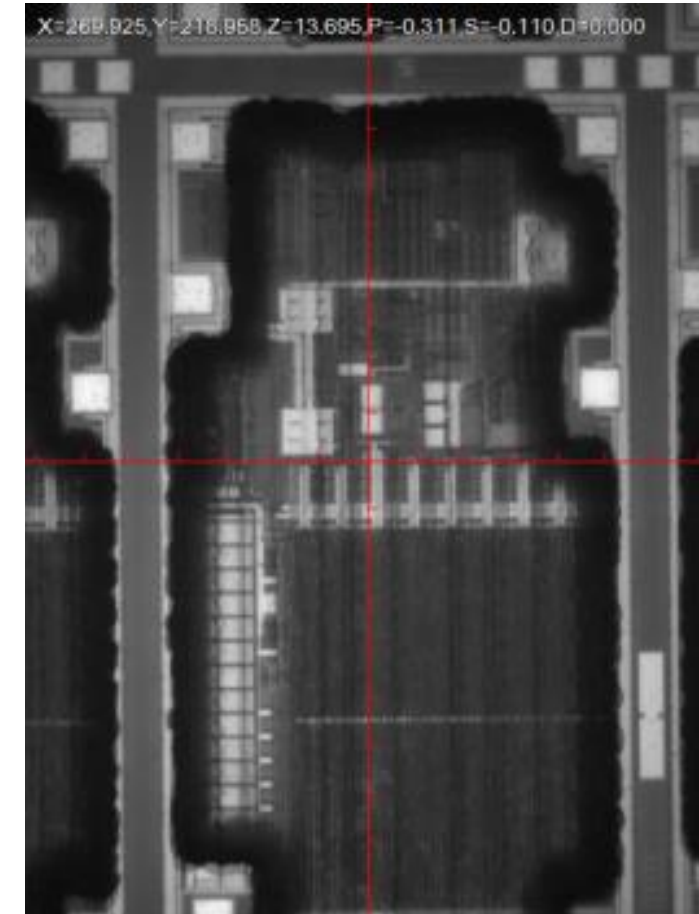
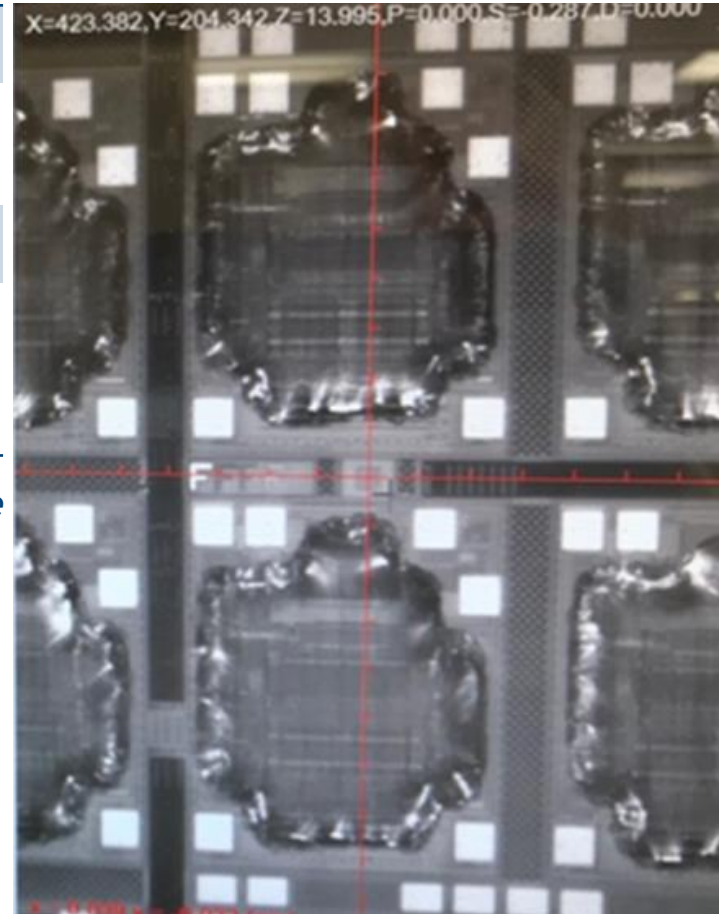
INKJET PRINTING OF DIELECTRICS

DIELECTRIC INKS

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Ink types	SU-8, Polyimide, Acrylate
Minimum feature size*	50 - 150 μm
Layer thickness*	1 - 100 μm
Applications	Isolation, protection, filling, stress buffer, encapsulation, solder resist

**Actual performance depending on ink, process and substrate*



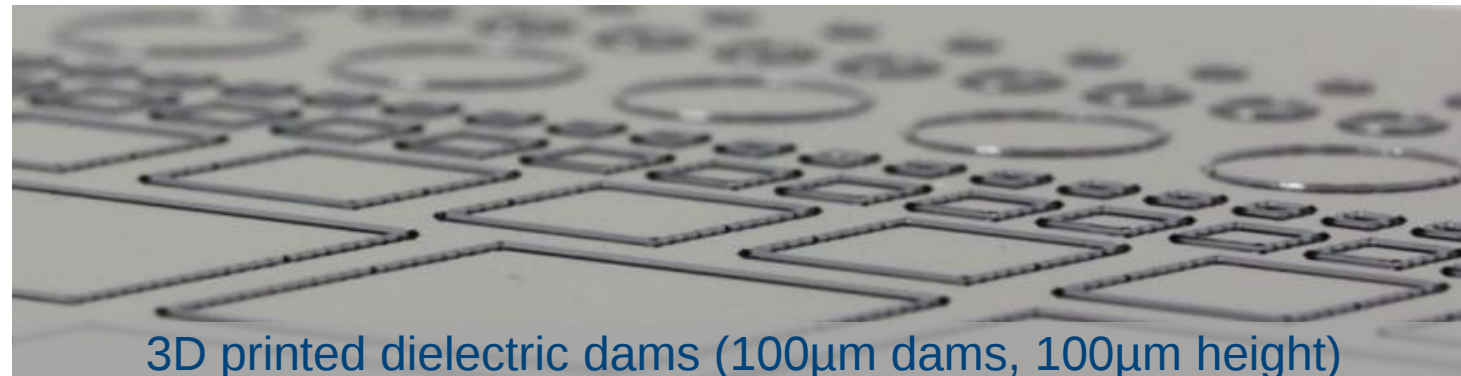
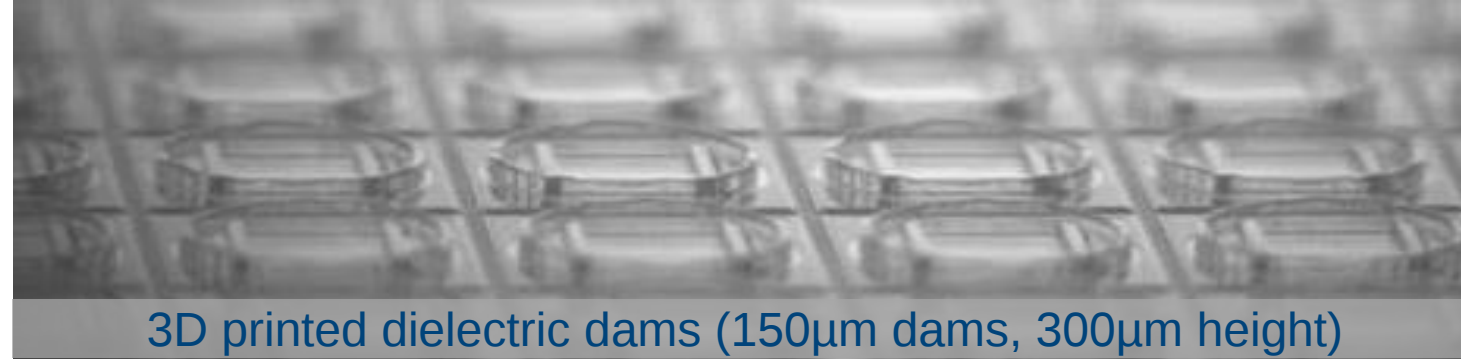
Stress buffer layers directly printed at wafer level
Courtesy Texas Instruments

DIELECTRIC INKS

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Ink types	SU-8, Polyimide, Acrylate
Minimum feature size*	50 - 150 μm
Layer thickness*	1 to >500 μm
Applications	Isolation, protection, filling, stress buffer, encapsulation, solder resist

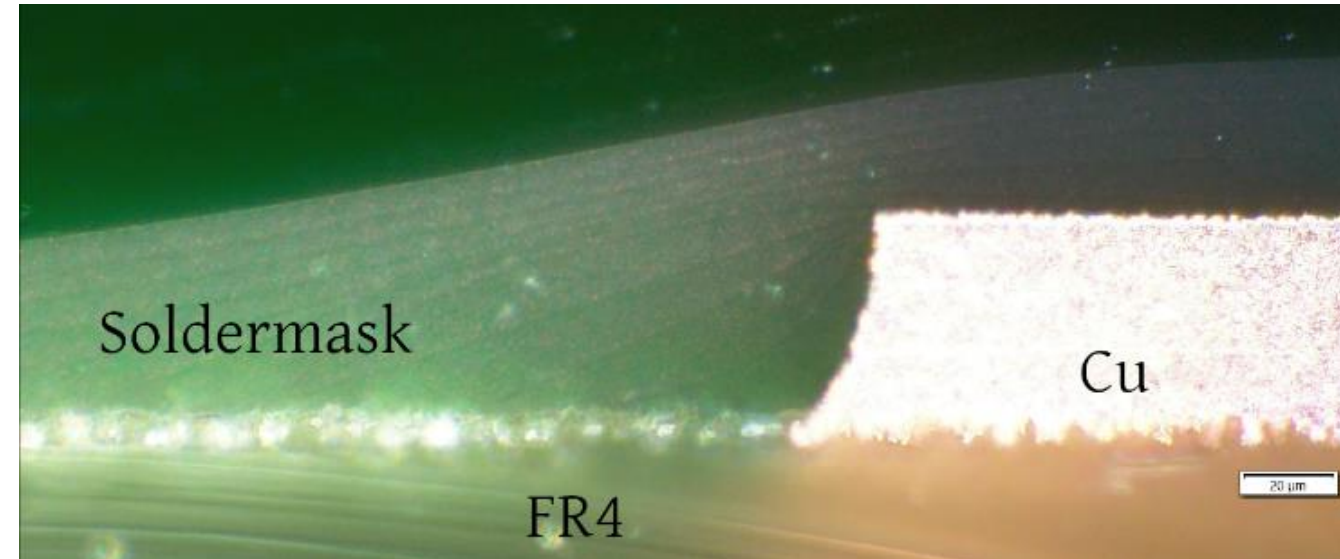
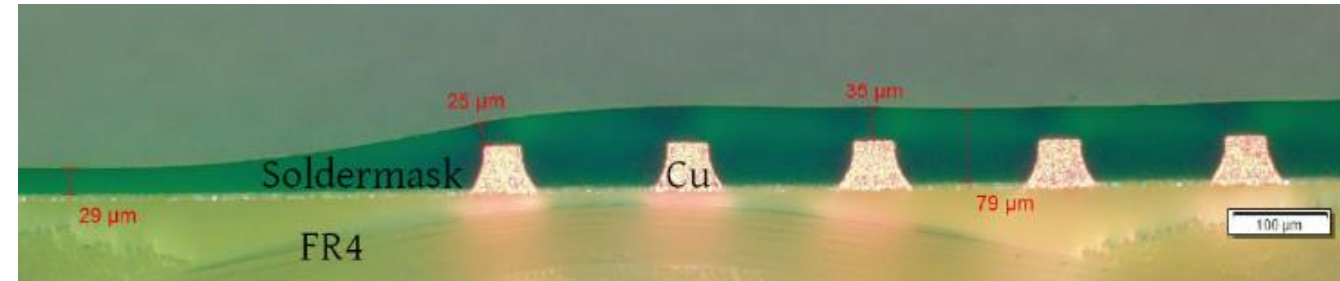
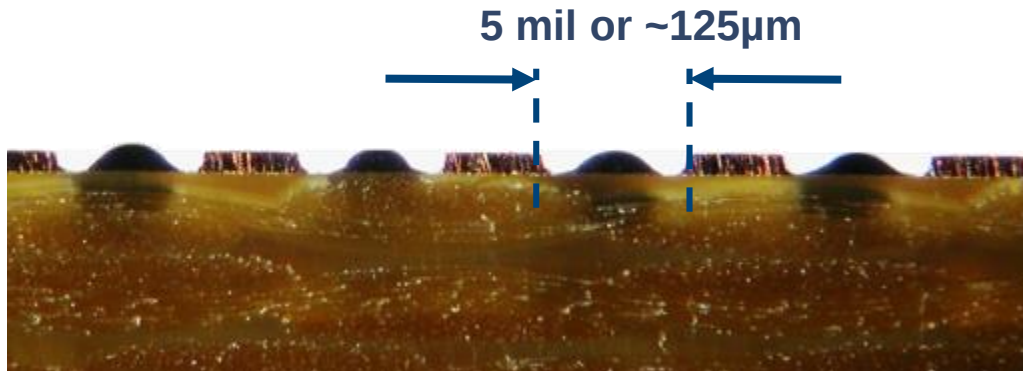
**Actual performance depending on ink, process and substrate*



SOLDER MASK ON PCB

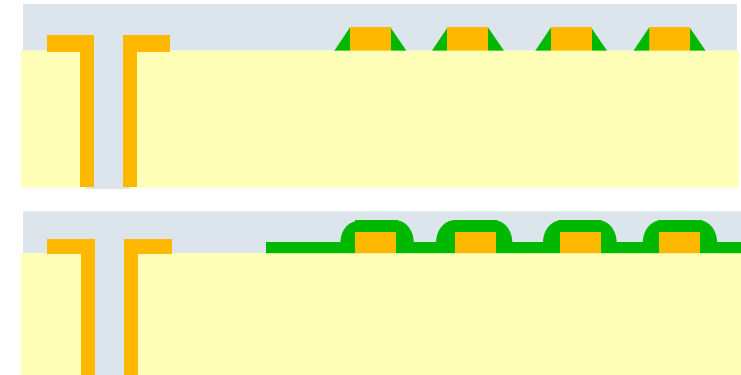
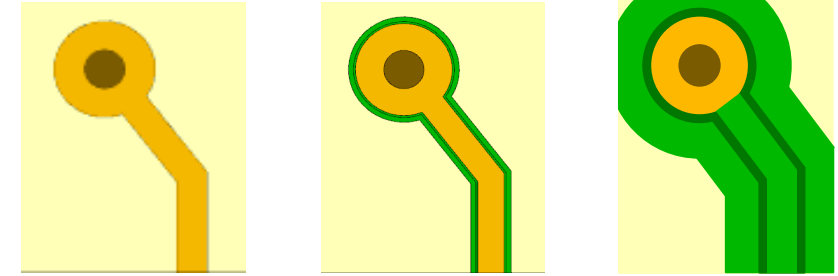
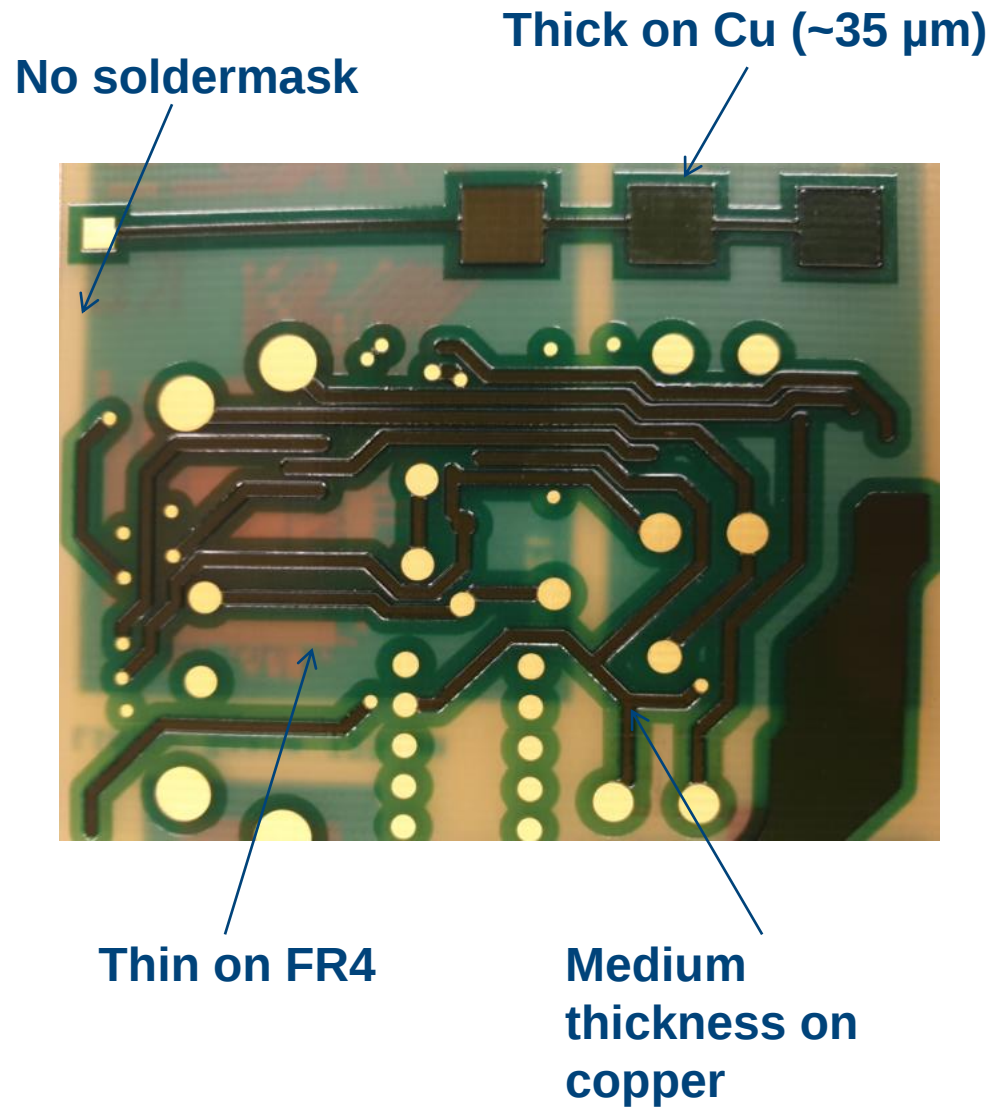
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Ink types	Solder mask
Minimum feature size*	>75 μm line/space
Layer thickness*	>5 μm
Applications	Isolation, protection, filling, stress buffer, encapsulation, solder resist



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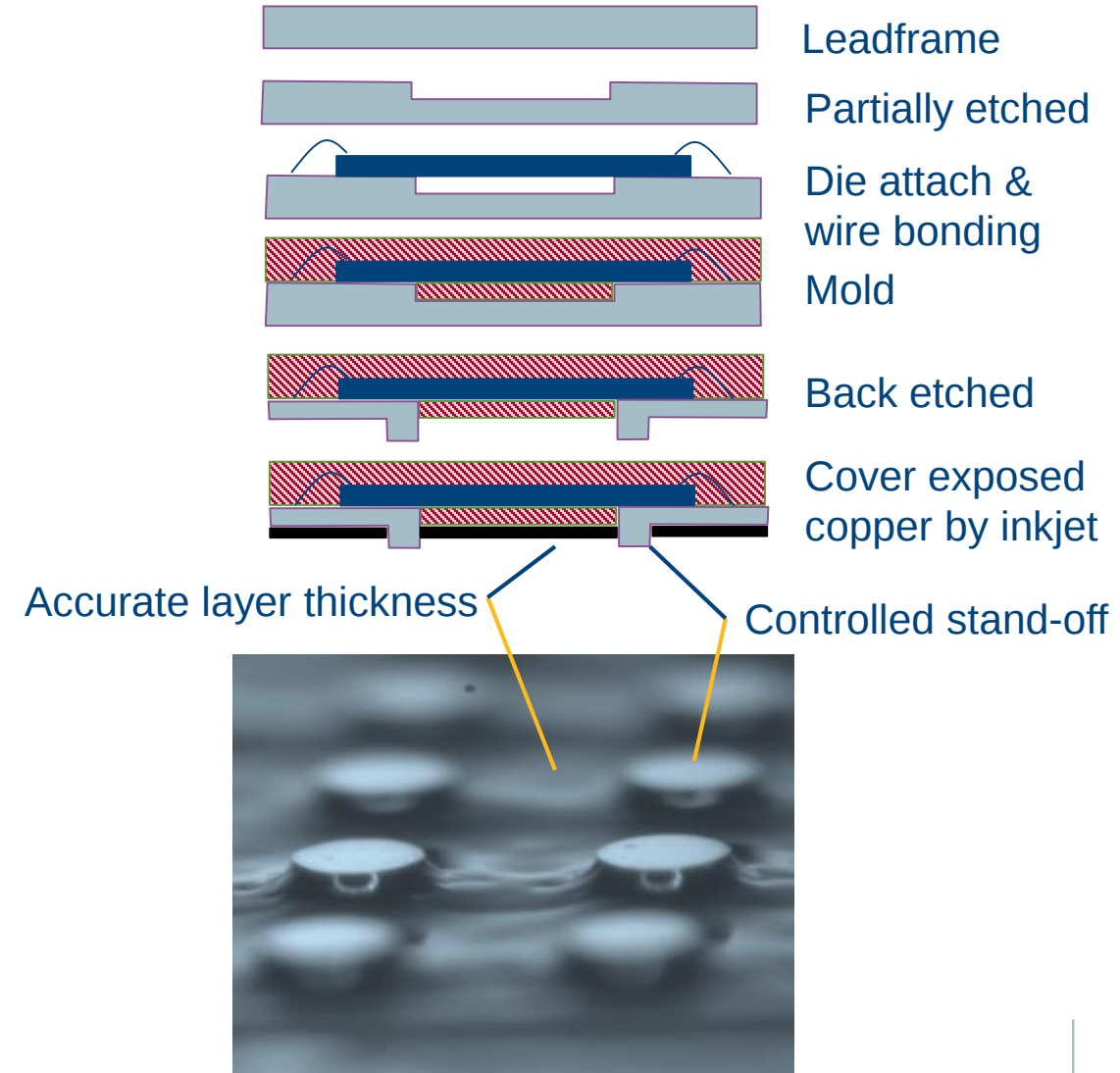
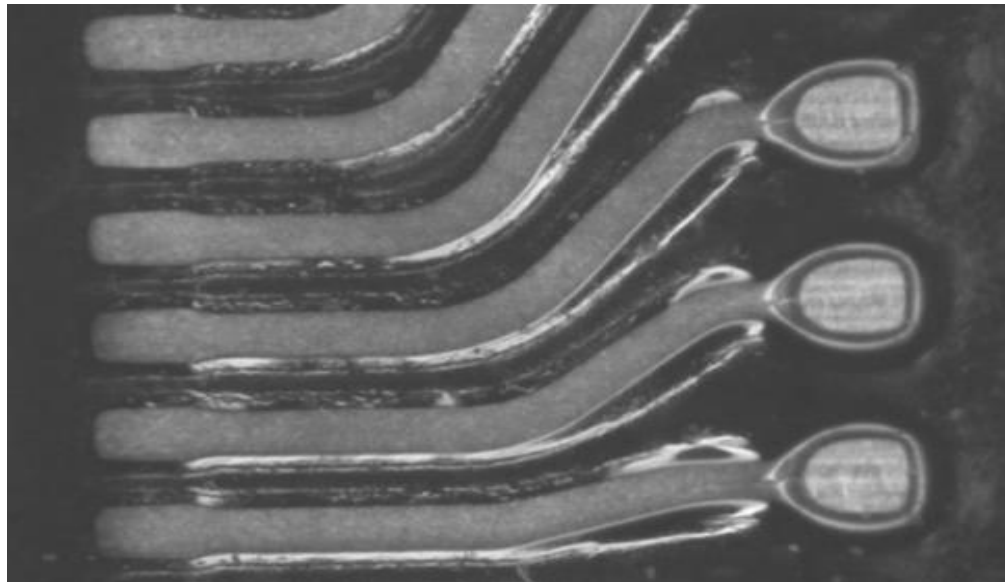
SOLDER MASK ON PCB



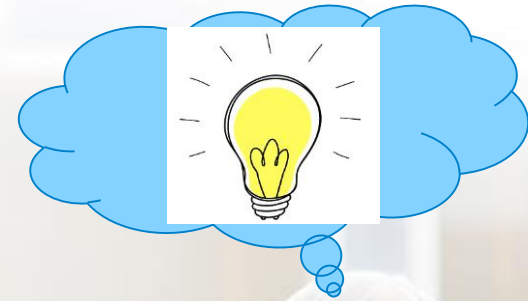
SOLDER MASK ON QFN

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+ Solder mask printing on Copper leadframe



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WHY USE INKJET PRINTING?

WHY USE INKJET PRINTING?

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What is inkjet printing?

- + Printing millions of small droplets to form a digital pattern
- + Creating features of $>50\mu\text{m}$
- + Typical print time ~ 1 min for 8" or 12" wafer

Which materials can be inkjet printed?

- + Resists: photoresist, inkjet masks
- + Dielectrics: SU-8, polyimide, solder mask

Which applications can be addressed with inkjet printing?

- + Full surface photoresist to save resist cost
- + Direct patterned resists
- + Stress buffer
- + Dams
- + Solder mask as protection

What are the advantages of inkjet printing?

- + Direct patterning of functional layers
- + Reducing handling, floor space, maintenance and cleaning
- + Efficient material usage
- + Green process, less chemistry and less waste disposal
- + No more need for mask production, storage and logistics
- + Individual scaling per product
- + Variable layer thickness
- + Compatible with non-flat topography
- + Printing on delicate surfaces

WHICH INKJET EQUIPMENT CAN WE USE?

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LP50 R&D inkjet printer



JETxM inkjet printer (24" x 30")



ACS with JETxS inkjet module (8" or 12")

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Thank you!

SUSS MicroTec Netherlands B.V.
Luchthavenweg 10
5657 EB Eindhoven
The Netherlands

www.SUSS.com

Joost.Hermans@suss.com