Development and processing of an ink jettable soldermask and advantages of use in PCB manufacture

www.electrapolymers.com

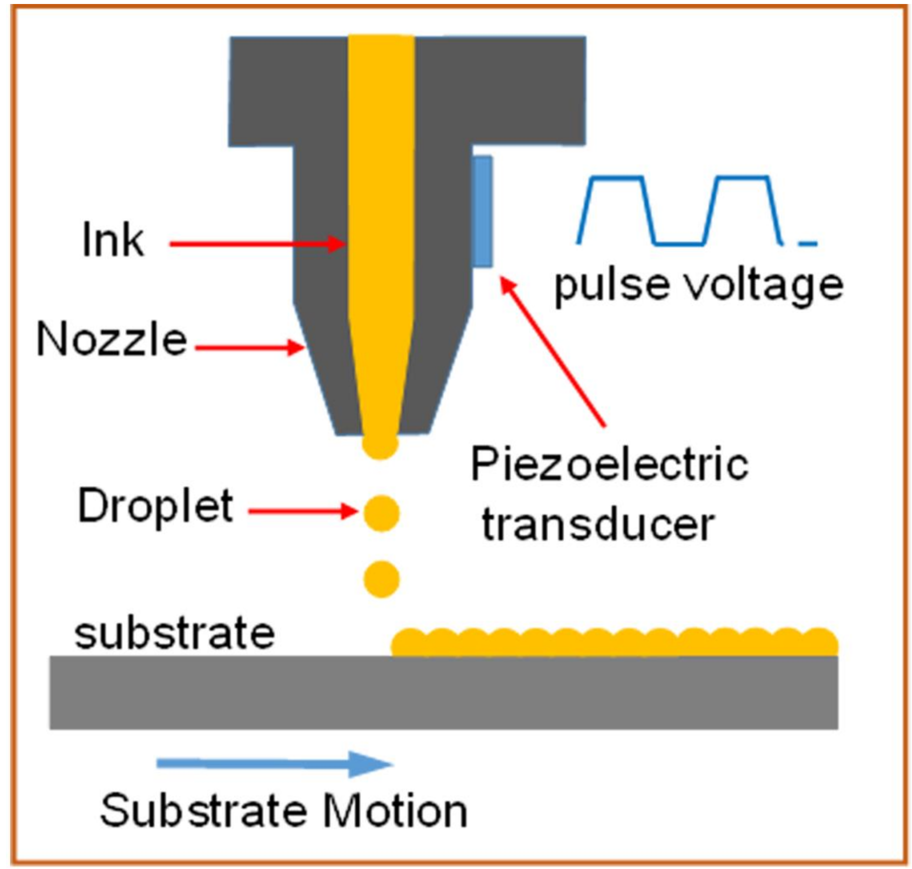
ICT Evening Seminar - 25 Feb 2020 – Manor Hotel

Development process for Inkjet Soldermask

- Understand Inkjet application process
- Identify Inkjet Soldermask formulation constraints
- Identify and source suitable candidate raw materials
- Meet soldermask performance requirements
- External compliance requirements
- Advantages of inkjet soldermask process
- Strategies for Print Optimization

Understand Inkjet application process

1. Types of head
    1. DOD Piezo
    2. Recirculating
    3. Non-recirculating
2. Influence of head type
    1. Droplet size
    2. Resolution
    3. Heating capability



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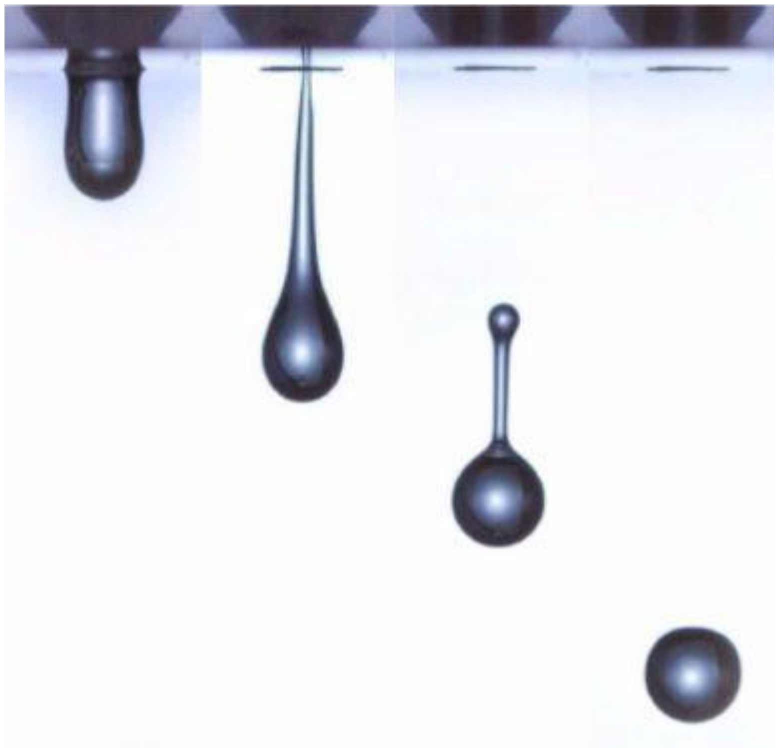
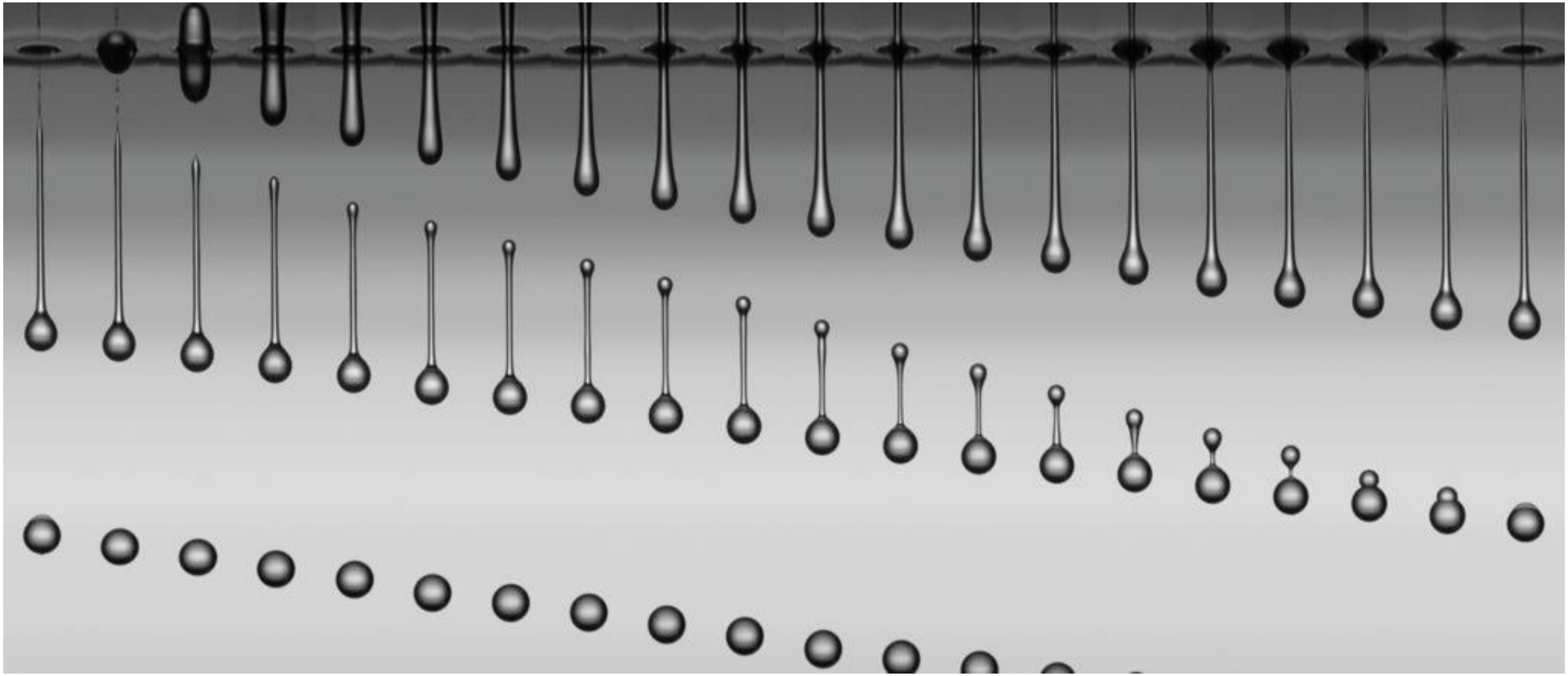
Ink droplets



Ink droplets



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Inkjet head manufacturers

KONICA MINOLTA

Dimatix FUJIFILM ™

SII

XAAR®

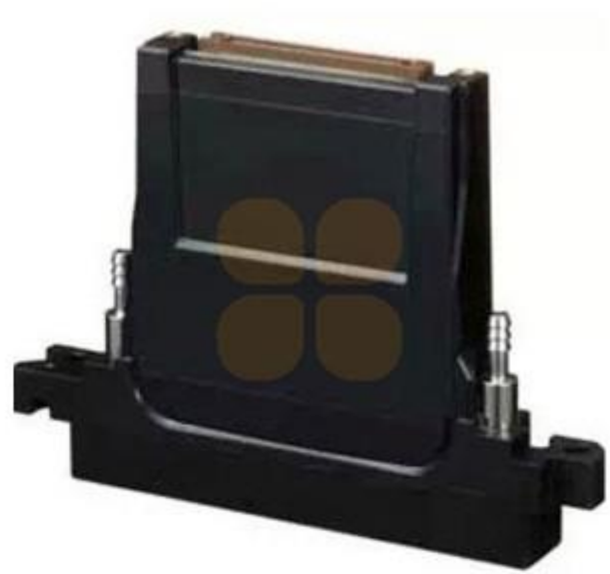
KYOCERA

TOSHIBA TEC

RICOH

Non-recirculating head

- Konica Minolta KM1024i
  - 360npi (90npi x 4 lines)
  - 6pl
  - Typical freq 50kHz
  - Max freq 60kHz
  - Width 72mm
  - Integrated heater



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Recirculating head

- Fujifilm Dimatix Samba G3L
  - 2,4pl
  - 2048 nozzles/head
  - 1200dpi
  - Width 43mm
- Claimed benefits
  - More stable jetting performance
    - Prevents pigment/particle sedimentation
    - Reduces nozzle clogging

Identify Inkjet Soldermask formulation constraints

- Limited raw material suitability
  - Restricted to v.low viscosity resins and monomers
  - Pigment particle size <200nm (c.f. 5 -15µm for conventional soldermasks)
- Low or no filler content c.f “conventional soldermask)
  - Affects flammability
  - thermal shock and
  - solder resistance.

Identify Inkjet Soldermask formulation constraints

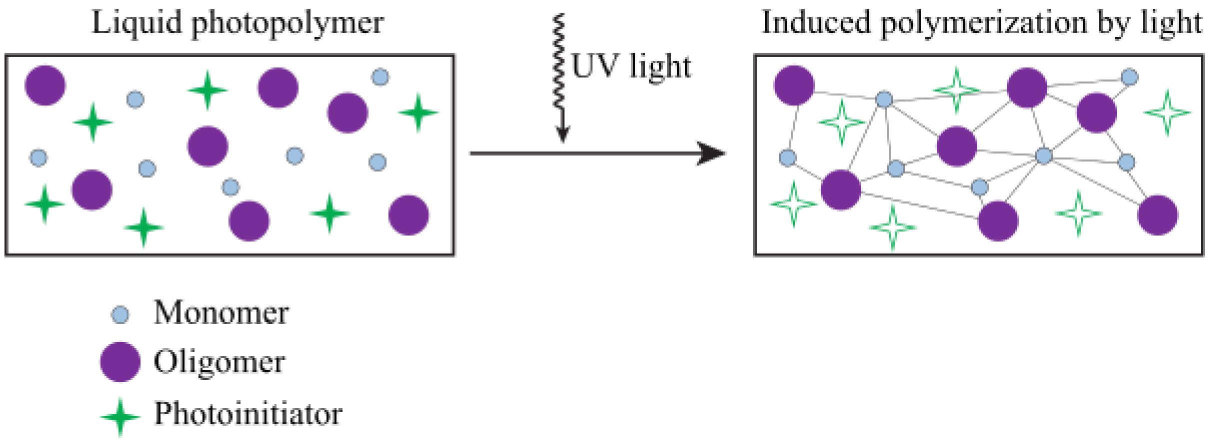
- Low viscosity, surface tension
  - Varies according to print head type
  - Constrained by laws of physics to achieve good jetting performance.
  - Results in tendency for pigment sedimentation on storage and to spreading, bleed and track edge thinning on printing.

Reynolds number	$Re = v\rho\alpha/\eta$
Weber number	$We = v^2\rho\alpha/\gamma$
Ohnesorge number	$Oh = \sqrt{We}/Re$
Fromm Z parameter	Z = 1/Oh
Stable drop formation	10 > Z > 1

- Contact angle
  - Influences coating performance of subsequent layers jetted onto pin-cured layers.

Identify Inkjet Soldermask formulation constraints

- UV cure type/speed



Acrylate – free radical cure
Epoxy – cationic cure
Hybrid – combination epoxy/acrylate system

- Thermal final cure

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Identify and source suitable candidate raw materials

- Low viscosity monomers
  - Restricted choice of monomers
  - (H&S concerns because of low viscosity)
- Suitable photoinitiators to achieve good pin/through cure
  - Prevent "wrinkling"
- Stable pigment dispersion(s)
- Flow agents/surface property modifiers/thermal curing agents . . .

Formulate test products

1. Screen formulations for basic solder mask properties
2. Modify formulations as required
3. Select formulations for jetting tests
4. Evaluate jetting performance of selected formulations
5. Evaluate cured coating performance
6. Modify formulations as required
7. Repeat 3 – 8 as required
8. Submit final formulation(s) for external compliance testing

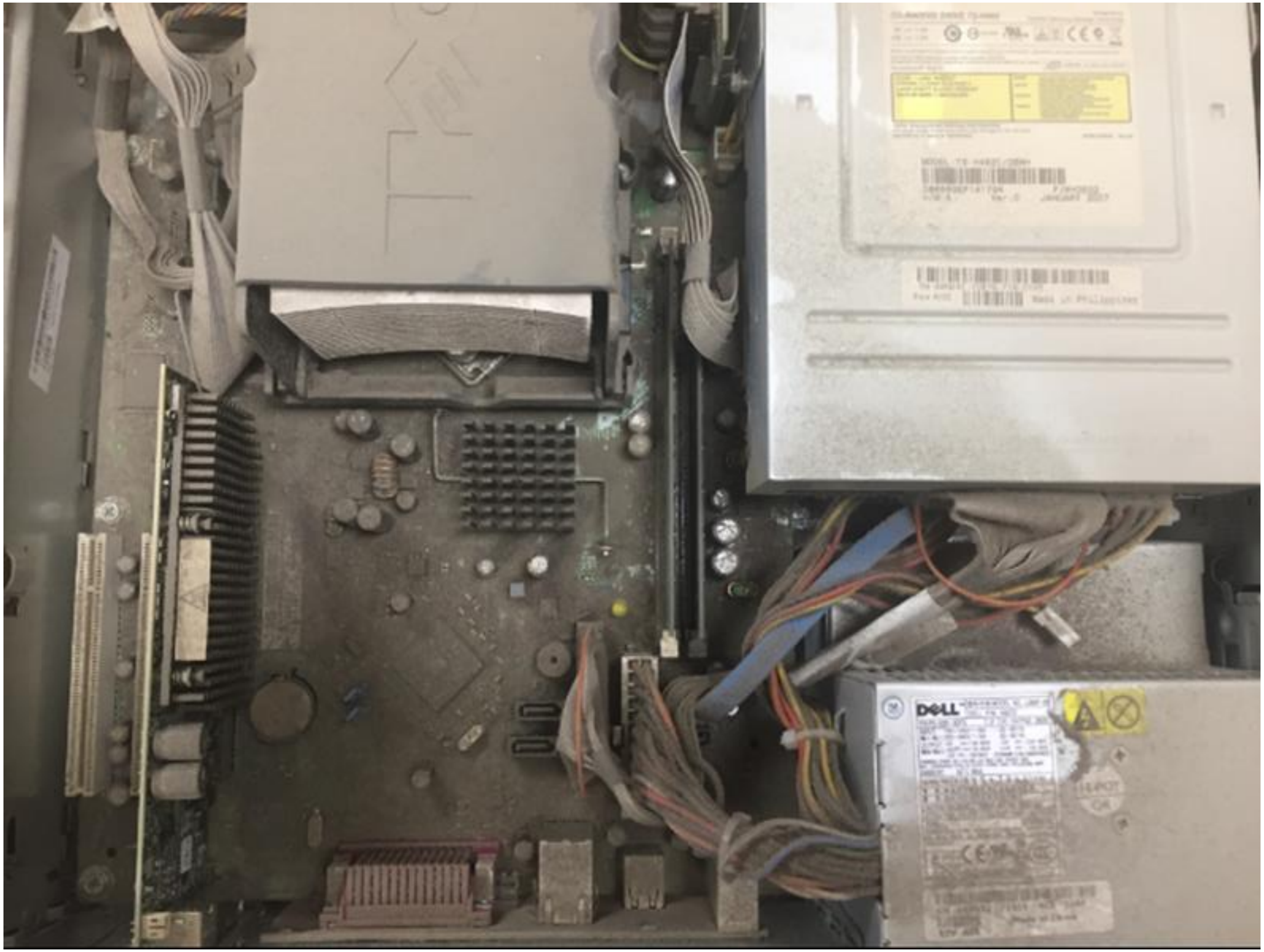
Lab printer

MEYER BURGER

Solder mask performance requirements

- Protect copper circuitry
  - Chemically
  - Electrically
  - Physically
- from
  - High Temperatures
  - Humidity and moisture
  - Corrosives
  - Dust, dirt, contamination

Why we need soldermask!

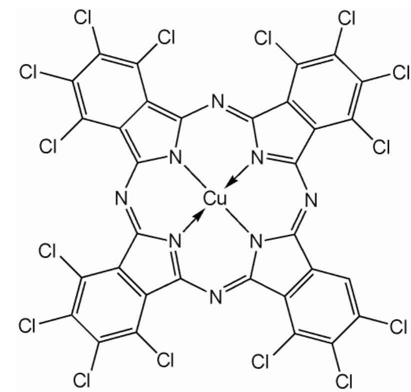


Solder mask performance requirements

- ENIG & Immersion Sn/Imm Ag plating chemistry
- Solder dam resolution
- Pb free soldering
- Multiple solder reflow cycles
- Conformal coating compatibility

Soldermask performance requirements

- Low Ionic contamination
- Low/no Halogen content
  - <900ppm Cl or Br
  - <1500ppm total halogen to be “halogen free”
  - Green colour achieved by blending pigments other than phthalocyanine green- $Cu(C_{32}N_8Cl_{14})$



- Universal product
  - Rigid/flexible
  - Suitable for recirculating and non-recirculating heads

External compliance requirements

- UL 94V0
  - more difficult on thinner laminates
  - May need to incorporate flame retardants
- ROHS compliant
  - No heavy metals
- SM840E – H or T
- NASA Outgassing
  - NASA spec - SP-R-0022A/ASTM E 595

External compliance requirements

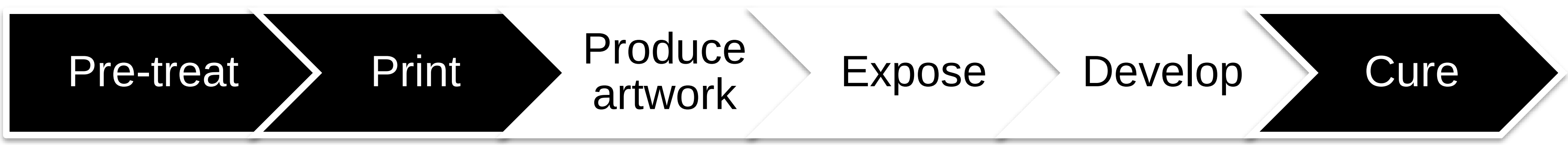
- Automotive Standards
  - Bosch -
    - TC7 – (-40/150 deg C, 1000 cycles)
    - TC8 - (-40/160 deg C, 1000 cycles)
    - TC9 - (-40/160 deg C, 2000 cycles)
  - Hella –
    - G2 - (500 cycles, -40/170 deg C)
    - G3 - (1000 cycles, -40/170 deg C)
    - (G4 - (2000 cycles, -40/170 deg C))??
- Customer specific specs

Advantages of inkjet soldermask process

- Reduction in process steps/time compared to LPISM process

Traditional process flow

Inkjet printing process flow



- Eliminates coating, artwork, exposure and development
- Elimination of drying ovens, high power UV exposure equipment
- Smaller process line footprint
- Reduction in energy costs
- Reduced WIP

Advantages of inkjet soldermask process

- Digital "artwork"
  - created straight from Gerber data or via bit-map
- Potential for high throughput
  - depends on number of heads, droplet size
- Additive process – minimal wastage
- Low/no solvent emissions
  - (150 kg/mth LPI ≡ 630kg/year solvent emitted
- Registration compensation
  - Image stretching and offset to allow for board distortion
- Reliability
  - Repeatable process
  - 100% solids
  - No undercut at image edges

Image edge characteristics

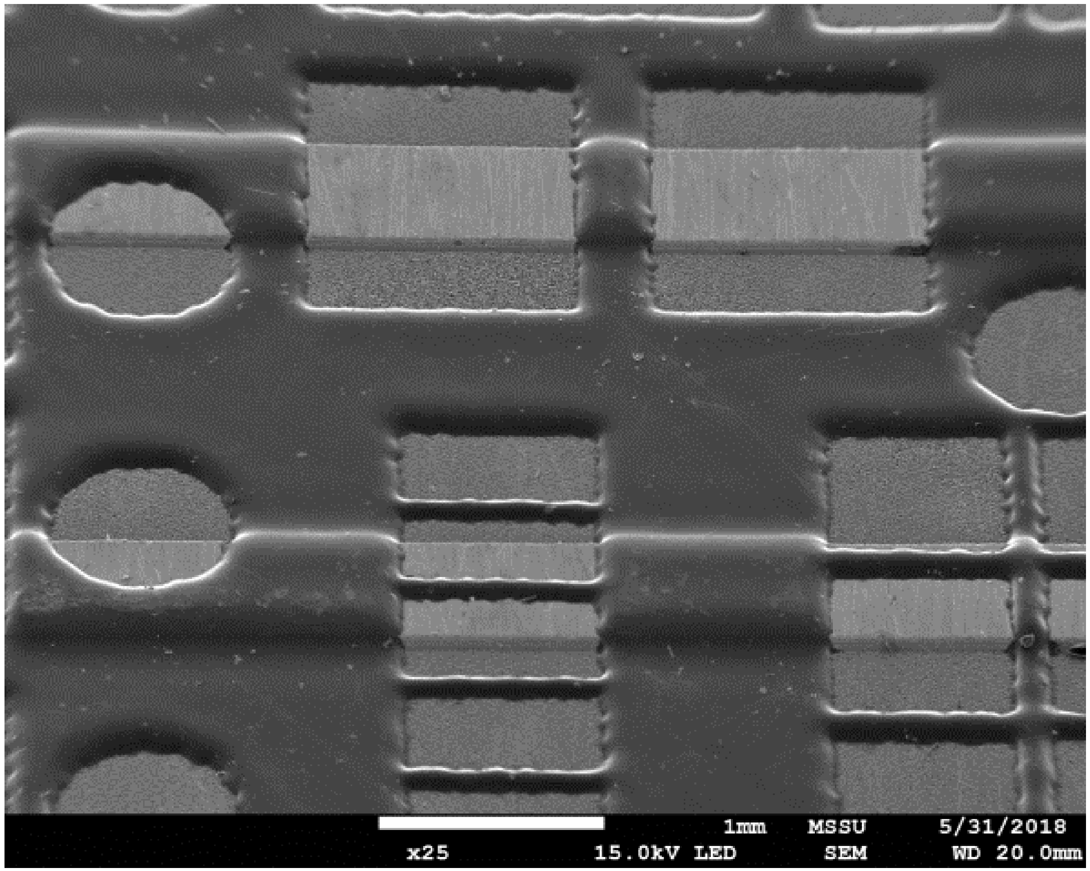
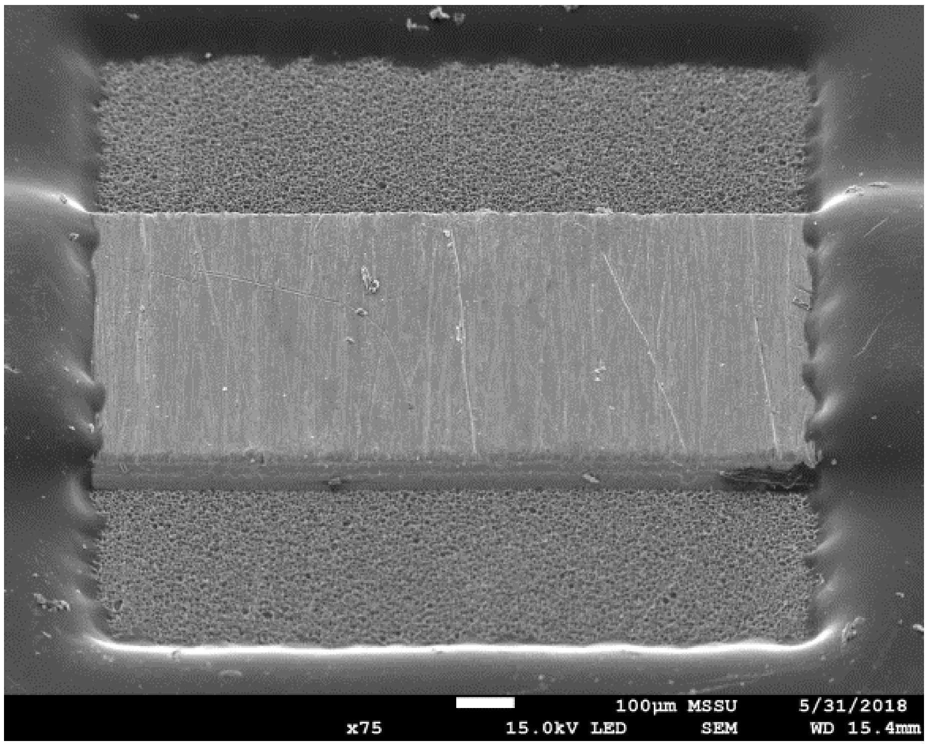
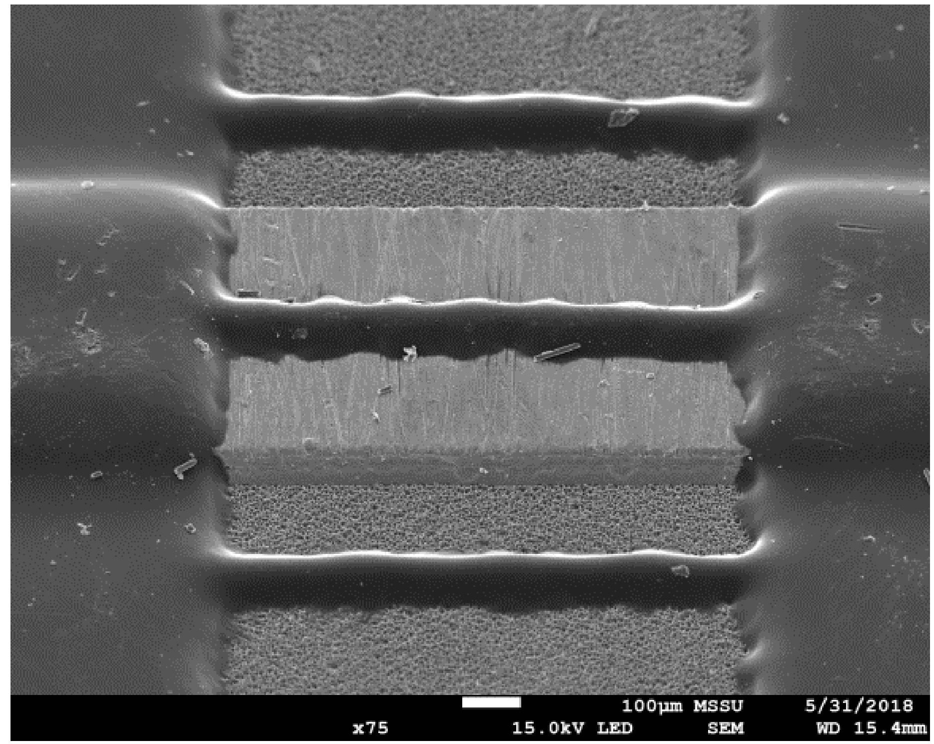


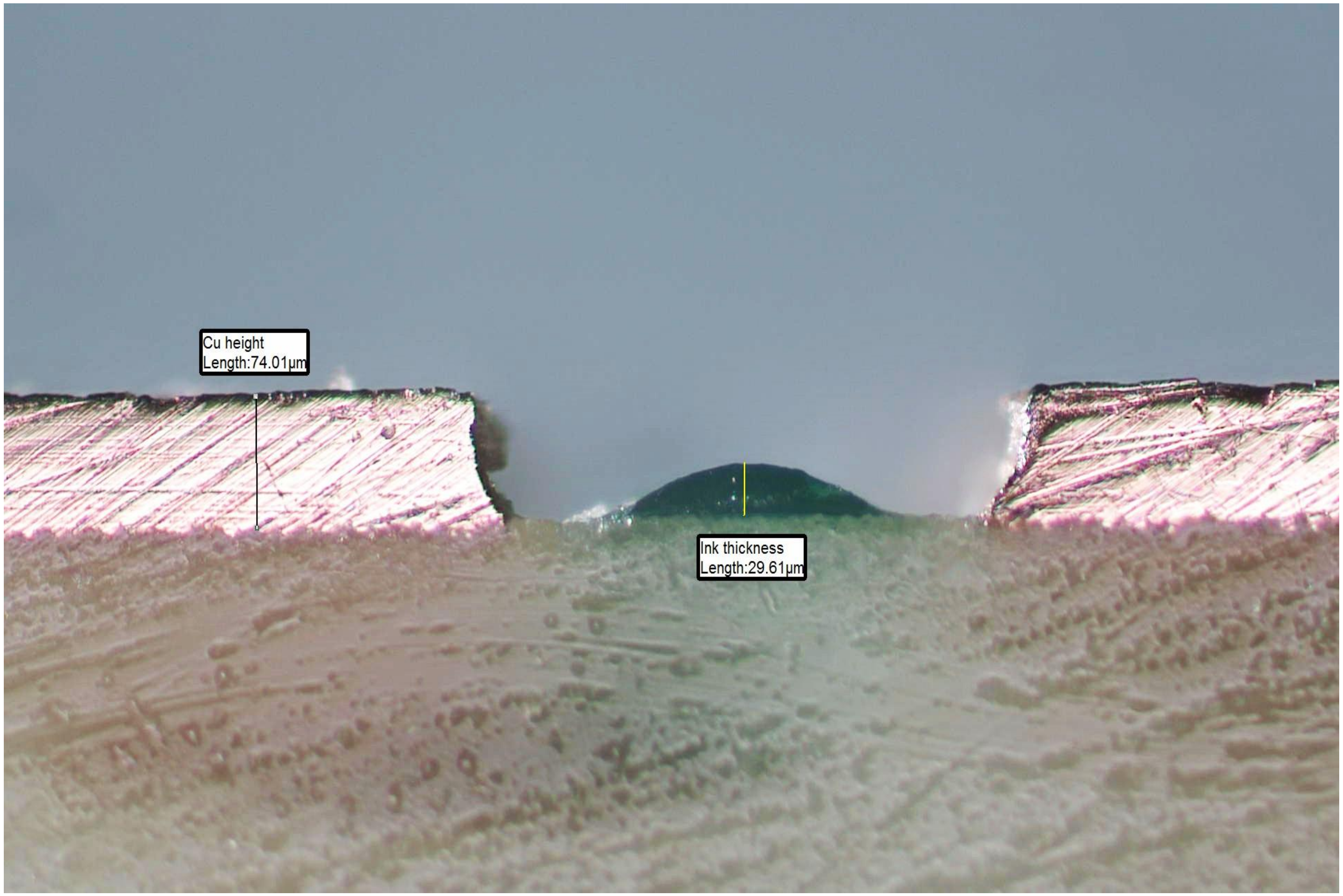
Image edge characteristics





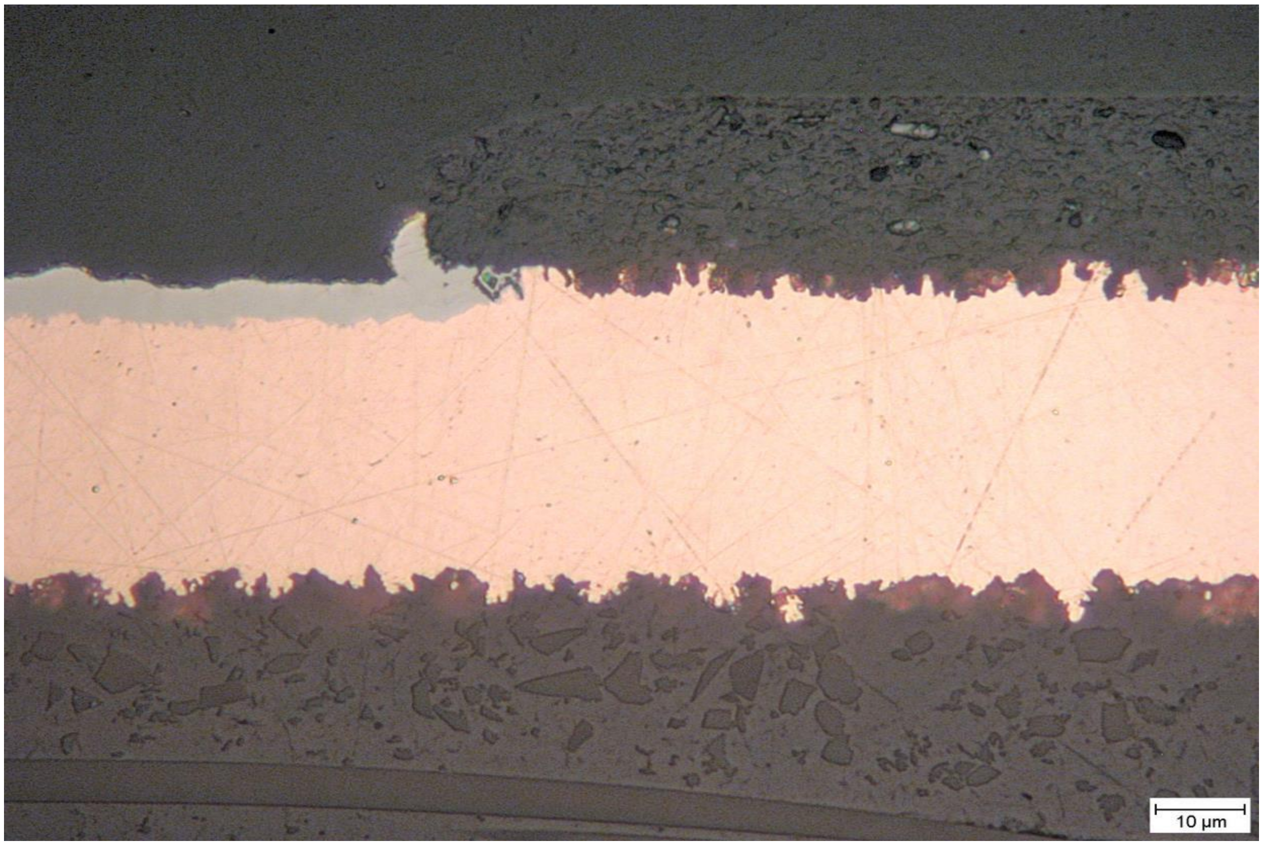
Inkjet soldermask Electrajet ® EMJ110

EMJ110 Desired Dam shape to stop chemistry entrapment



Inkjet soldermask Electrajet ® EMJ110

LPI screen soldermask undercut chemistry entrapment



Spoiler Alert

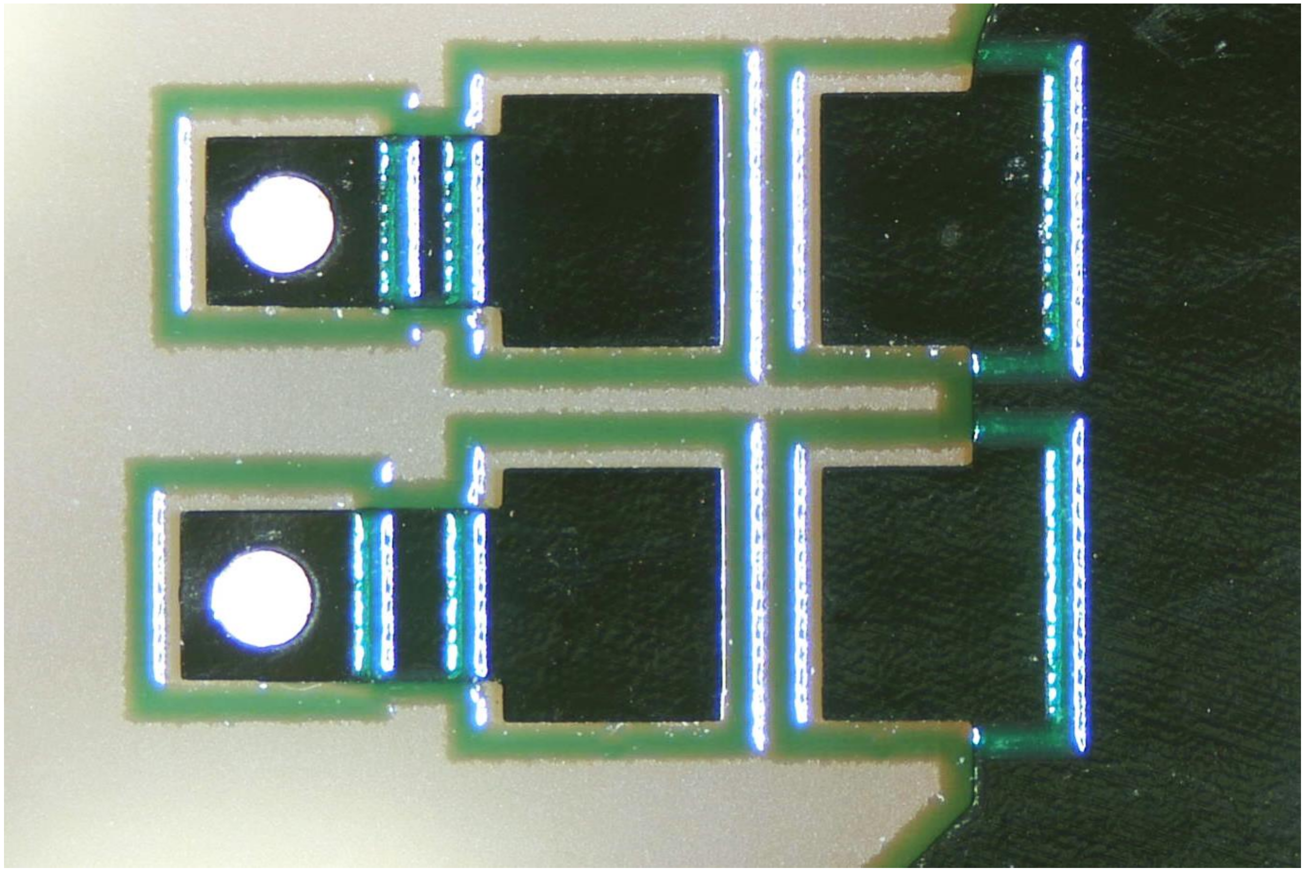
- Soldermask adhesion/chemical resistance and print quality very dependent on surface preparation
  - High roughness chemical clean gives best results to date.
  - Specialised surface treatments to minimize droplet spread.

Strategies for Print Optimization

- Pin cure to fix droplets in place
  - Low level UV cure for droplets in each layer
- Multilayer print profiles
  - create dams around pads and prevent thinning on track edges
  - Can be used to build thickness selectively thickness,
  - eliminate “striping” and stitch lines
  - different ink surface finishes.
- Print profiles(“recipes”) to suit different board designs

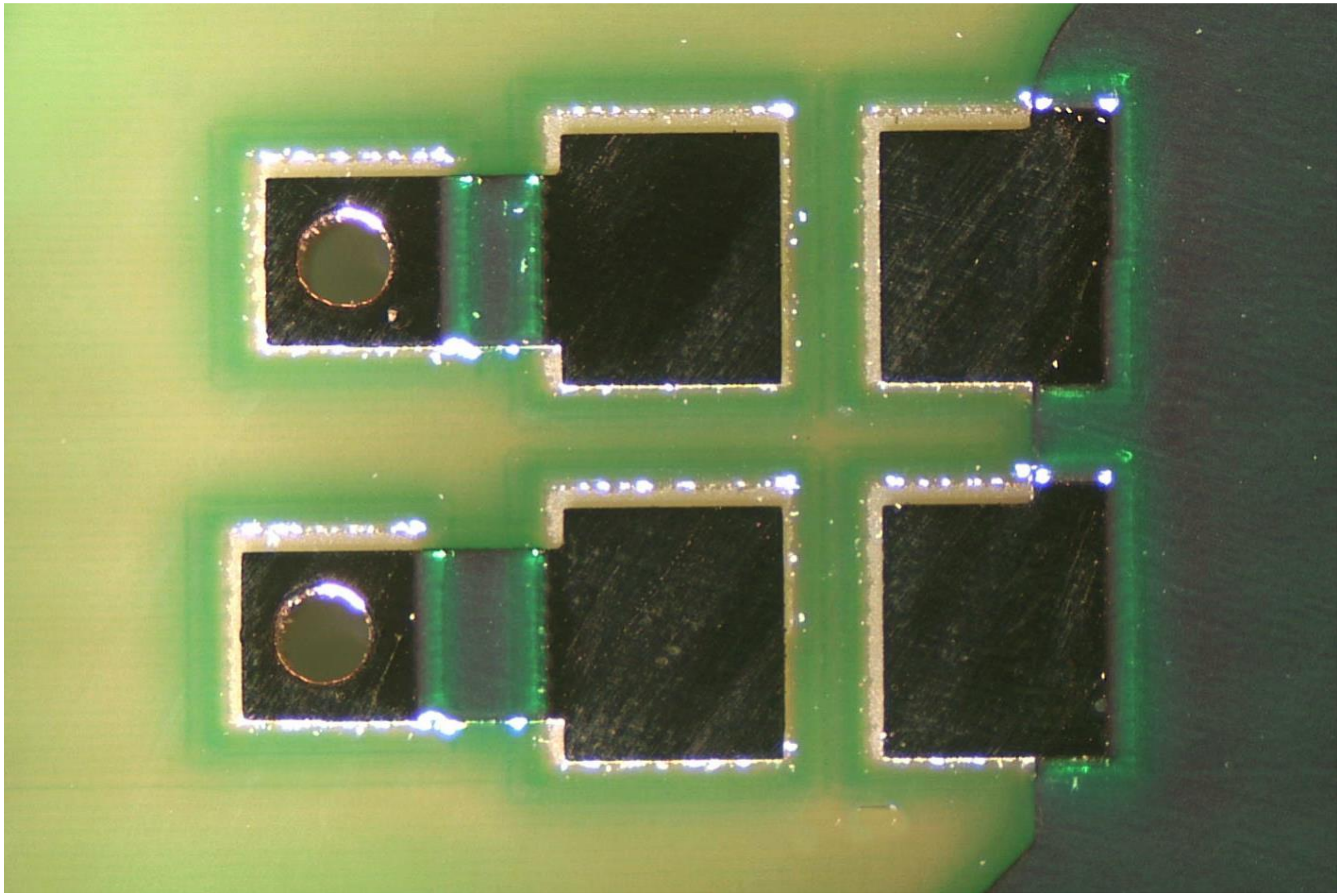
Strategies for Print Optimization

Layer 1 & 2 – dams + edges



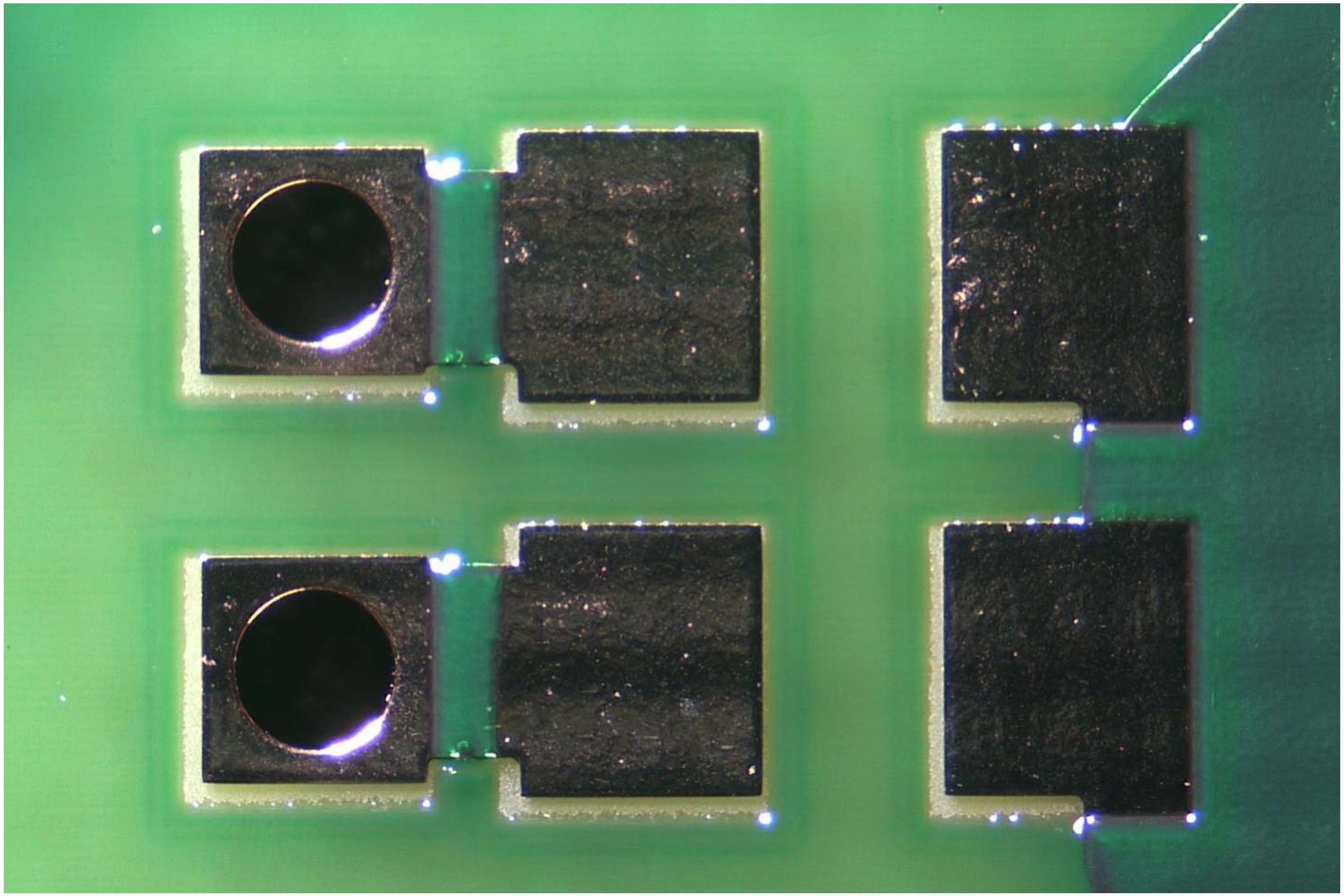
Strategies for Print Optimization

Layer 3 – print over Au and FR4



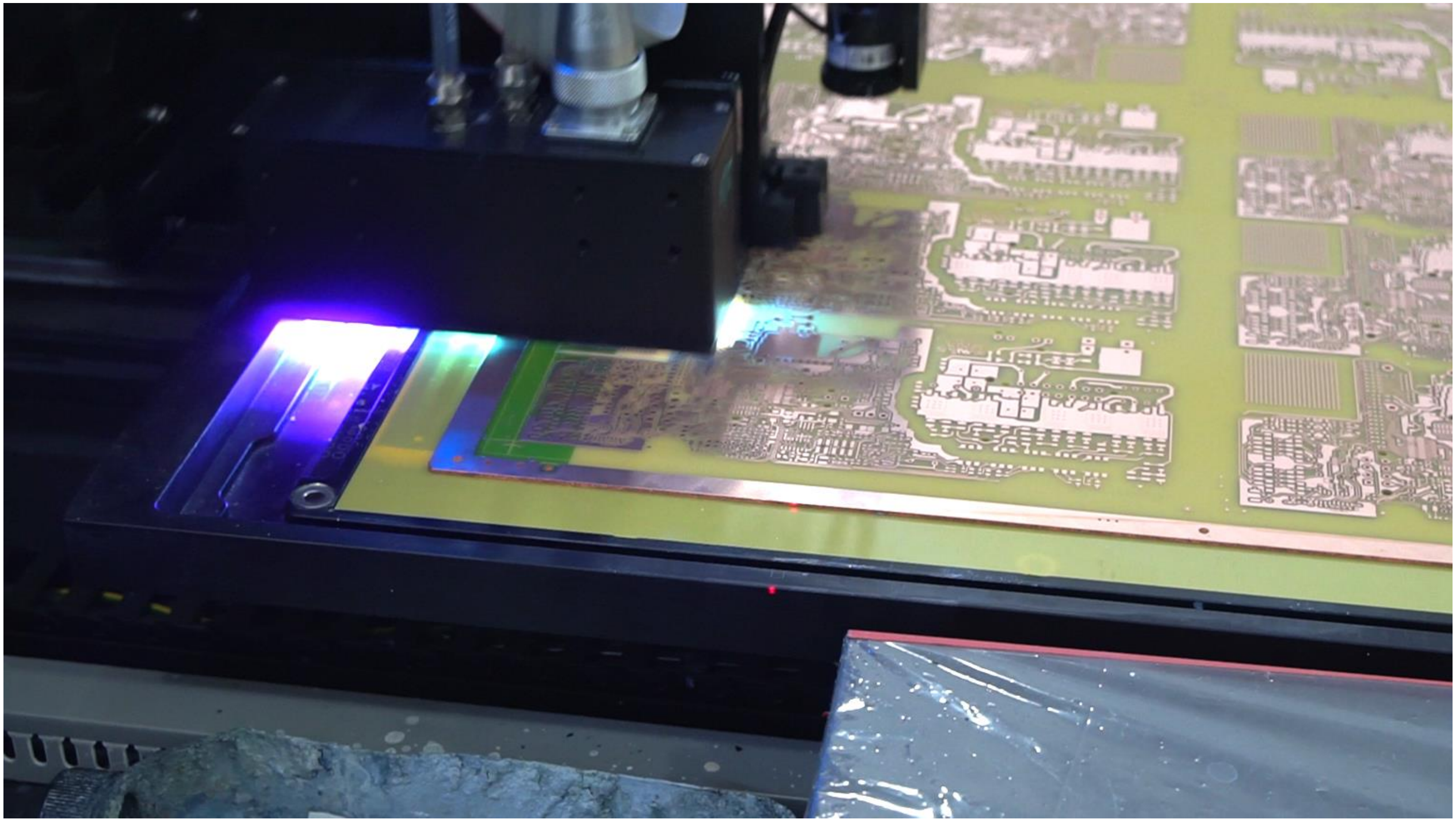
Strategies for Print Optimization

Layer 4 – final gloss finish



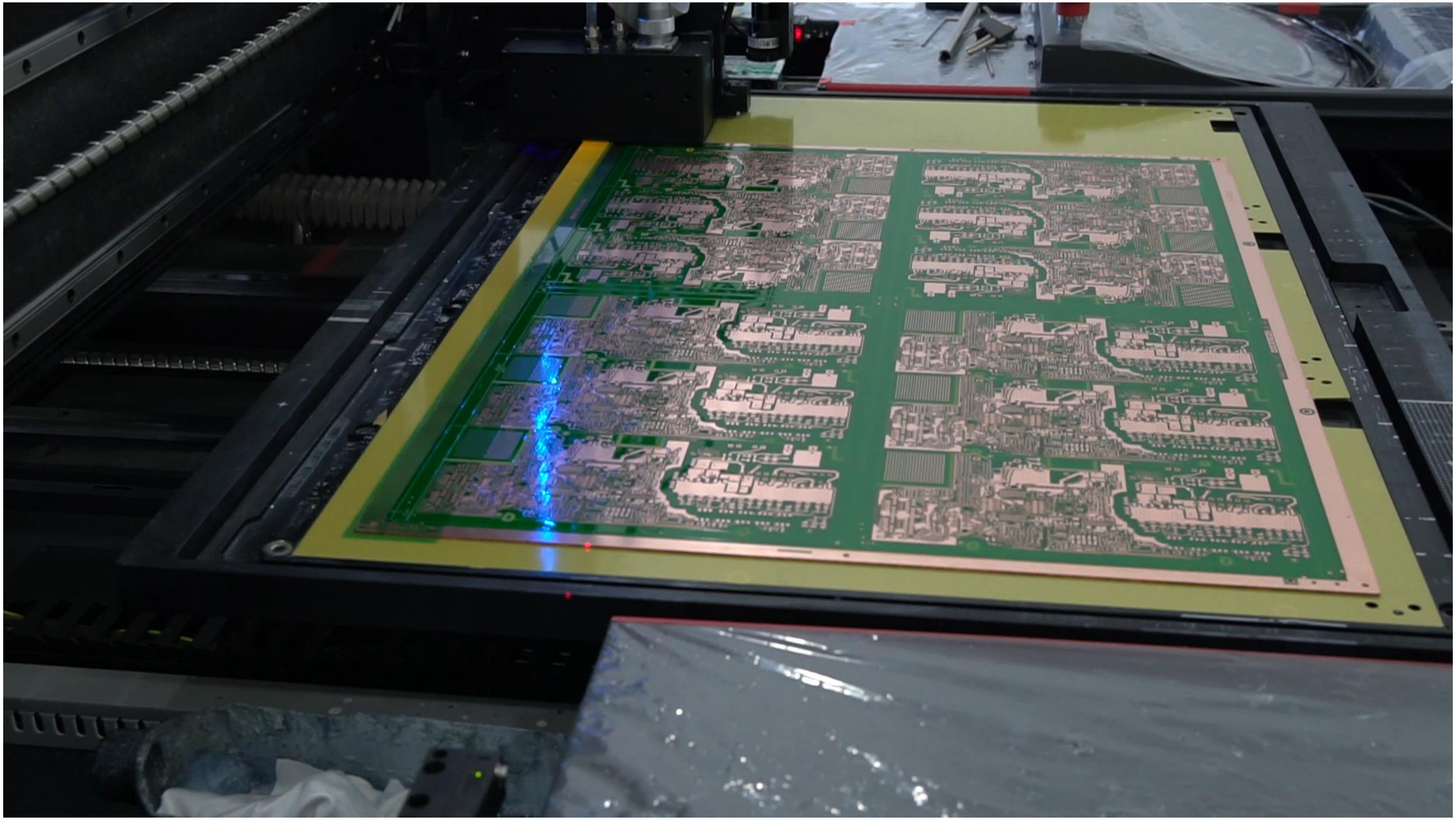
Strategies for Print Optimization

First layer - infill



Strategies for Print Optimization

Second layer – top coat



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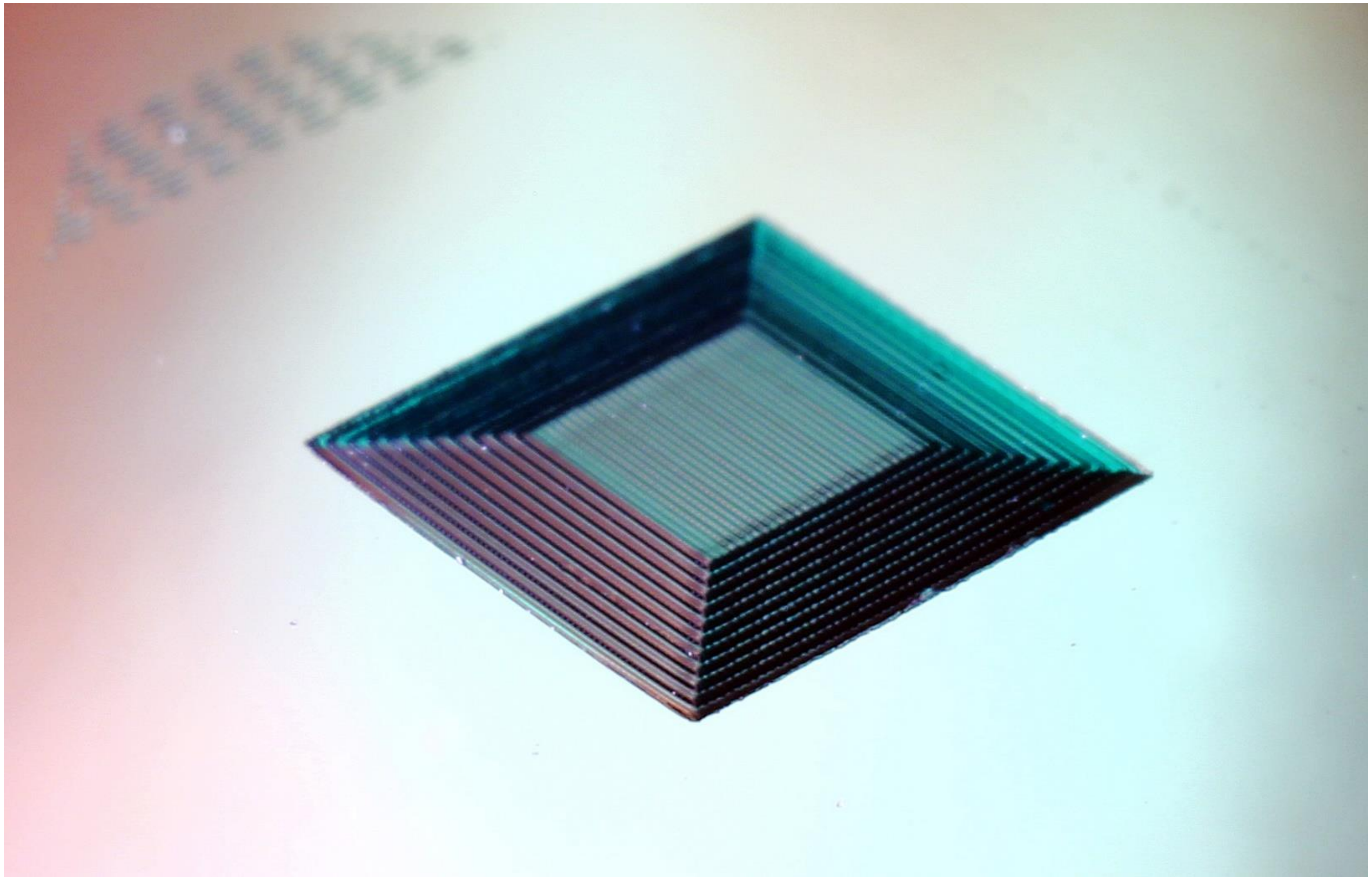
Strategies for Print Optimization

Pyramid structure – 180 microns



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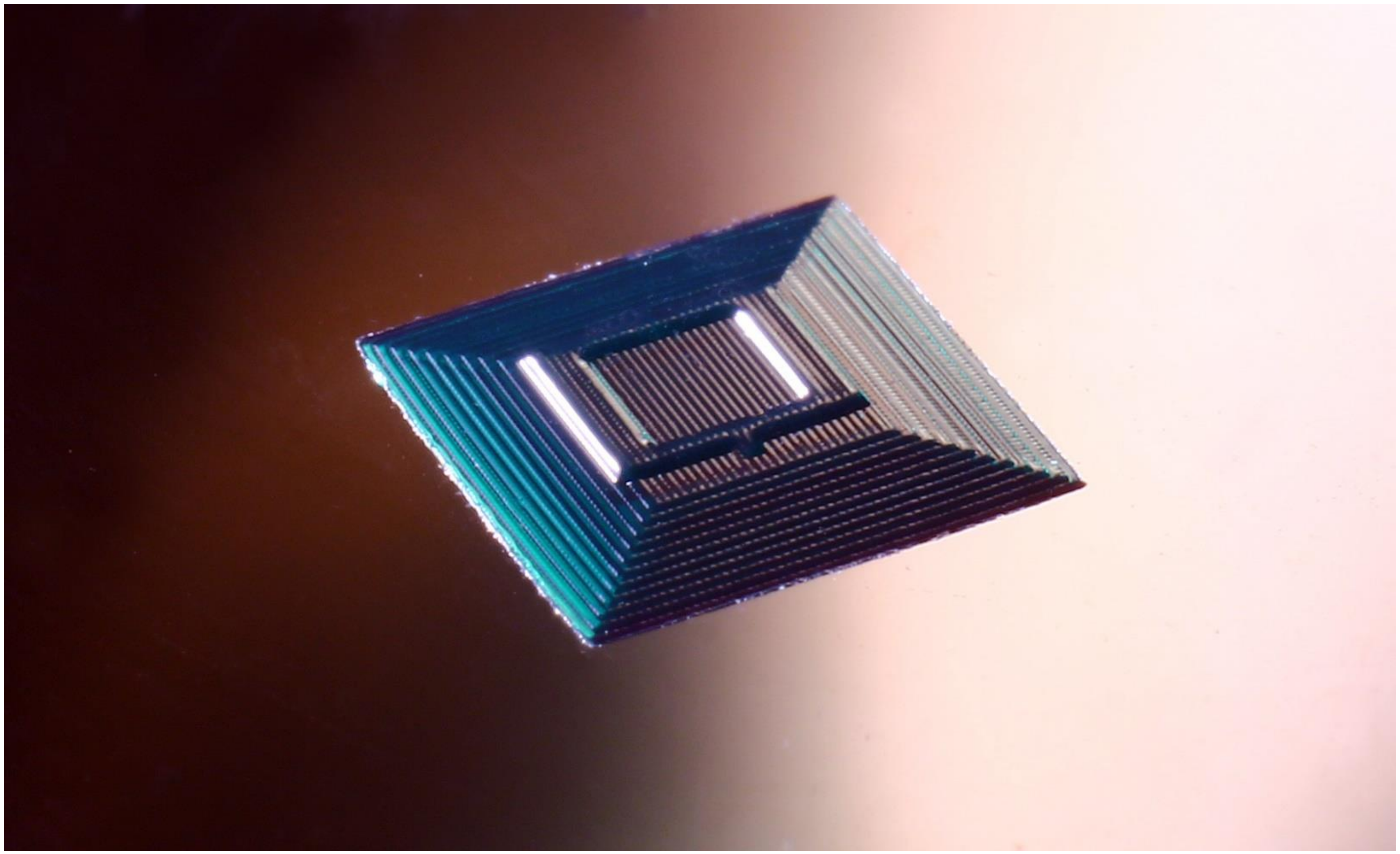
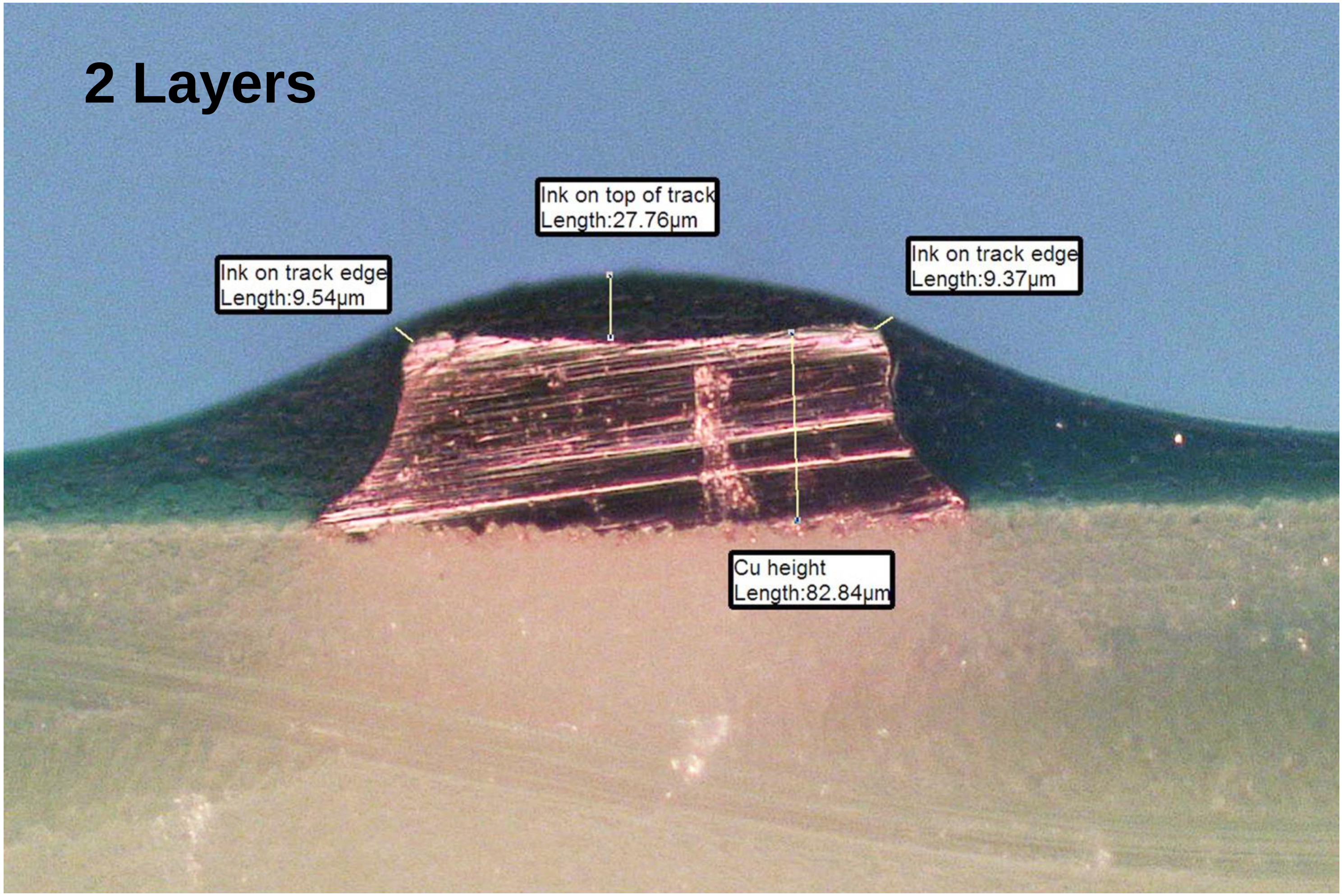
Strategies for Print Optimization

Pyramid structure – >200 microns



Inkjet soldermask Electrajet ® EMJ110
Track coverage



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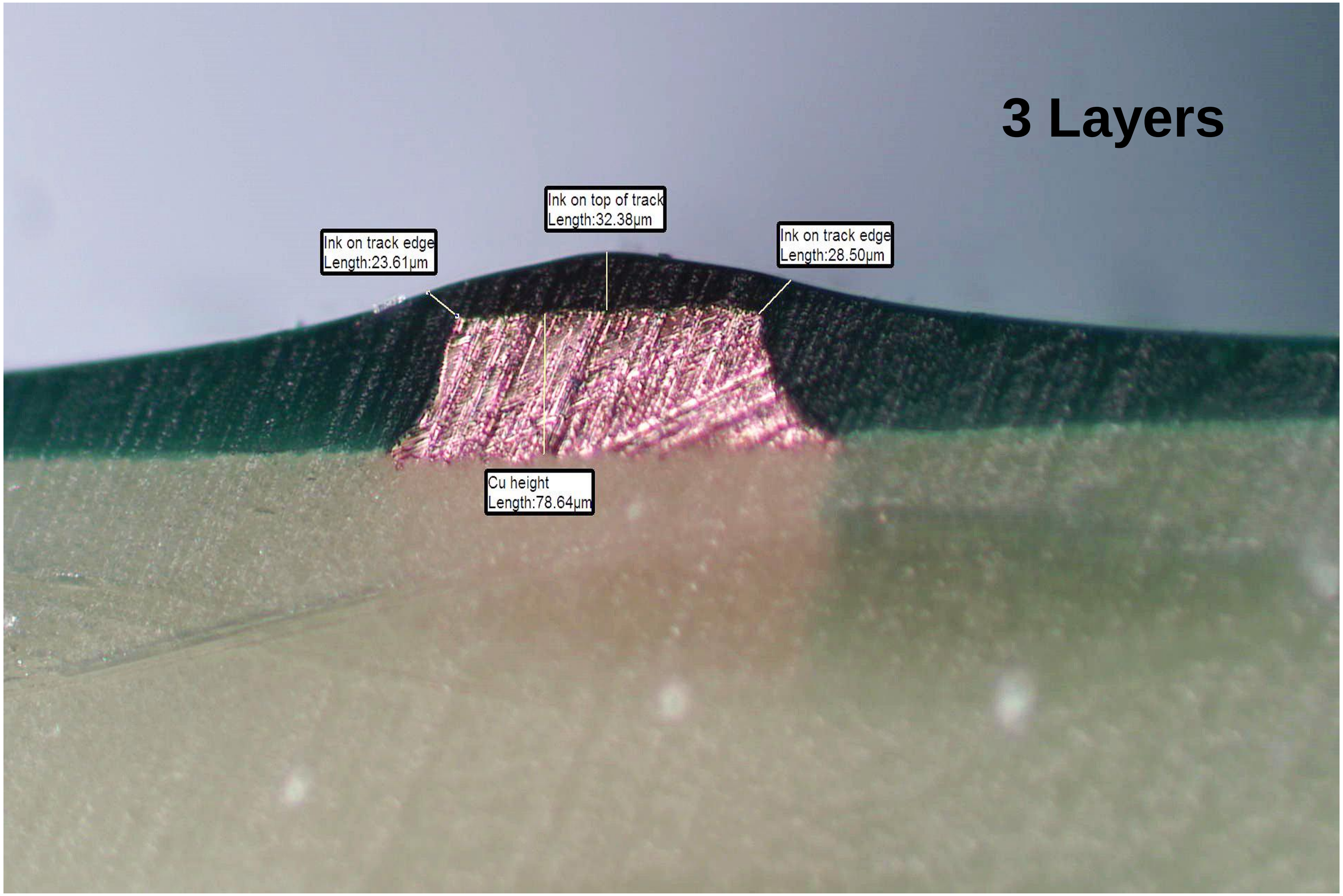
Track coverage



Inkjet soldermask Electrajet ® EMJ110

Final properties

TEST/STANDARD	REQUIREMENT	RESULT
IPC SM-840 E	CLASS T & H	PASS
UL94	V-0	PASS
THERMAL STORAGE DIN IEC 60068-2-2	TC7 1000h at 150°C	PASS
THERMAL SHOCK DIN IEC 60068-2-14	TC7 -40°C, 150°C, 1000 cycles TC8 G3	PASS
ADHESION TO GOLD	Cross-hatch & tape test	PASS
FLEX TEST	180° crease – tape test	PASS
SOLVENT RESISTANCE	30 seconds methylene chloride	PASS

TEST/STANDARD	REQUIREMENT	RESULT
ACID RESISTANCE	10% HCl, 30 min dip at 20°C – tape test	PASS
ALKALI RESISTANCE	10% NaOH, 30 min dip at 20°C – tape test	PASS
LEAD-FREE SOLDER	3 x 10s at 288°C – tape test	PASS
ENIG RESISTANCE	Ni 5-10 microns, Au <0.1 microns – tape test	PASS
PRESSURE COOKER (PCT)	100 min at 121°C (2 atm) – tape test	PASS
DIELECTRIC CONSTANT	Measured at 10GHz, 22°C	2.99
DISSIPATION FACTOR	Measured at 10GHz, 22°C	0.0228

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Electrajet® EMJ110

Inkjet soldermask Vs LPI screen print soldermask

	ELECTRAJET EMJ110 SOLDERMASK	LPI SCREEN PRINT SOLDERMASK
IPC SM840 E Class H & T	PASS	PASS
UL 94 V-0	PASS	PASS
THERMAL STORAGE TC7 1000h at 150°C TC9 2000h at 160ºC HELLA $E3_{1000}$ HELLA $G3/4_{2000}$	 PASS UNDER TEST PASS UNDER TEST	 PASS PASS PASS PASS
THERMAL SHOCK TC7 -40°C, 150°C, 1000 cycles TC9 -40°C, 160°C, 2000 cycles HELLA $E3_{1000}$ HELLA $G3/4_{2000}$	 PASS UNDER TEST PASS UNDER TEST	 PASS PASS PASS UNDER TEST
REACH & RoHS	PASS	PASS

Thank You!

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