Capabilities and Challenges in Taking The Step From HDI to "Advanced HDI"

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Agenda

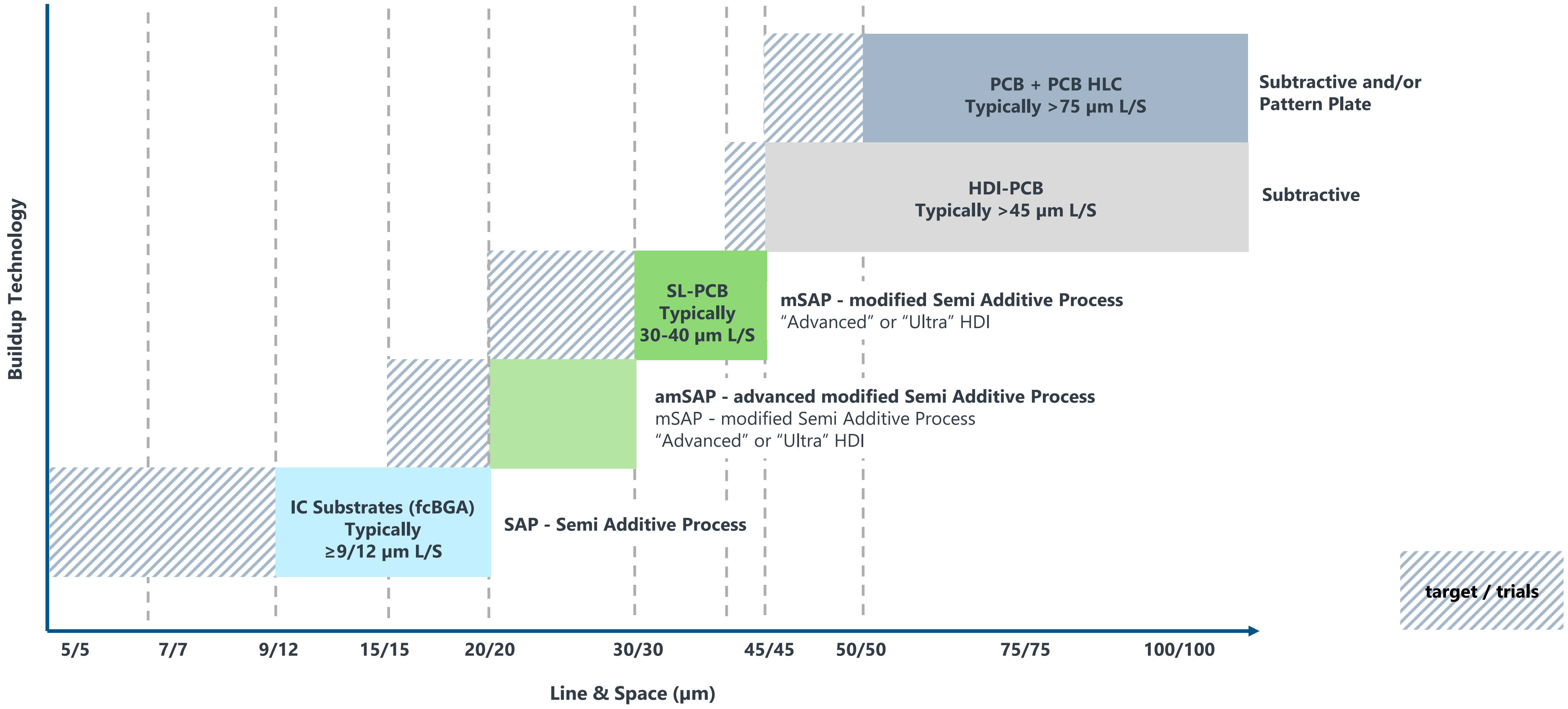
- PCB Buildup Technologies and Their Capabilities
  - Application & Fine Line Capabilities
  - Process Sequences
  - Which efforts are required to adopt them?

- Specific Process Adaptations for mSAP and beyond
  - Focus: Desmear/Electroless Cu, Surface Treatment

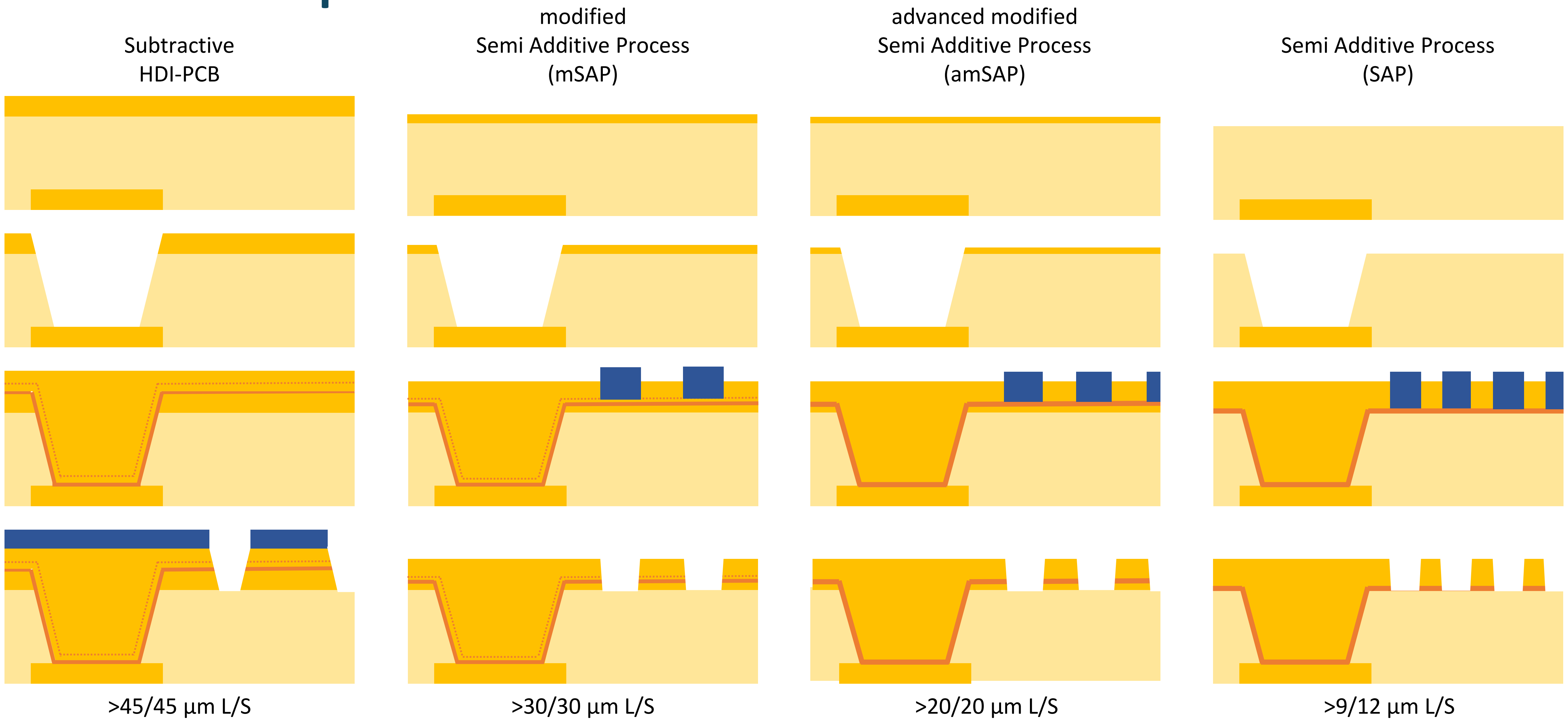
- Q&A

Build-up Technologies and Their Capabilities

Build-up Technologies and Their Capabilities
Fine Line Resolution



Build-up Technologies and Their Capabilities
Process Sequences



Build-up Technologies and Their Capabilities In Figures

	HDI Subtractive	mSAP	amSAP	SAP
		“Advanced HDI” or “Ultra HDI”		
Surface Copper foil thickness (µm)	> 9	3 – 5	< 3	0
Electroless Copper thickness (µm)	0.35 – 0.5	0.35 – 0.5	0.5 – 1.0	0.25 – 1.0
Flash Copper thickness (µm)	2 – 5	1 – 3		
Panel plated Copper thickness (µm)	15 – 20			
Pattern plating required	No	Yes	Yes	Yes
Total surface Copper thickness (µm)	> 26	4 – 10	< 3	<1
Achievable feature size (µm)	> 45	> 30	> 20	>9/12

Total Surface Copper is the main limiting factor for achievable feature sizes.

Build-up Technologies and Their Capabilities From Subtractive HDI to …

mks Atotech

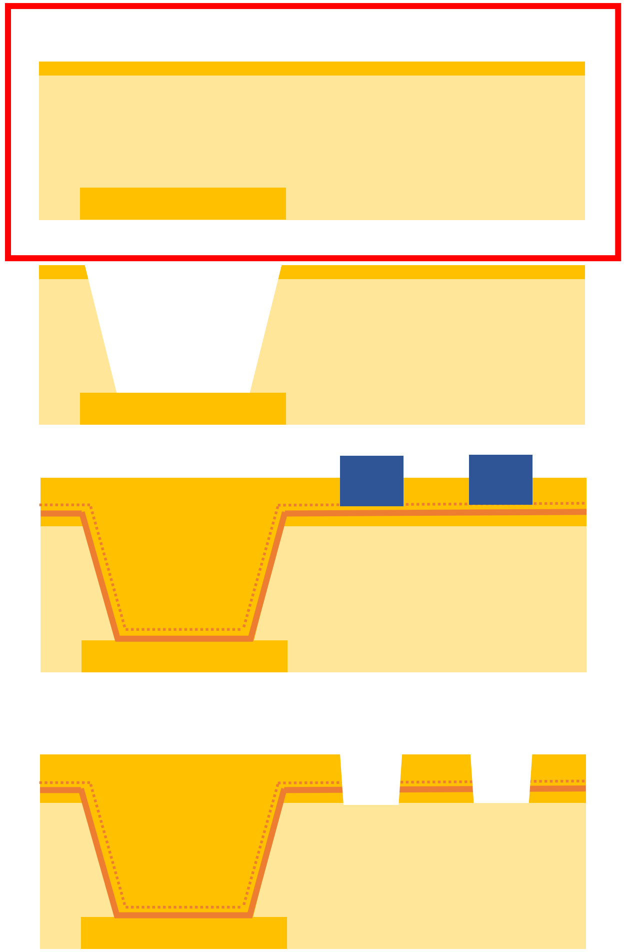
	HDI Subtractive	mSAP	amSAP	SAP
		"Advanced HDI" or "Ultra HDI"		
Preferred Panel Orientation	DSM/ELESS Cu – Hor. Flash Plate – Hor. Panel Plate – Hor.	DSM/ELESS Cu – Hor. Flash Plate – Hor. Pattern Plate – Ver.	DSM/ELESS Cu – Hor. Pattern Plate – Ver.	DSM/ELESS Cu – Ver. Pattern Plate – Ver.
Pre/Post LDD Chemistry	Standard	New	New	
Desmear/E'less Cu Chemistry	Standard	Standard	New	New
Flash Plate Chemistry	Standard	Standard / New		
Panel Plate Chemistry	Standard			
Pattern Plate Chemistry		New	New	New
Imaging Etch Chemistry	Standard	New	New	New
Inner Layer Adhesion	Standard	Standard / New	New	New
Pro	Production proven Equipment installed Chemistry qualified Low CoO Reliability	Production proven Some existing equipment Some existing chemistry Capability Reliability Incremental step	Production proven Some existing equipment Capability Reliability	Production proven Capability Reliability
Con	Capability	Medium CoO New equipment New chemistry	Medium/High CoO New equipment New chemistry Learning curve	High/V. High CoO New equipment New chemistry Learning cliff

Build-up Technologies and Their Capabilities
Conclusions

- The are several well-established build-up technologies beyond substrative HDI, not only SAP.
- mSAP and amSAP are capable and mature technologies for 20-45 µm L/S, achievable with reasonable changes to be adapted.
- Capability increase comes at a cost
- Factors to be considered
  - Mid- to long-term L/S roadmap
  - Existing infrastructure & know-how
  - CapEx + materials costs
  - ...

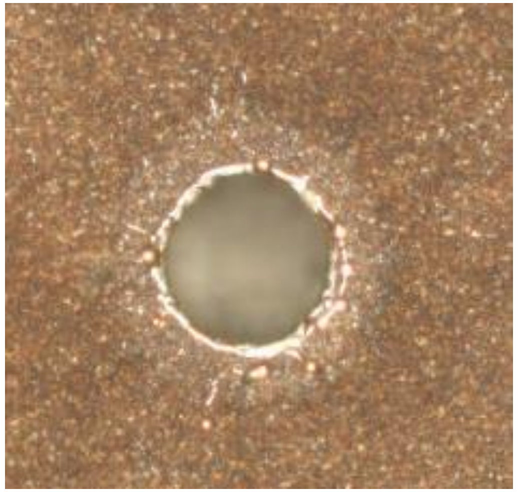
Specific Process Adaptations for mSAP and beyond

Make the Change and Adopting (a)mSAP LDD Pre and Post Treatment

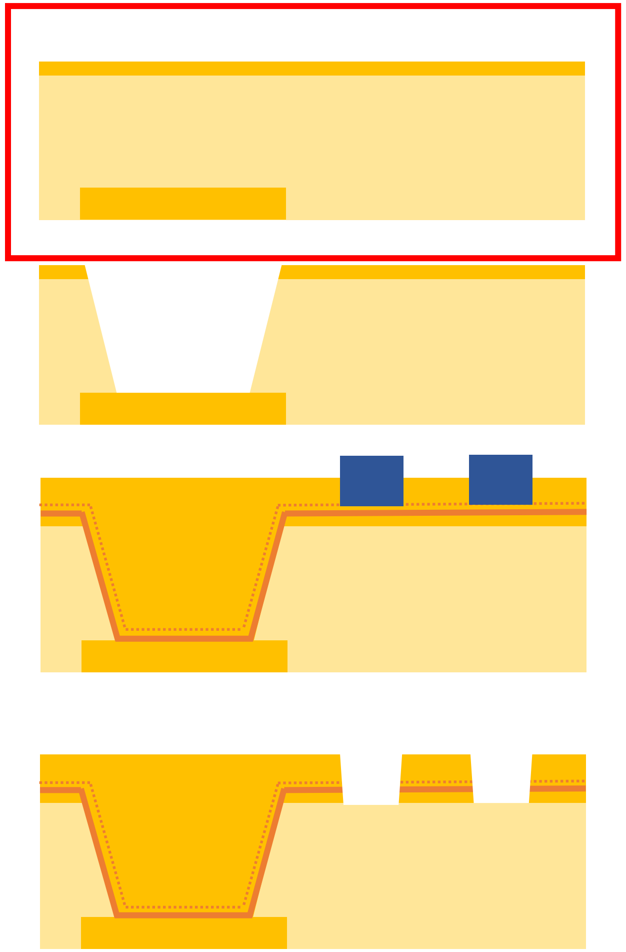


- HDI
  - Typical Cu foil >9µm
  - Pre-treatment typically etch 2-3µm
  - Post treatment 1-2µm

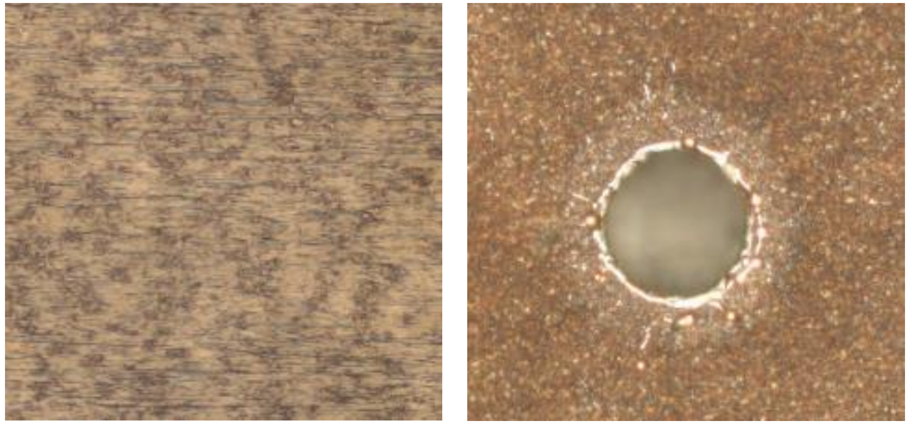
- mSAP
  - Typical Cu foil 3-5um
  - mSAP needs a new process
    - Pre-treatment etch ≈ 0.5-1.0µm
    - Post-treatment etch ≈ 0.3-0.5µm



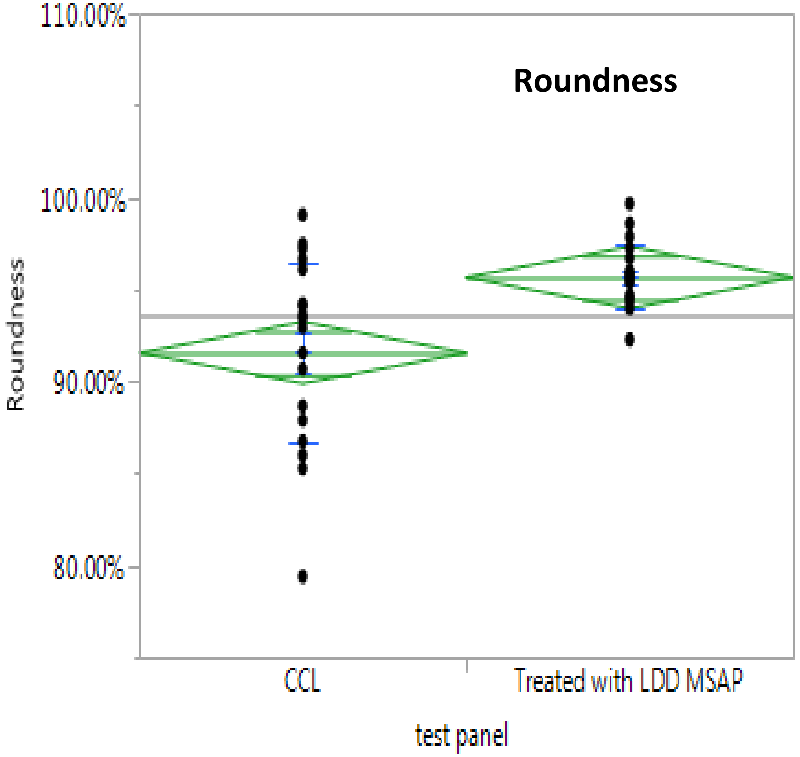
Make the Change and Adopting (a)mSAP LDD Pre and Post Treatment



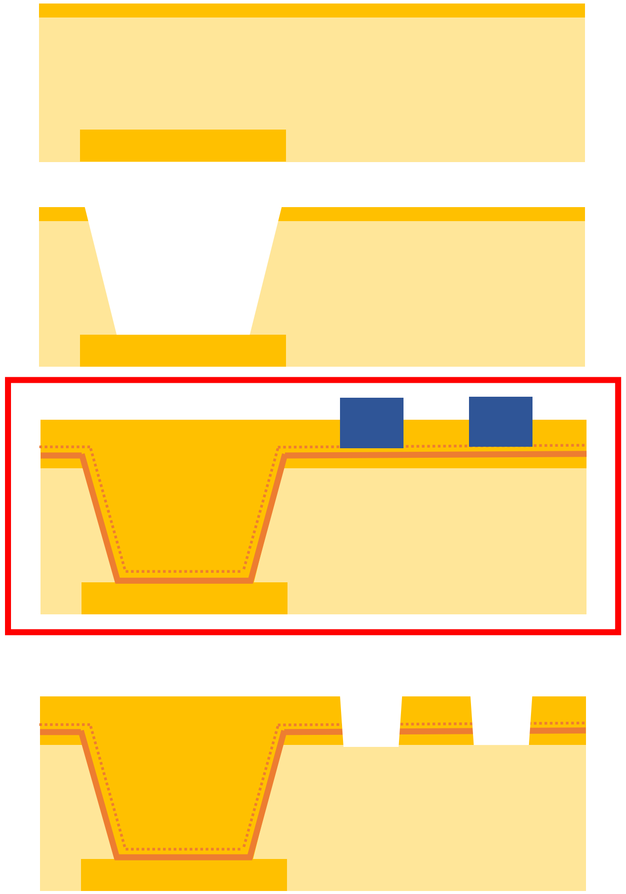
3µm Cu foil
0.5 µm Etch Depth



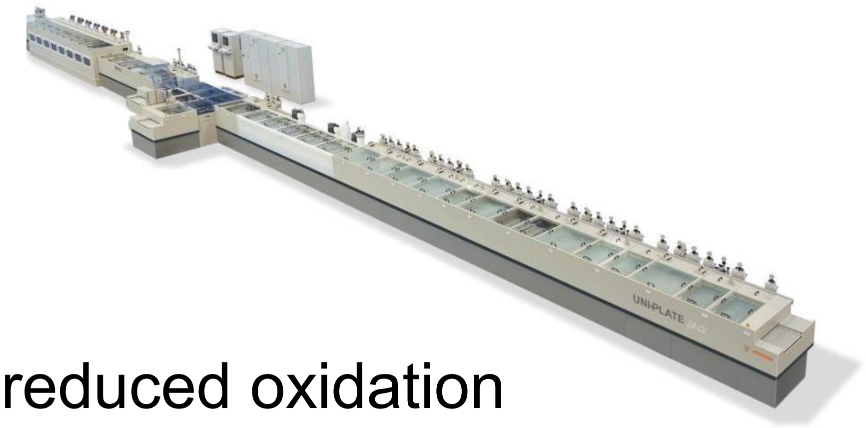
Untreated CCL	Treated CCL
R_a= 0.20µm	R_a= 0.21µm
R_z = 2.06µm	R_z = 2.8µm
Laser Energy 4mJ	Laser Energy 4mJ

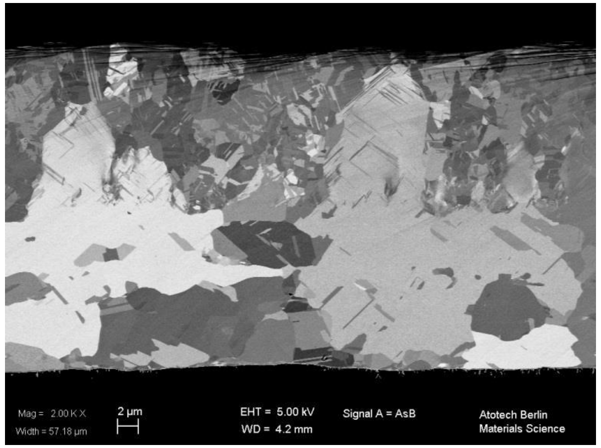


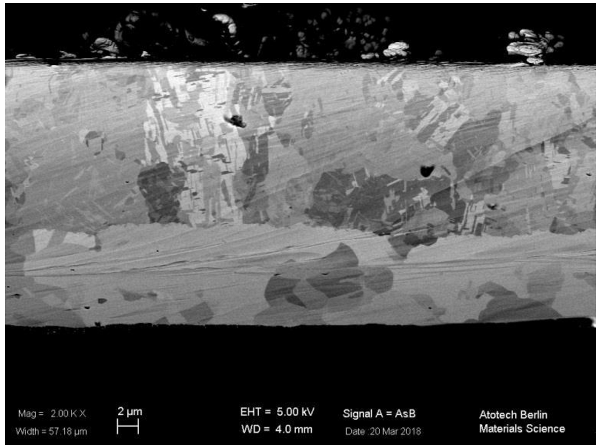
Make the Change and Adopting (a)mSAP
Horizontal In-Line Processing for ELESS Cu & Flash Plate



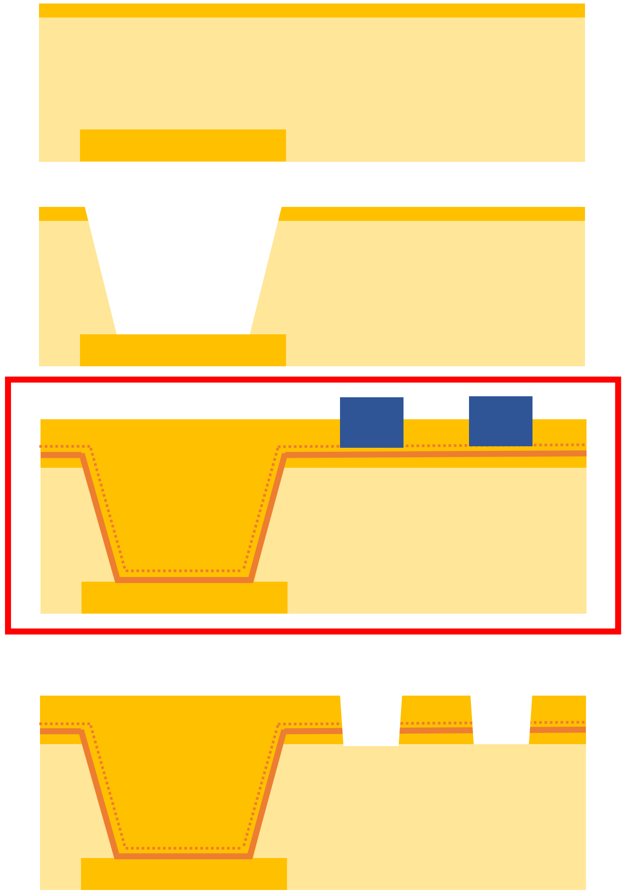
- Panel to panel variation
  - Plating distribution
  - Etch performance
- Wet-to-wet processing
  - Continuous wettability and reduced oxidation
  - Reliability



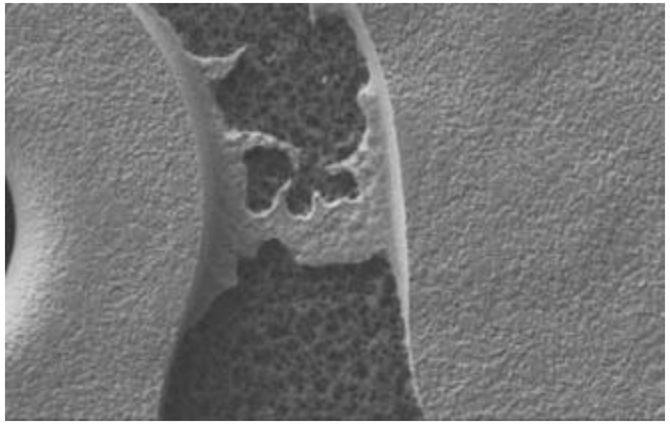




Make the Change and Adopting (a)mSAP
ELESS Cu – Pd Shorts

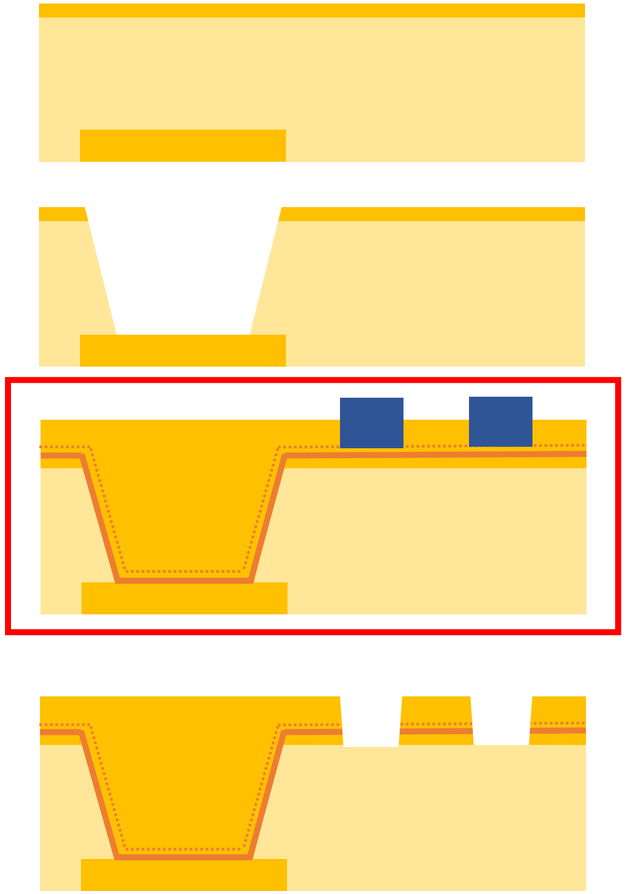


- Interaction between the pre-dip and the Pd activator
  - Pre-dip drags into activator
  - Pd precipitates
  - Deposits on the board
  - Acts as etch mask – shorts
    - Critical for fine line applications



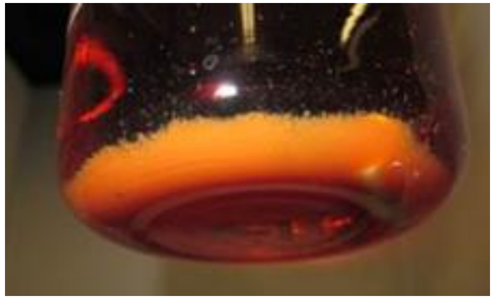
- HDI
  - Over etch and undercut the Pd
  - Plated Cu is thick enough to accommodate this
- mSAP
  - Over etch risks opens/voids
  - Pre-dip to be “inert” towards the activator
  - Activator to be more robust

Make the Change and Adopting (a)mSAP
ELESS Cu – Pd Shorts



- Pre-dip concentrate added to Activator – force precipitation

HDI Pre-Dip

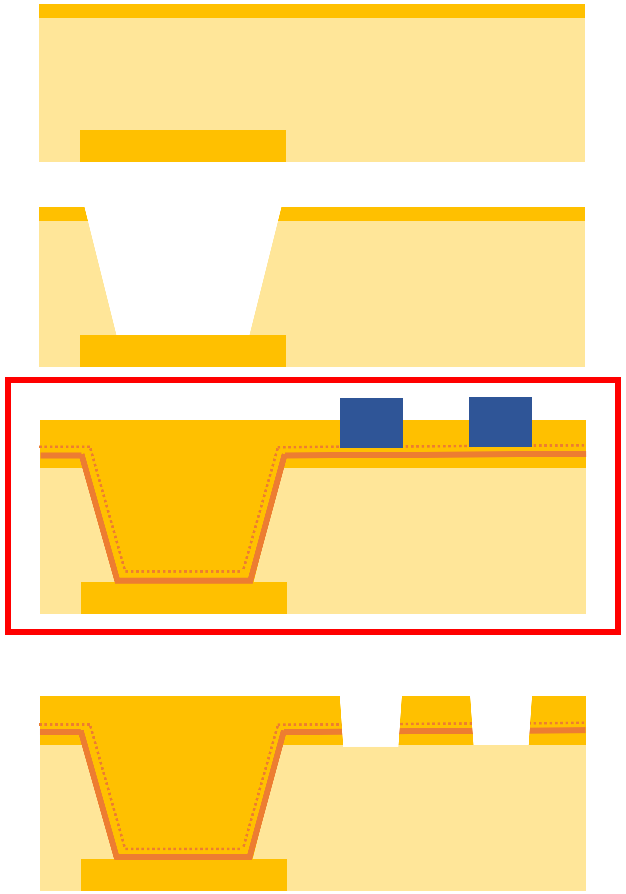


mSAP Pre-Dip

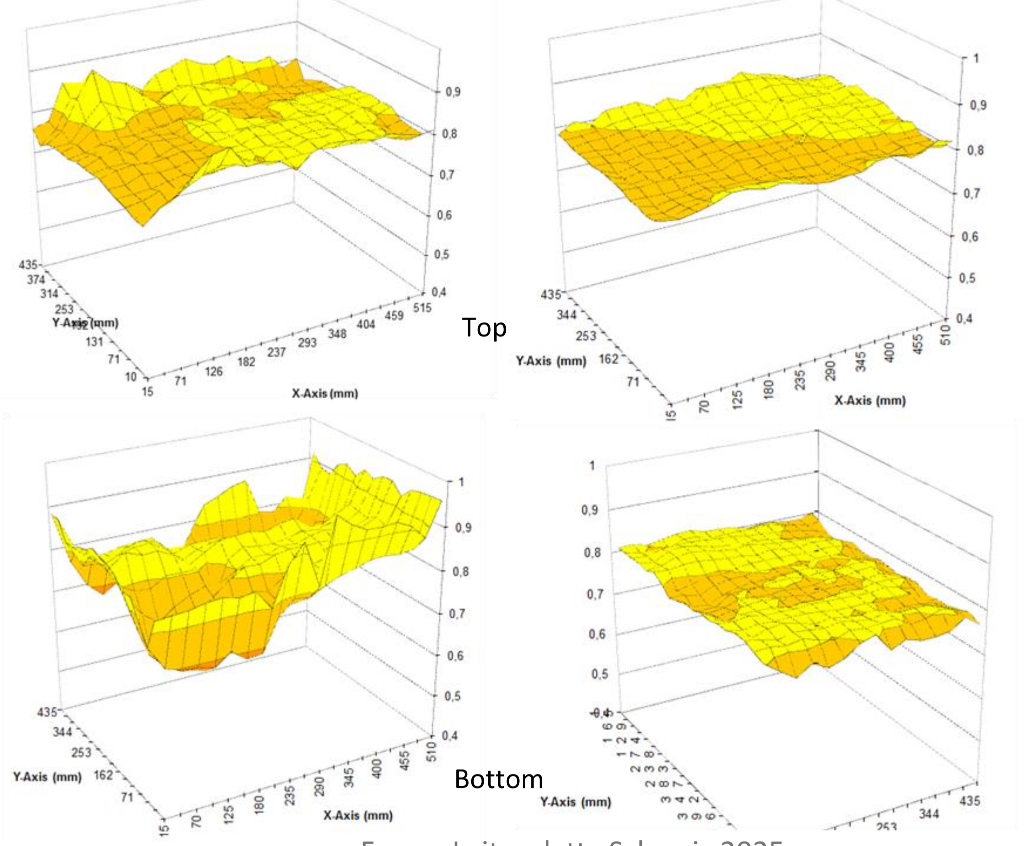
Activator contaminated with	Total Particle Count (#/ml)	Mean Particle Size (µm)	Standard Deviation (µm)
DI Water	34000	3.11	1.14
HDI Pre-Dip	168200	2.72	1.03
mSAP Pre-Dip	68000	2.87	1.46

		HDI Pre-Dip	mSAP Pre-Dip
Test 1	Sample Size (units)	22008	14952
	Defects Detected	1202	383
	Defect Rate	5.46%	2.56%
Test 2	Sample Size (L/S 40/40)	1 lot	1 lot
	Defect Rate	8.50%	2.18%
Test 3	Pd Shorts/panel	1.5	0
	AOI Scan time (600pnl)	360 min	180 min

Make the Change and Adopting (a)mSAP ELESS Cu – Thickness Distribution



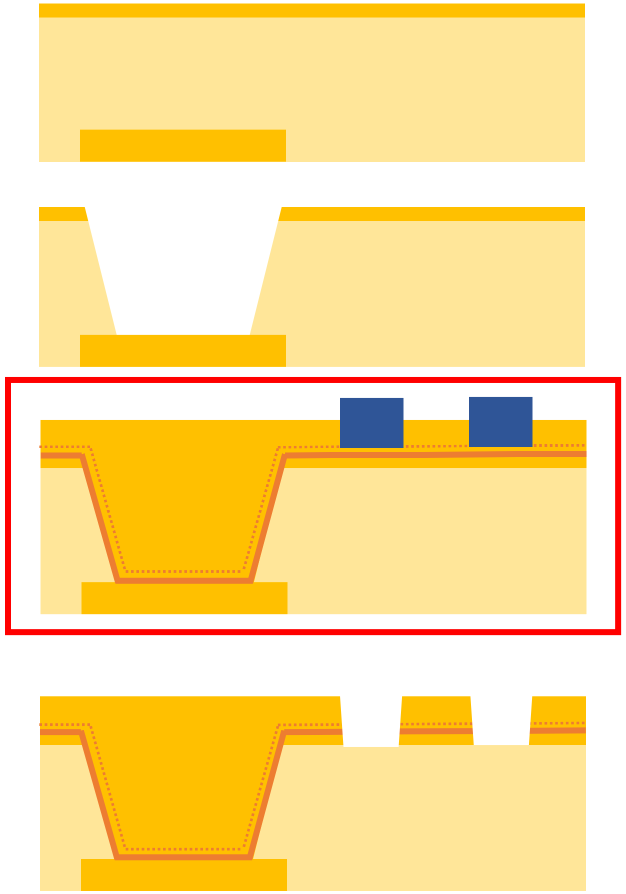
- Latest generation ELESS baths outperform previous versions



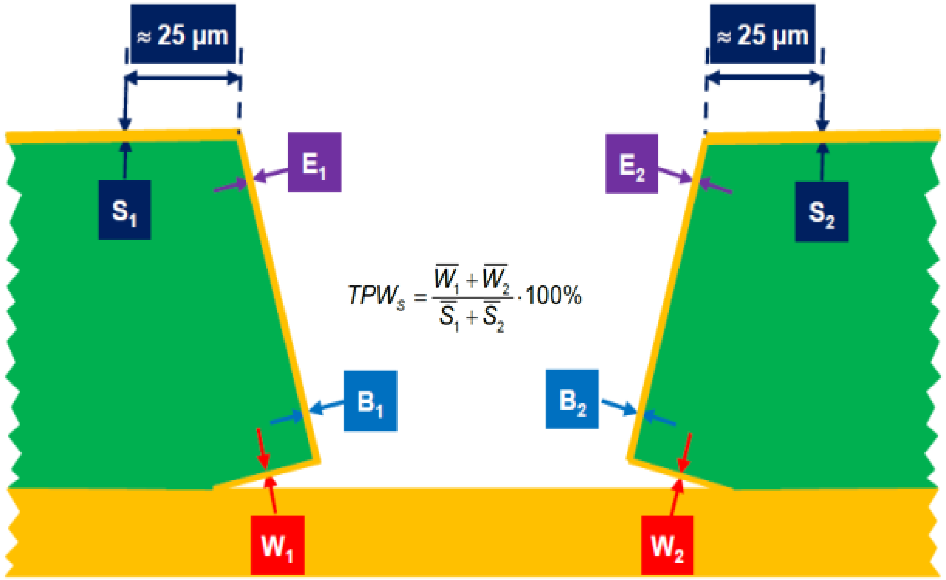
Thickness	HDI ELESS	mSAP ELESS
Mean (µm)	0.80	0.80
Range (µm)	0.18	0.08
Std Deviation (µm)	0.02	0.02

Thickness	HDI ELESS	mSAP ELESS
Mean (µm)	0.80	0.80
Range (µm)	0.32	0.07
Std Deviation (µm)	0.07	0.01

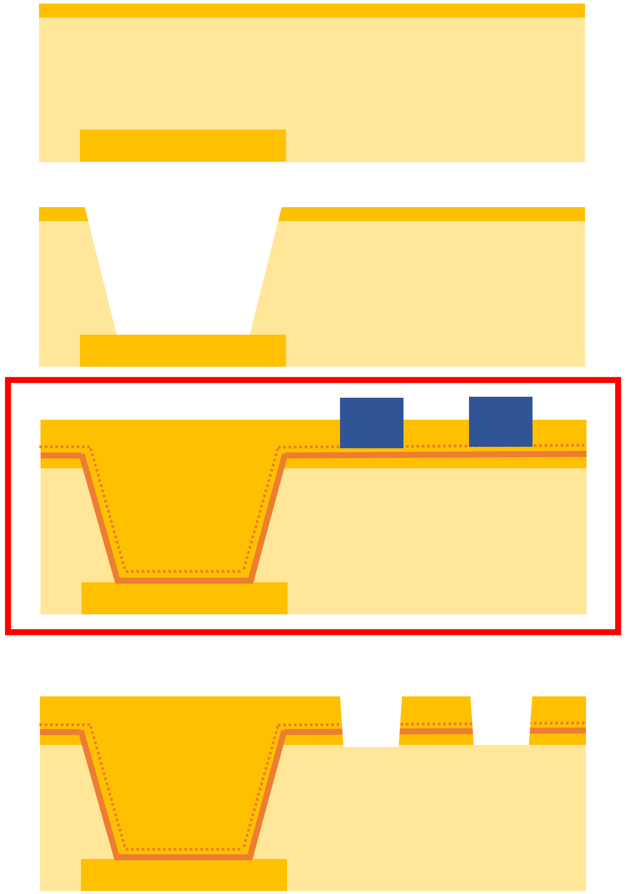
Make the Change and Adopting (a)mSAP
ELESS Cu – BMV Throwing Power



- $TP\% = \dfrac{\text{ELESS Cu layer thickness on the Surface or at Entry}}{\text{ELESS Cu layer thickness at the Bottom or in the Wedge}}$



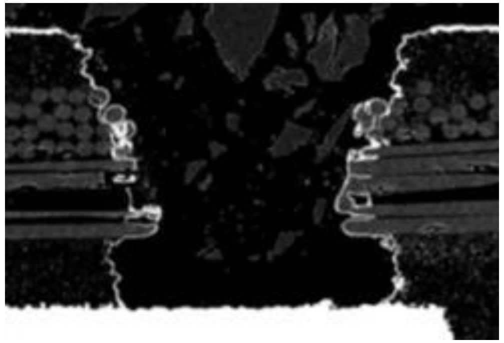
Make the Change and Adopting (a)mSAP ELESS Cu – BMV Throwing Power

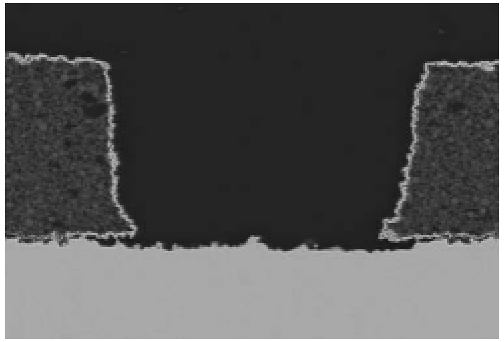


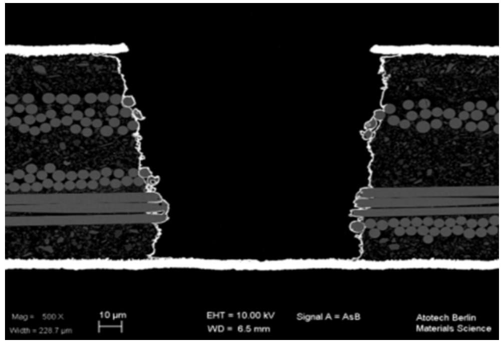
- Cu thickness on the surface to be minimized
  - Etch capability
- Cu thickness in the BMV to be maximized
  - Reliability

- HDI ELESS – typical throwing power 30-40%
  - 1µm on the target pad ≈ 2µm on the surface
  - mSAP targets 4-10µm total Cu on the surface
  - + 20-50% surface Cu due to ELESS

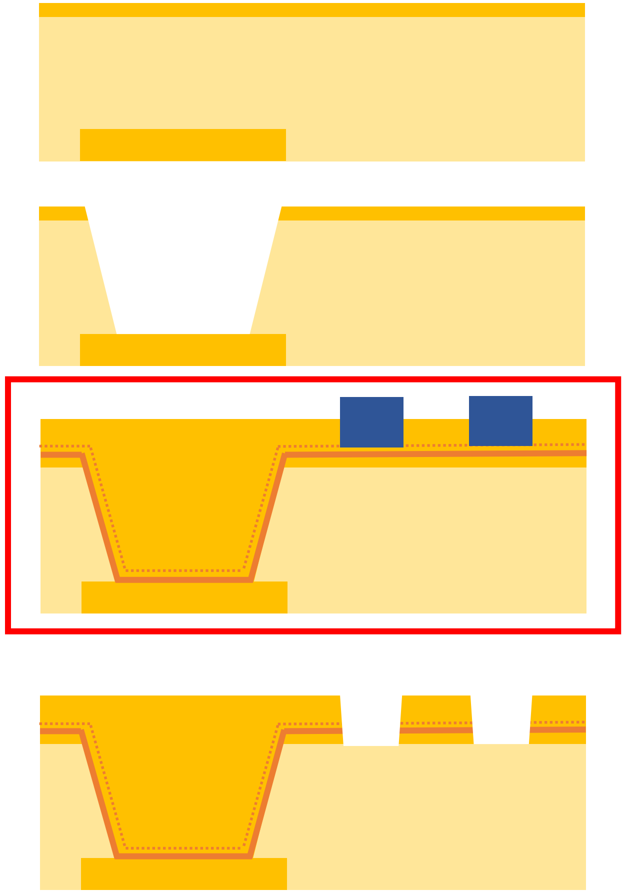
- (a)mSAP ELESS – typical throwing power >75%





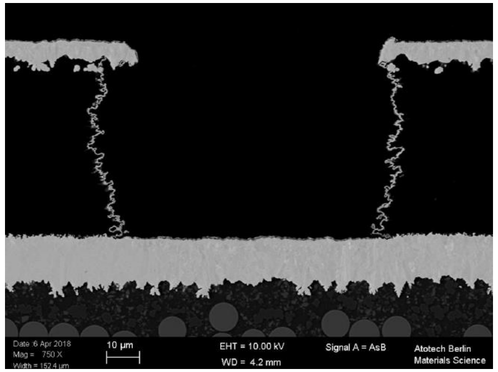


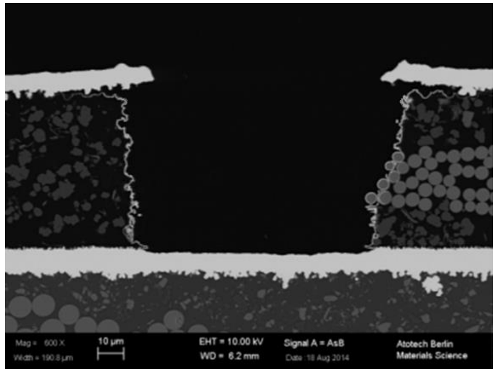
Make the Change and Adopting (a)mSAP ELESS Cu – BMV Throwing Power

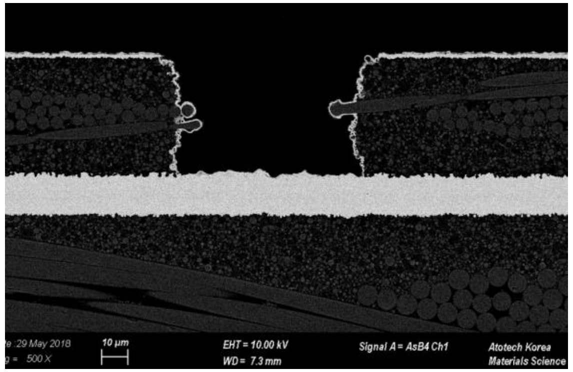


- Latest generation ELESS Cu baths outperform previous versions

Via Dia x Height (µm)	HDI ELESS Bath Surface Cu (µm)	HDI ELESS Bath BMV Cu (µm)	TP (%)	mSAP ELESS Bath Surface Cu (µm)	mSAP ELESS Bath BMV Cu (µm)	TP (%)
100 x 60	0.45	0.15	33	0.43	0.32	75
100 x 65	0.30	0.08	28	0.37	0.27	73
	0.35	0.12	34			
100 x 85	0.82	0.38	46	0.37	0.34	91
	0.71	0.39	55	0.46	0.40	86
75 x 65	0.18	0.08	45	0.17	0.13	76
110 x 100	0.38	0.20	53	0.32	0.24	75

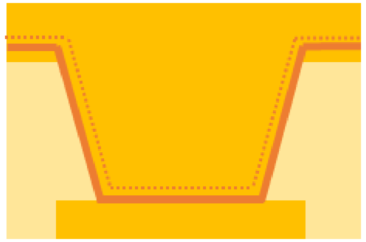


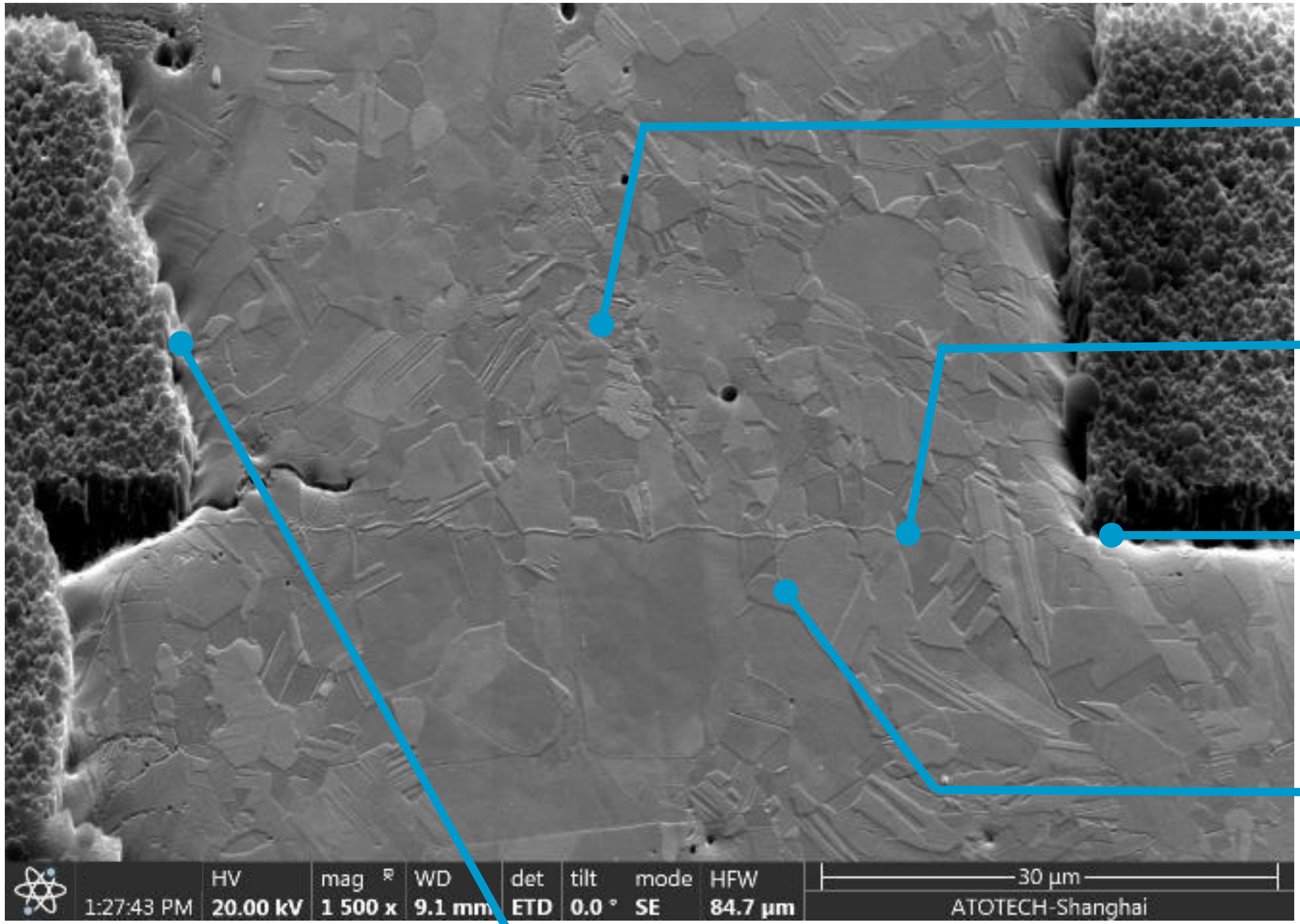




What Makes a Reliable MicroVia?

“There is No Silver Bullet”





Electroplated Cu
Microstructure, Epitaxy, Nanovoid & inclusion density, leveller/brightener codeposition

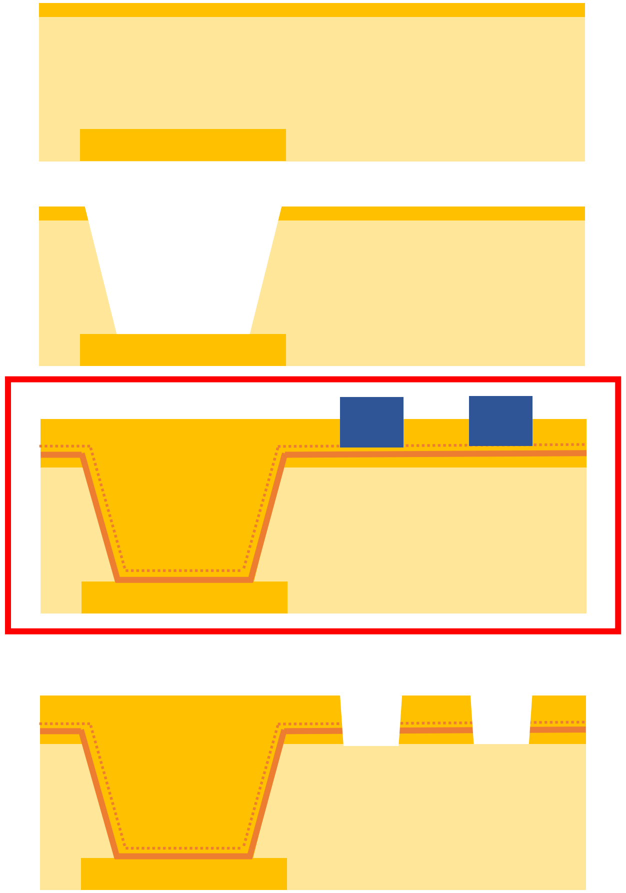
Electroless Cu layer
Microstructure, Epitaxy, Nanovoid & inclusion density, surface facets

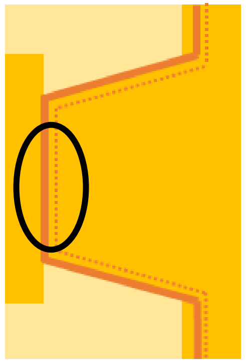
BMV Wedge
Aspect ratio, cleanliness, electrical contact to target pad

Target Pad
Microstructure, before and after laser drill, flatness, roughness

BMV Shape
Drilling & hole quality

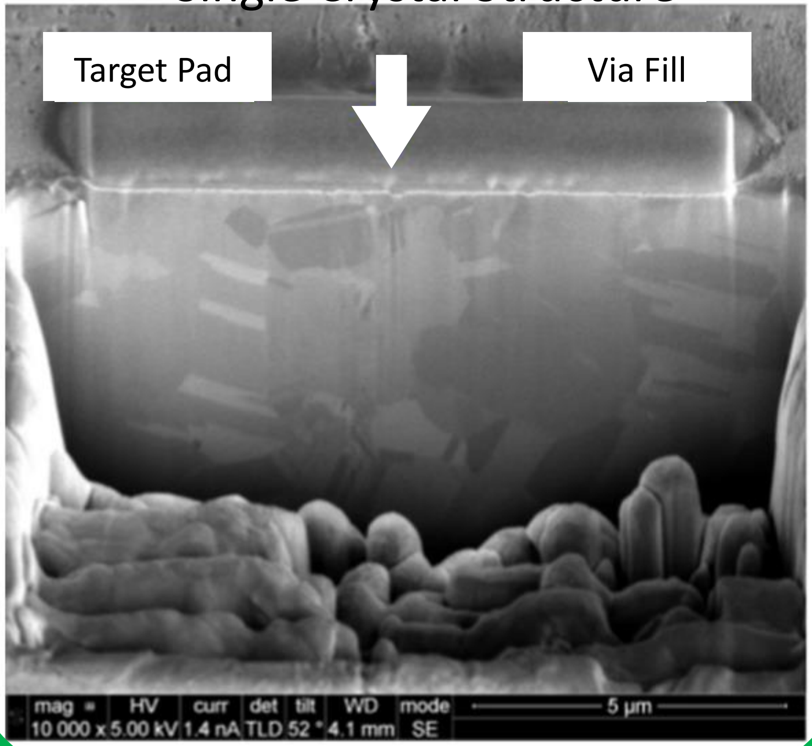
Make the Change and Adopting (a)mSAP ELESS Cu – BMV Reliability



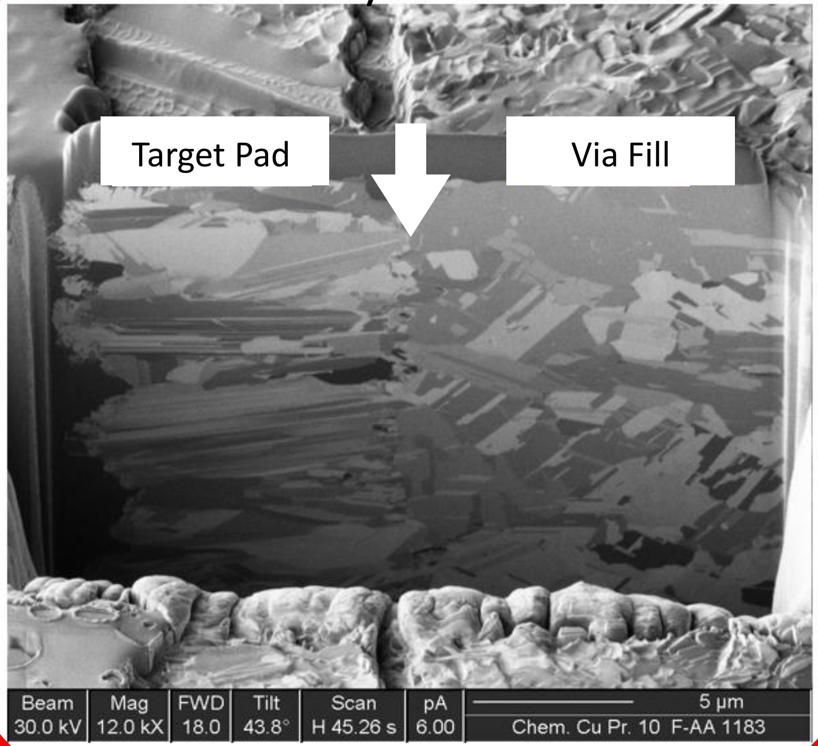


- Latest generation ELESS Cu baths outperform previous versions

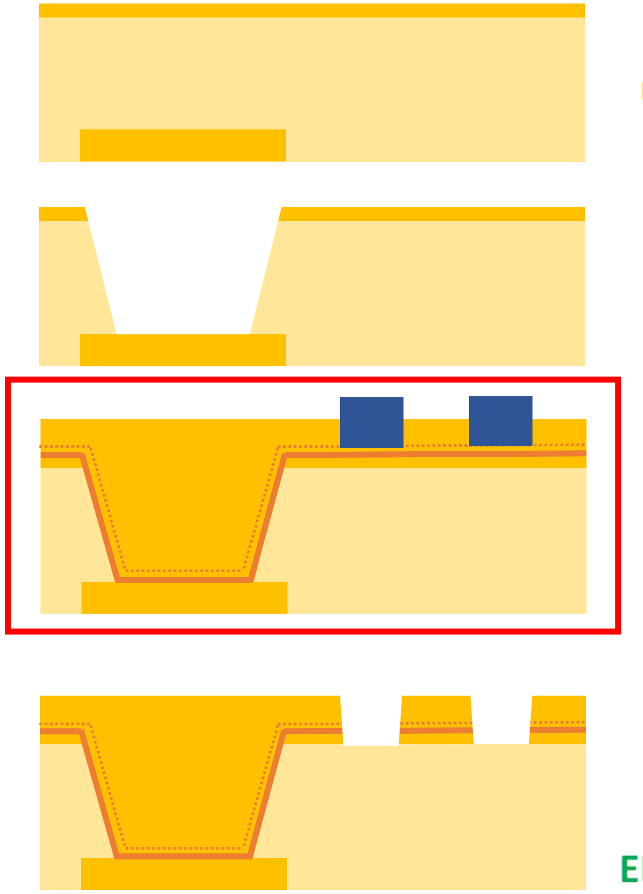
Single Crystal Structure



Broken Crystal Structure



Make the Change and Adopting (a)mSAP
ELESS Cu – BMV Reliability



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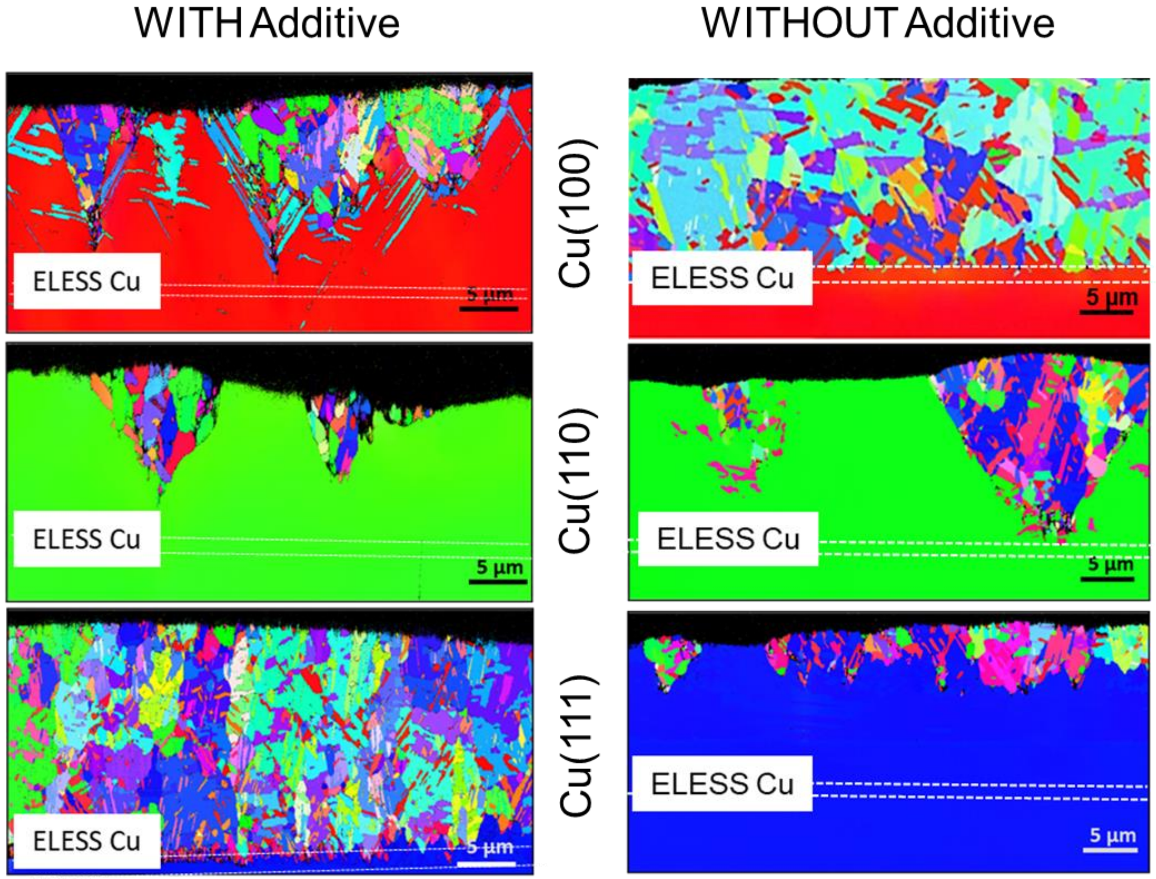


ELESS & ELYTC Bottom Up

ELESS - Bottom Up
ELYTC - Top Down

ELESS & ELYTC Bottom Up

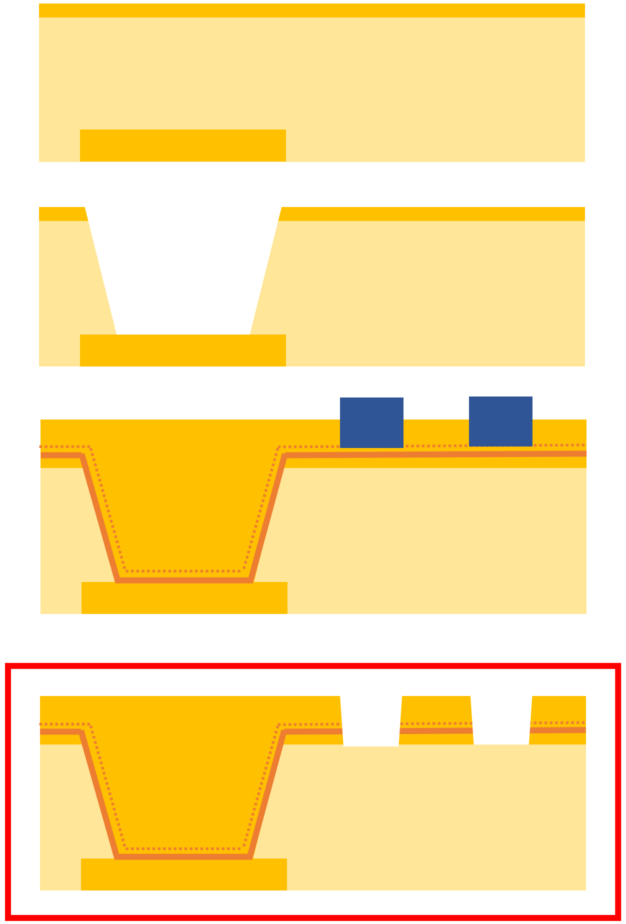
ELESS & ELYTC Bottom Up

ELESS - Bottom Up
ELYTC - Top Down

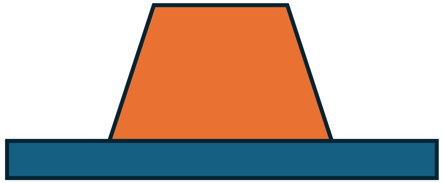
ELESS & ELYTC Bottom Up

EBSD =
Electron backscatter diffraction
(Elektronenrückstreubeugung)

Make the Change and Adopting (a)mSAP
Final Etch – Track Geometry

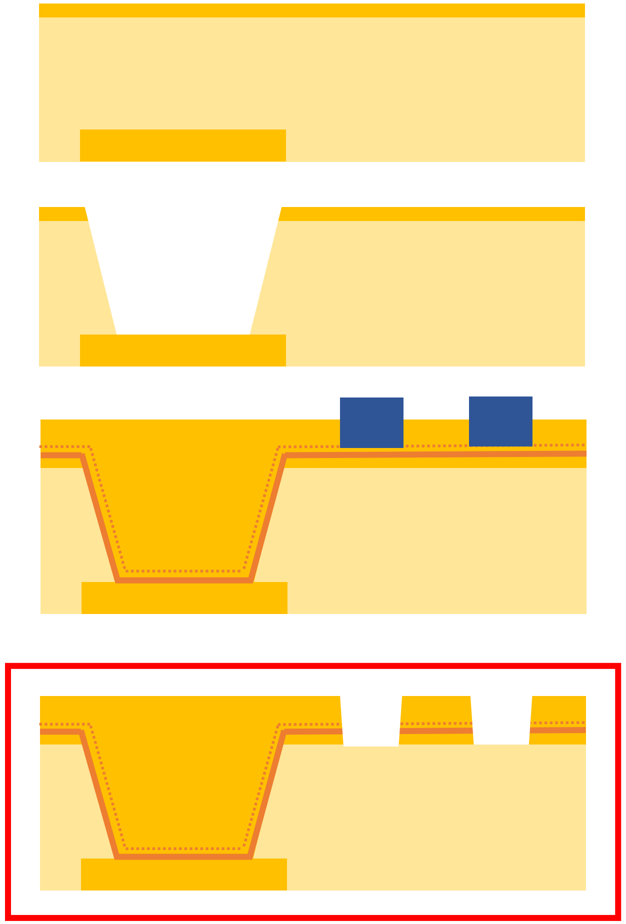


- Dependent on
  - Surface Cu thickness
  - Etch chemistry
- HDI
  - Generic chemistry
  - Very high etch rate (>20 µm surface Cu)
  - Significant side wall attack – trapezoid

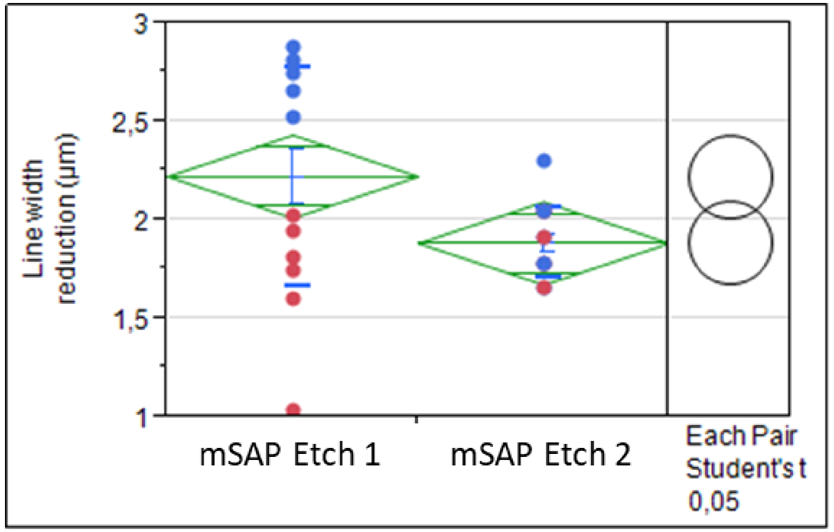


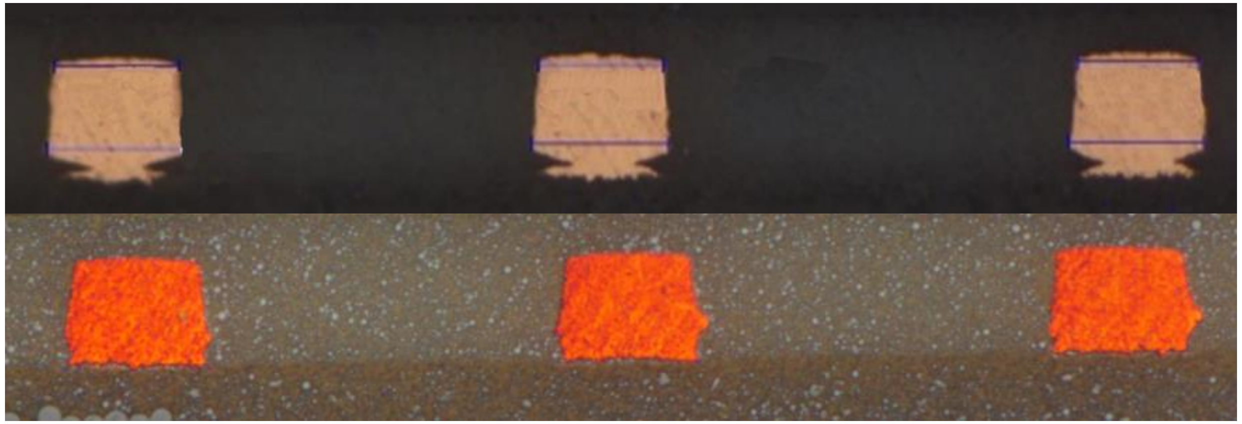
- mSAP
  - Proprietary chemistry required
  - Low etch rate (<5 µm surface Cu)
  - Low side wall attack – square
  - Minimise undercut to avoid track lift-off

Make the Change and Adopting (a)mSAP
Final Etch – Track Geometry



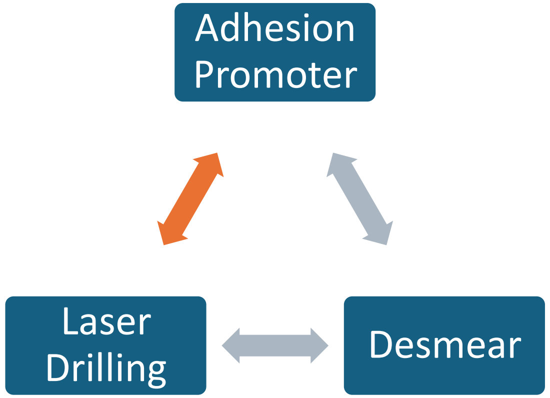
- Additives
  - Stabilise the etch rate
  - Minimise side wall attack
    - <3 µm is achievable
  - Minimise undercut



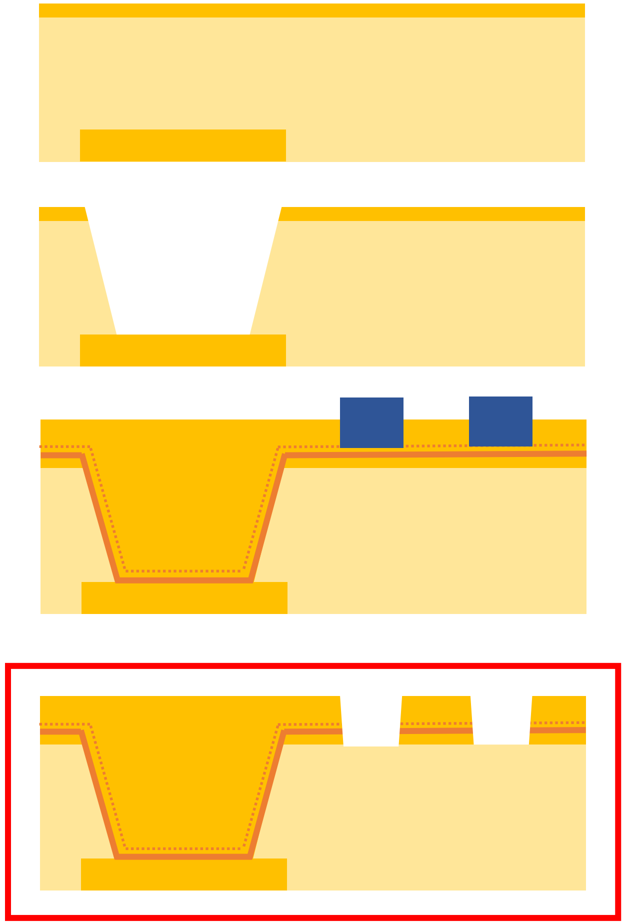


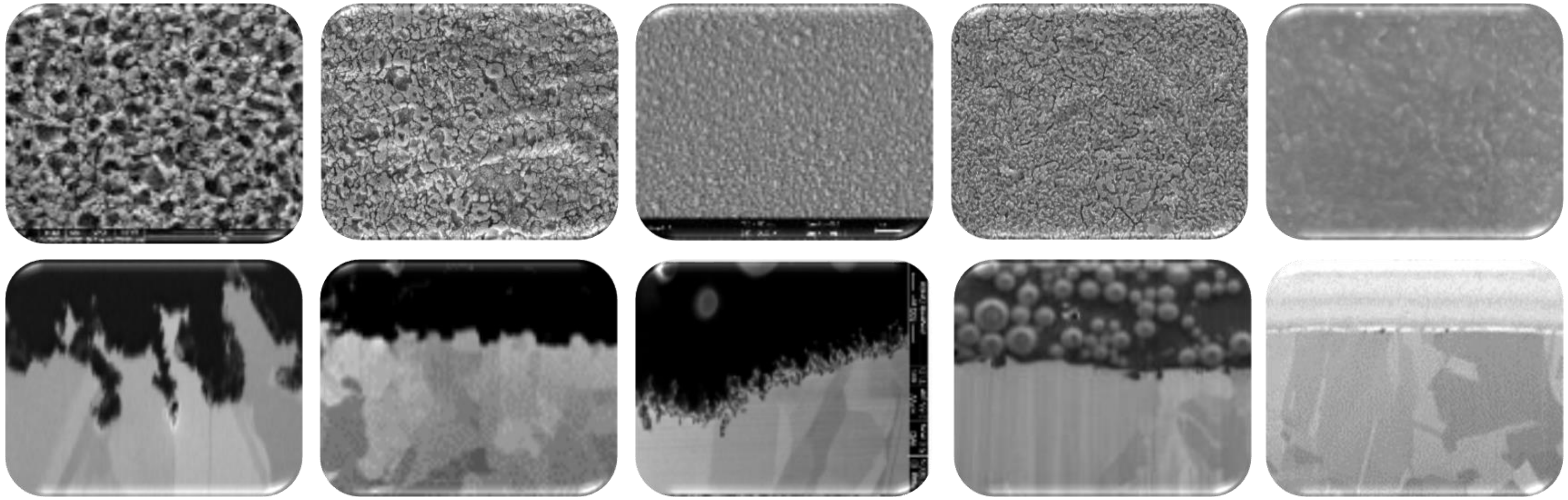
EcoFlash® S 300 (Fe^{3+})

Make the Change and Adopting (a)mSAP Inner Layer Adhesion



- Existing oxide alternative process etc. are compatible with mSAP
- Trend to move towards low etch/low roughening processes

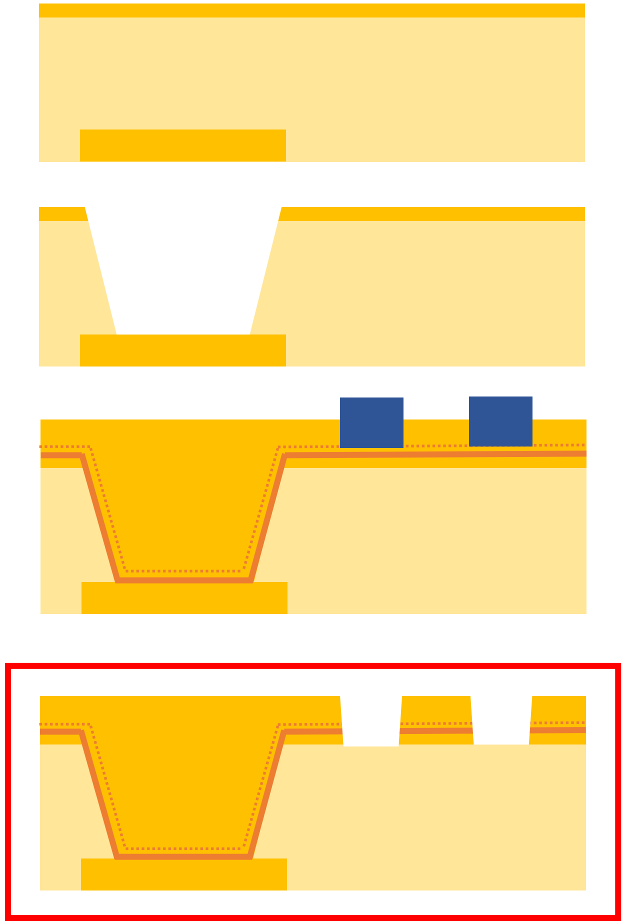




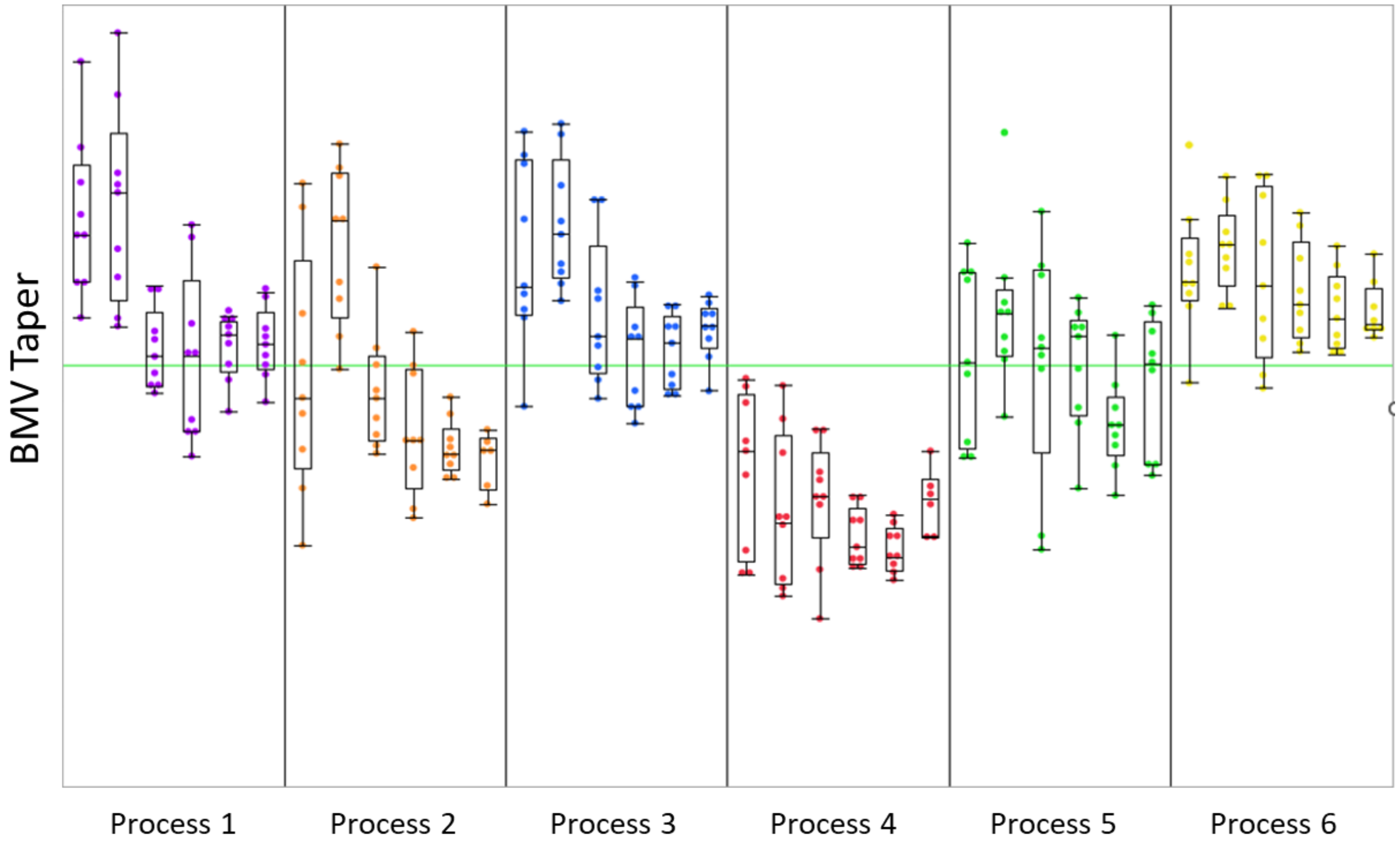
Rq ≈ 400-600nm | Rq ≈ 150-200nm | Rq ≈ 100-150nm | Rq ≈ 50-100nm | Rq ≈ 25-50nm

- Side effects elsewhere

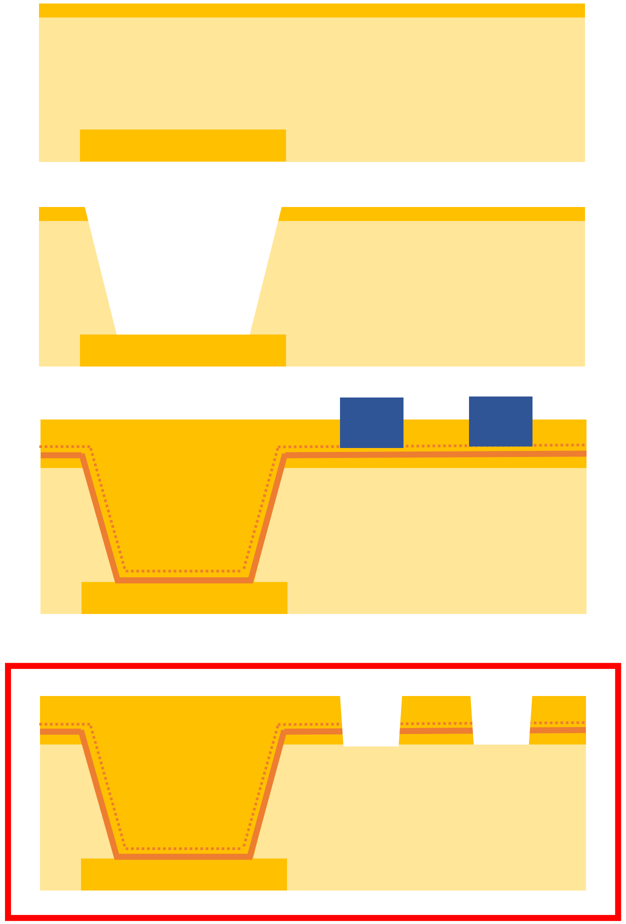
Make the Change and Adopting (a)mSAP
Inner Layer Adhesion



- Impact of adhesion promoter on LDD & BMV performance



Make the Change and Adopting (a)mSAP Inner Layer Adhesion



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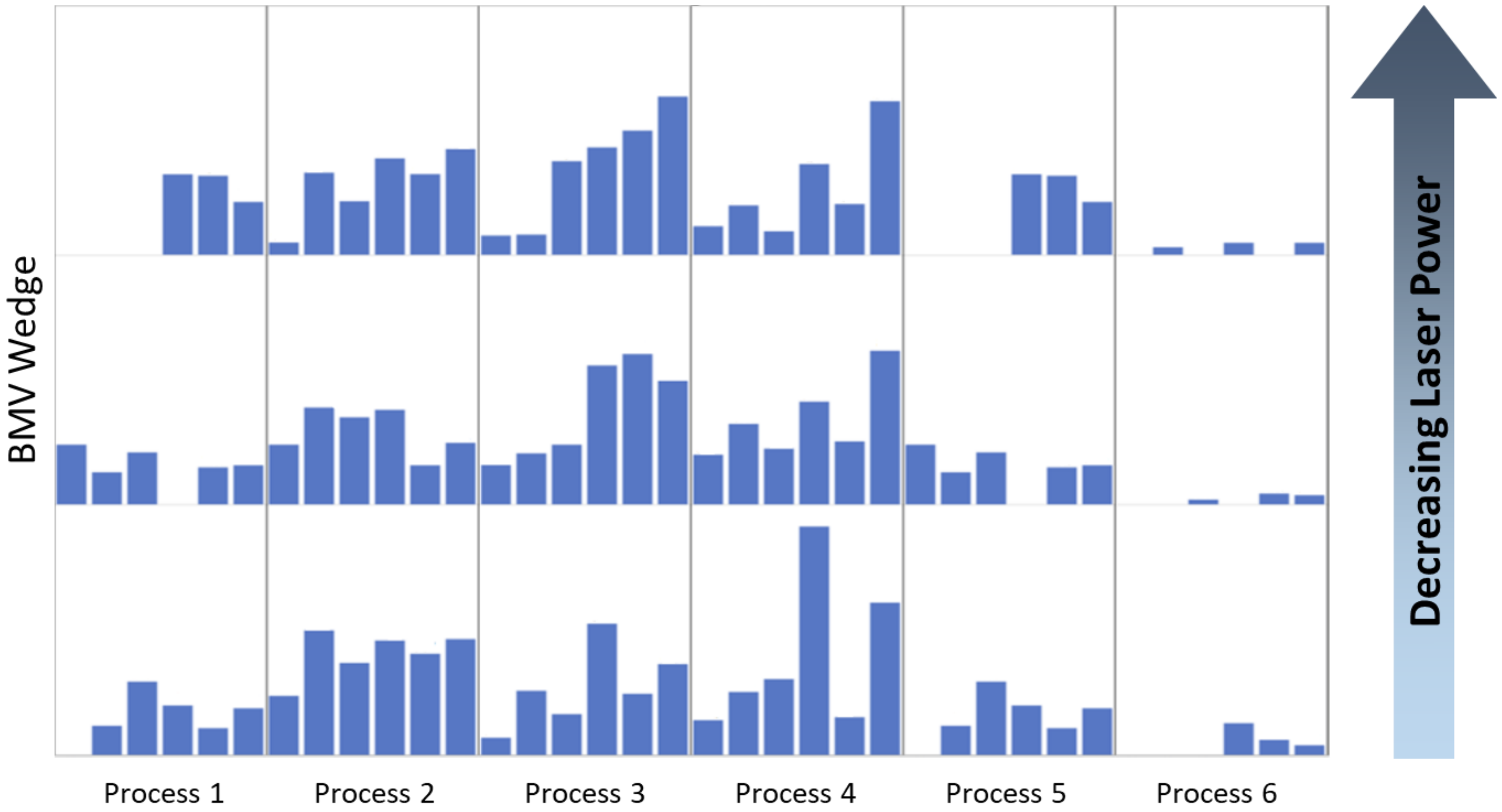
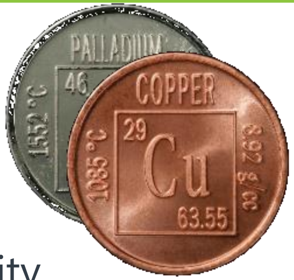


Make the Change and Adopting (a)mSAP Summary

- Subtractive HDI limited to 40/45 µm L/S
- SAP best suited for less than 20/20 µm L/S
- "Ultra HDI" best selection for achieving 30-40 µm L/S
  - Options to extend further to 20-40 µm L/S
- "Ultra HDI" is in volume production – processes already exist
  - Operating costs are higher compared to traditional HDI processes
  - Opportunities to adopt existing infrastructure
    - Inline horizontal plating is the POR
    - New chemical processes are required
      - Minimize Cu foil removal
      - Maximize BMV coverage with minimal surface Cu
      - Enhanced etch capabilities
- Experienced process suppliers are your best partners when moving to "Advanced HDI"

Cupraganth® MV Activation
Pd Free Activation for Package Substrates

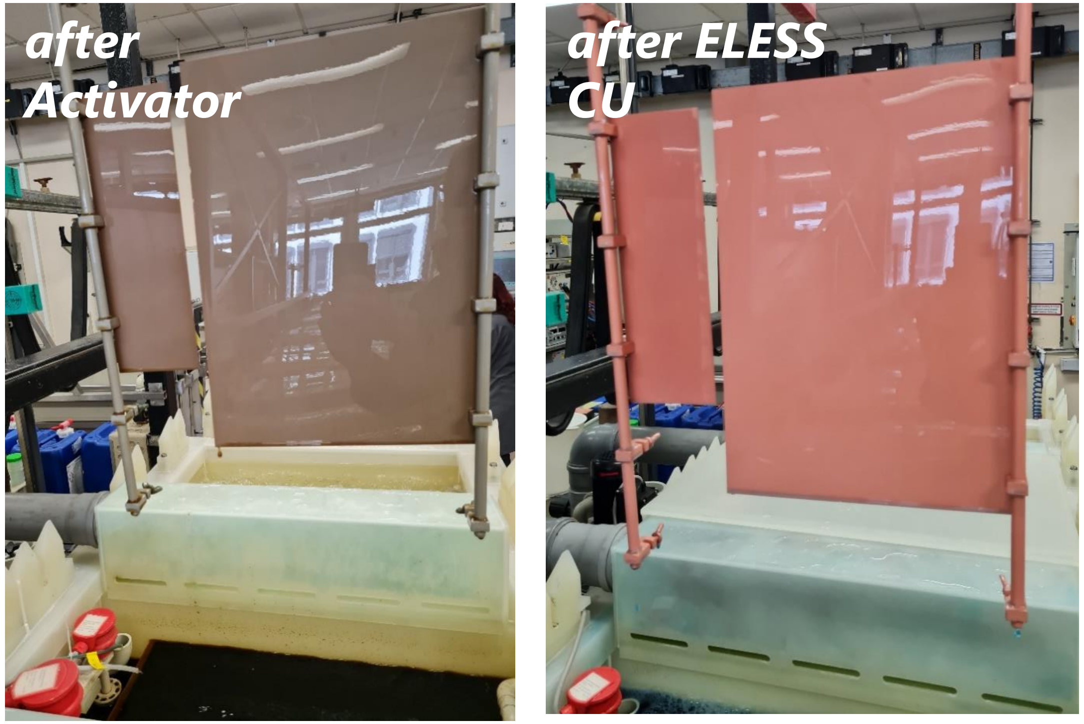
Features



- Pd Free activation based on Cu colloids
- Robust and stable process, easy to operate
- Improved differential etch control and capability
- Activation performance at least comparable to POR (Pd)
- E'less Cu coverage and adhesion performance at least comparable to existing POR Pd based processes
- Fully compatible with most vertical e'less Cu baths and drop-in for typical SAP basket lines

Benefits

- Enables higher track pitches at higher yield rates
- Reduced operating costs
  - Pd 1000 $/Oz vs Cu 10 $/kg
  - Removal of dedicated Pd strip step
  - No dependency on Pd spot price



ABF GL102 & GL103, Printoganth® MV TP2 (10 min, 31 °C)

Status / References

- Internal scale up finished, internal full scale qualification stage under evaluation
- Sampling of full-sized customer panels started
- **Looking for beta site candidates / onsite tests**

Thank you for listening.
Any questions?

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