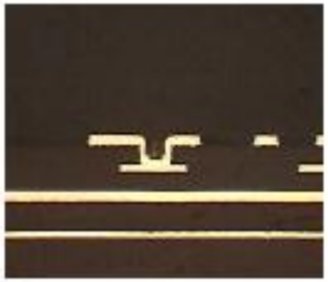
Speaker is an invited presentation

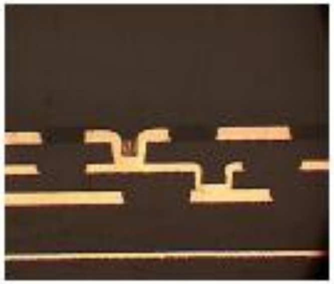
A Technical Paper was not required for the 2014 APEXPO™ Technical Conference

The Total Environmental Solution for Any-layer HDI Production

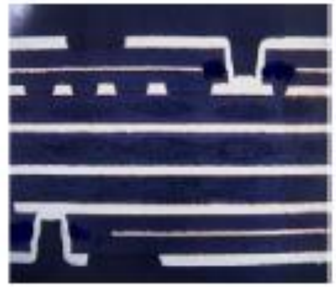
Steven Tam, Andreas Gloeckner, Christian Rietmann
Enthone Inc.



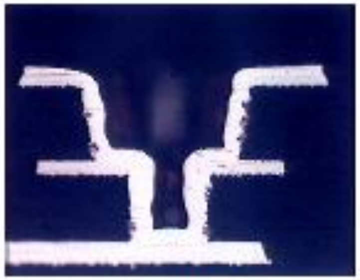
Blind Via



Stagger Via



Skip Via



Stack Via

(Step type)

Stack Via

(Cu fill)

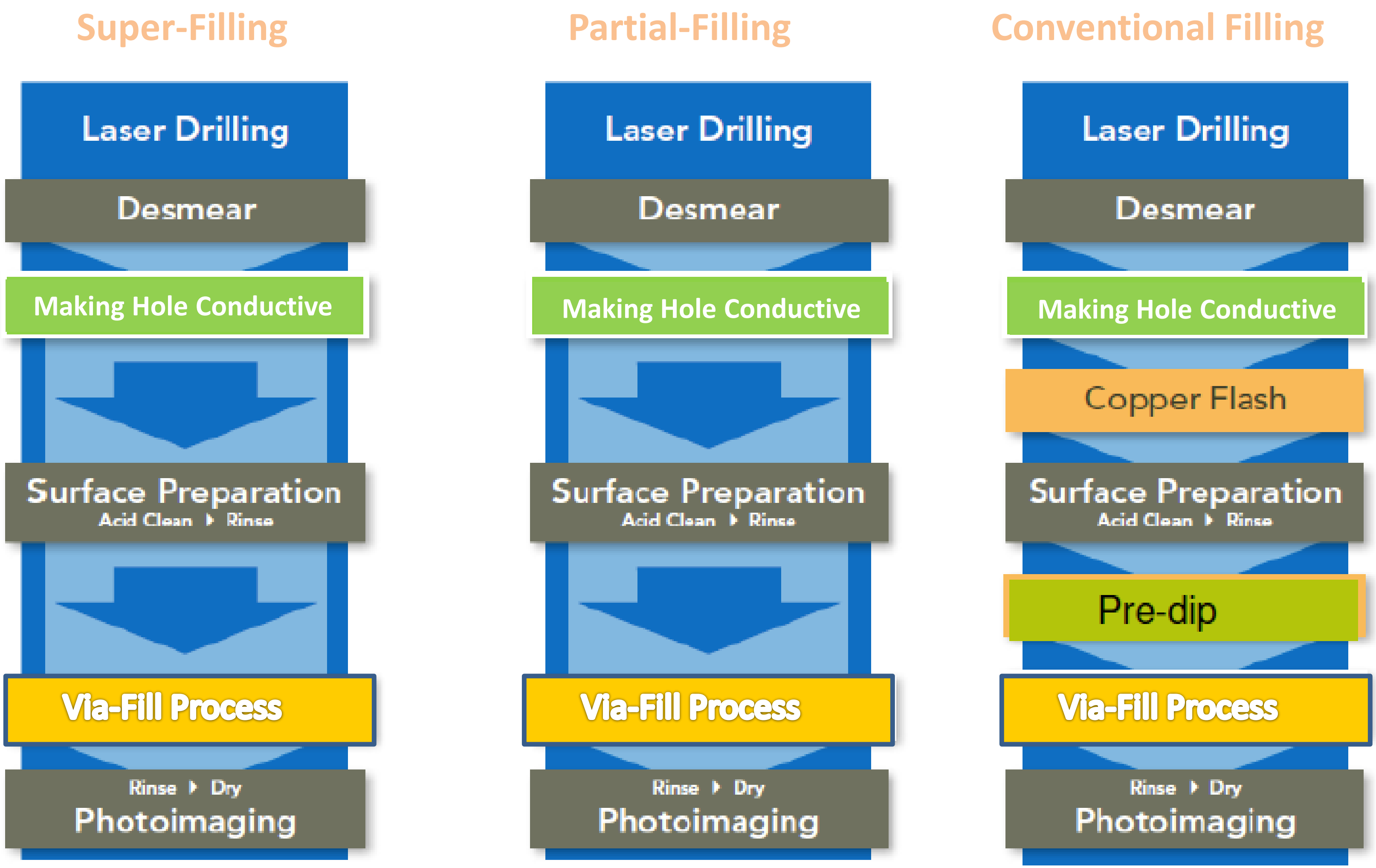
1+N+1 HDI Structure

2+N+2 Stacked Via Structure

3+N+3 Stacked Via Structure

Any Layer Structure

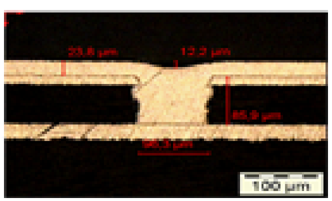
Overview of different Via-Fill Technology



Process Value of new developed Via-Fill Process

Traditional Via-Fill Process
6 Steps

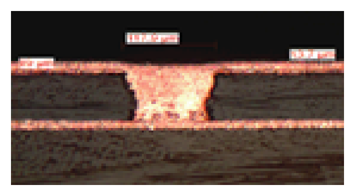
- Laser Drilling
- Electroless Copper
- Cu Flash (10 mins)
- Traditional Copper Via-fill
- Copper Reduction
- Photo-imaging



Typical result
Total Surface Copper < 25 um
Plating CD : 15 ASF

Innovative Via-Fill Process
4 Steps

- Laser Drilling
- New Conductive Polymer Seeding
- Novel Copper Via-Fill
- Photo-imaging



Typical result
Total Surface Copper < 15 um
Plating CD : 20 ASF

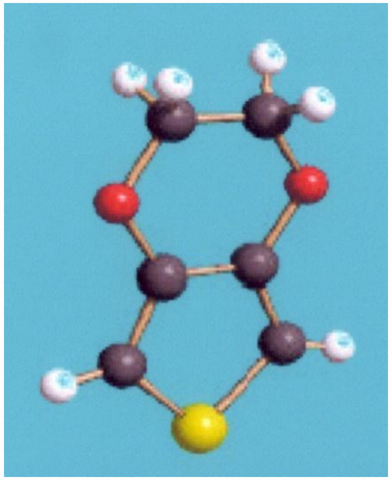
No Copper Flash is required. Machine Footprint reduce 10%.

Faster Filling Time, reduce 30%

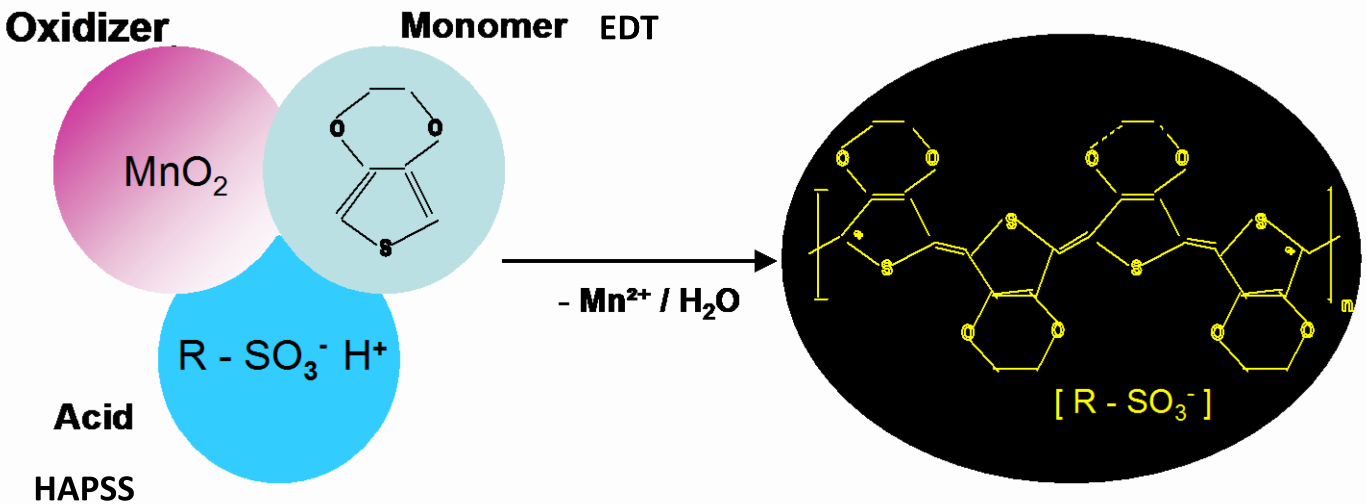
No copper reduction
→ Process cycle time reduction & reduce copper usage

Conductive Polymer Mechanism

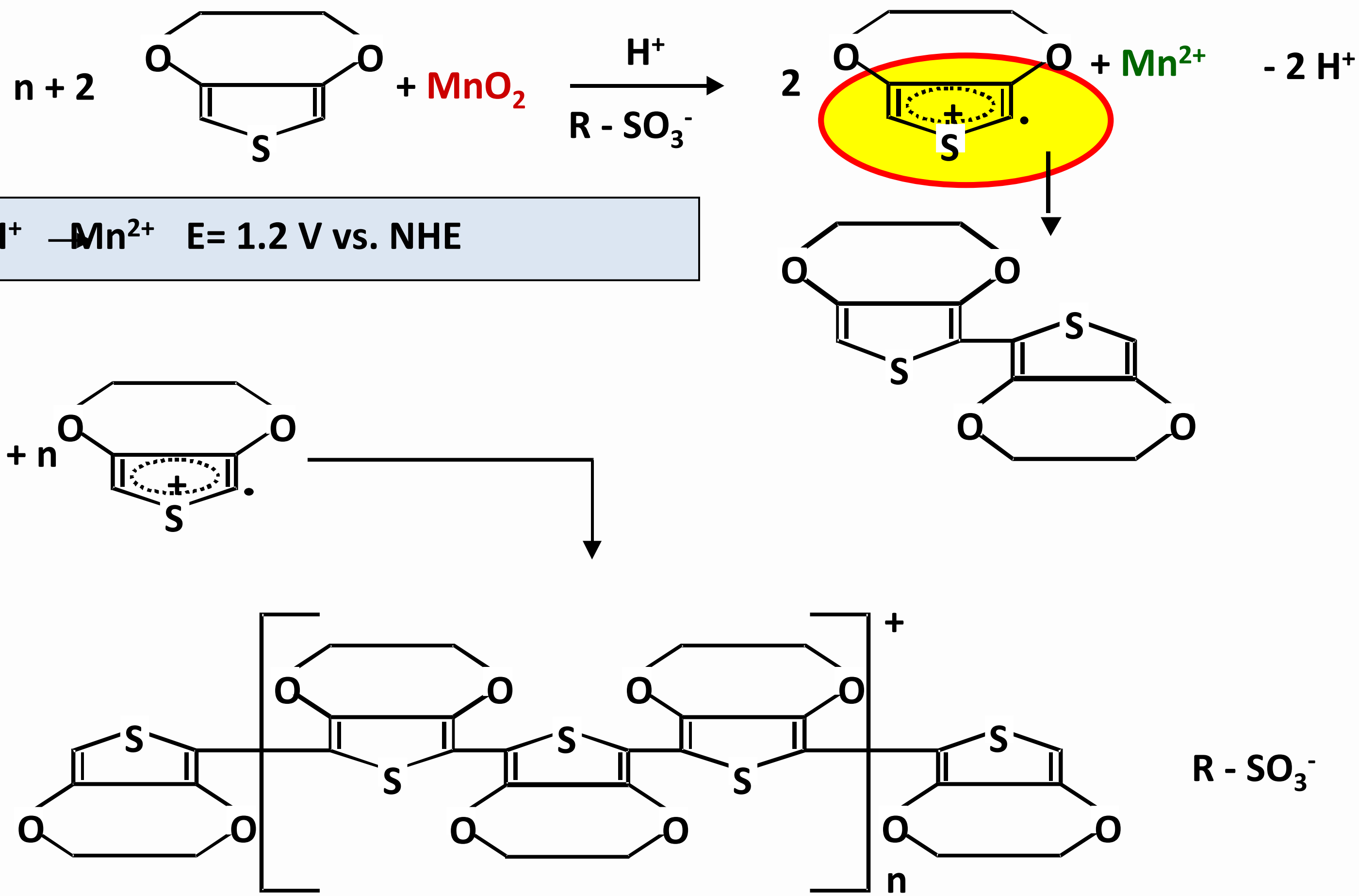
- **Reaction Mechanism Simplified**
  - Activation of Dielectrics only
    - Selective MnO_2 formation (Initiator)
  - Polymerization of
    - Monomer - EDT
    - Organic Sulfonic Acid - HAPSS



Corner Stone: EDT

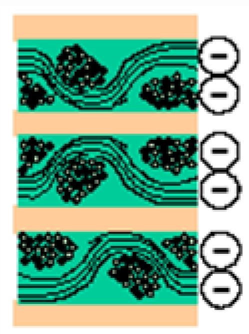
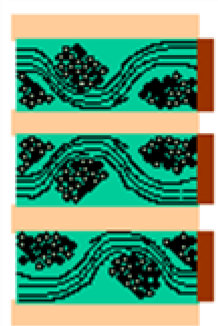
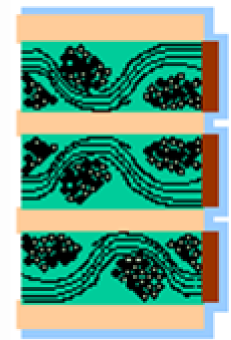
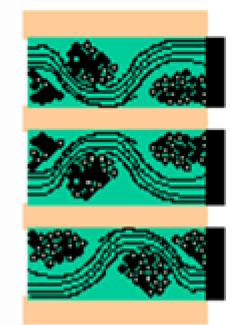


Reaction mechanism



$[MnO_2]_s + H^+ \rightarrow Mn^{2+}$ E= 1.2 V vs. NHE

Formation of Conductive Polymer

			
Step 1 Conditioner	Step 2 Initiator Permanganate treatment	Step 3 Catalyst Polymerization	Conductive Polymer
Cationic polymer improves MnO2 absorption	Selective MnO2 Deposition on Glass and resin	EDT monomer coats MnO2 and is oxidized in the presence of PSS PSS donates H+ Ions making the coating conductive	

This selective properties of Conductive Polymer can be proven by analytical techniques.

Properties Of Conductive Polymer

- **Appearance**
  - Uniformly Dark Greenish to Anthracite/Black
  - Thickness approximately 100nm
- **Characteristics**
  - High Mechanical Stability
  - Thermal Stability (400° C)
  - Resistance approx. 5 KΩ / inch
- **Stability**
  - Sensitive to Chemical Oxidation (or Reduction)
  - Marginal loss of Conductivity
    - Storage Dependent (4-5 Days Guaranteed)

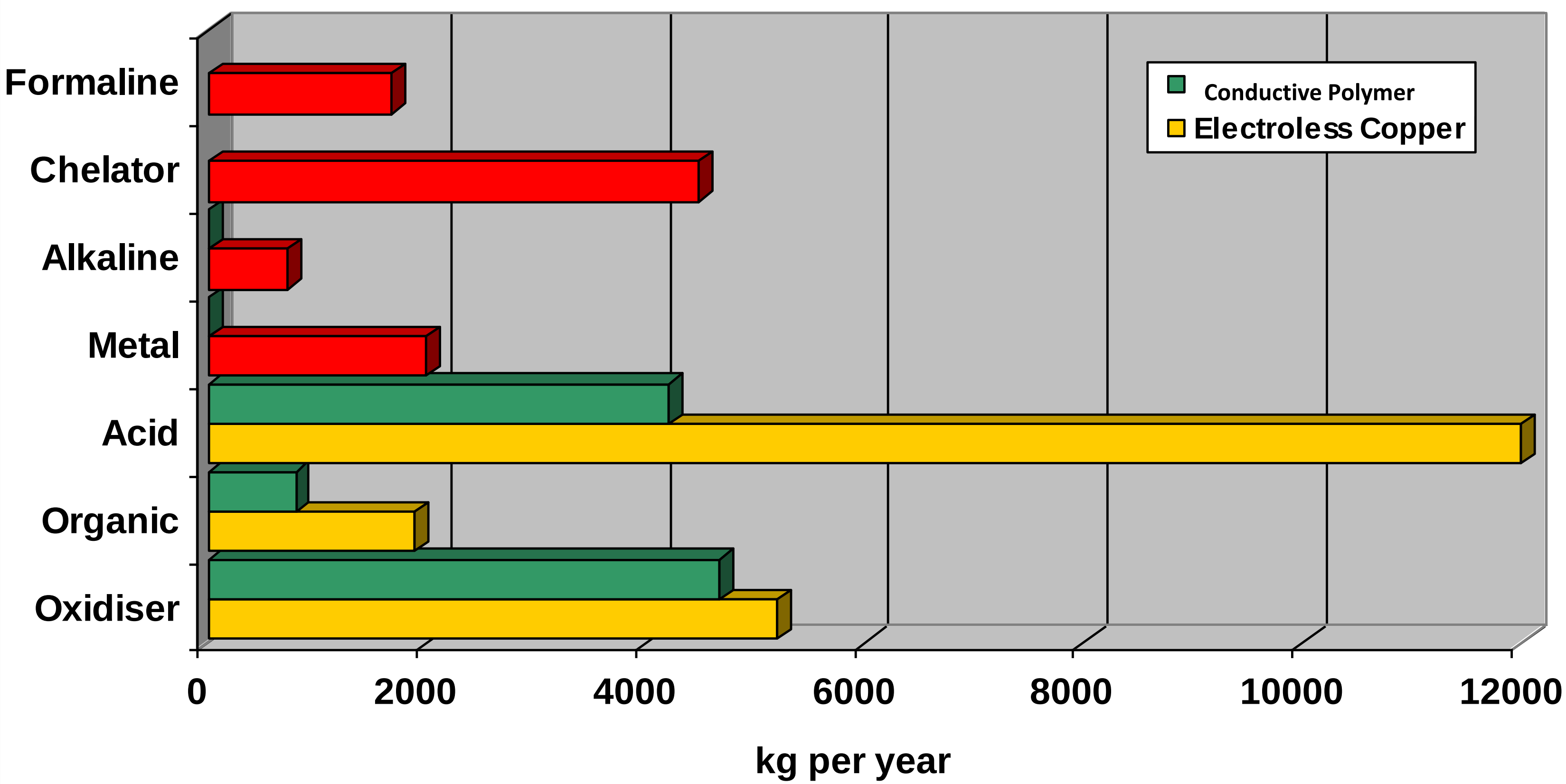
Environmental Benefits

Environmental friendly

No chelators, No formaldehyde

- Improved worker's health
- Reduced waste generation
- Reduced water and energy consumption
- Simplified waste water treatment
- Lower water consumption
- **Lower costs**

Cumulative Consumption of Chemicals per Year



400 000 m² Laminate / Year, horizontal

Cumulative Consumption of Chemicals per Year

	Typical Electroless Copper	Conductive Polymer
Oxidizing Agents	5200 kg	4680 kg
Acid	14148 kg	4180 kg
Organic	1864 kg	784 kg
Metal	2008 kg	-
Alkaline	720 kg	-
Chelator	4480 kg	-
Formaldehyde	1680 kg	-

Based on: Horizontal Drag Out 80mL/L, 400,000 m^2 board per year

Direct Metallization
Alternatives to Electroless Copper (E'Cu)

- **Direct Metallization**
  - Pd Seeding
    - Activation on Dielectrics & Copper Surfaces
    - Etch-Back Removal of Activated Copper Surfaces
  - Graphite- & Carbon Activation
    - Activation on Dielectrics & Copper Surfaces
    - Etch-Back Removal of Activated Copper Surfaces
  - Intrinsic Conductive Polymer (ICP)
    - **Activation of Dielectrics Only**
    - **Without Etch-Back Removal of Activated Copper Surfaces**

Importance of Selective Activation

- **Selective Activation**
  - Performance Reliability
  - Only Dielectrics

    Laminate Resin

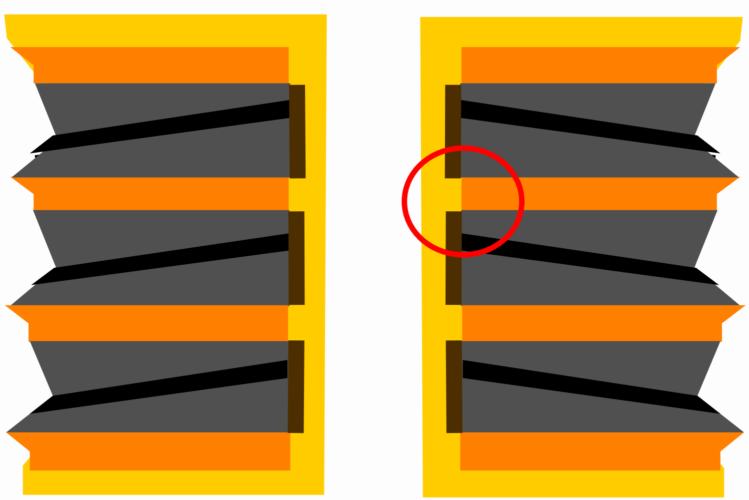
    Glass Reinforcement

- **Non-Selective Activation**
  - Performance Failure
  - Total Surface Activation

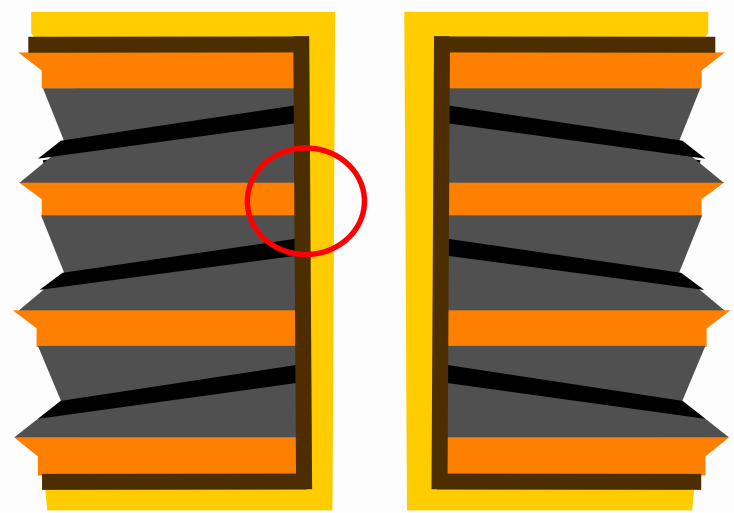
    Laminate Resin

    Glass Reinforcement

    Copper Surface



No Inner Connect Defect



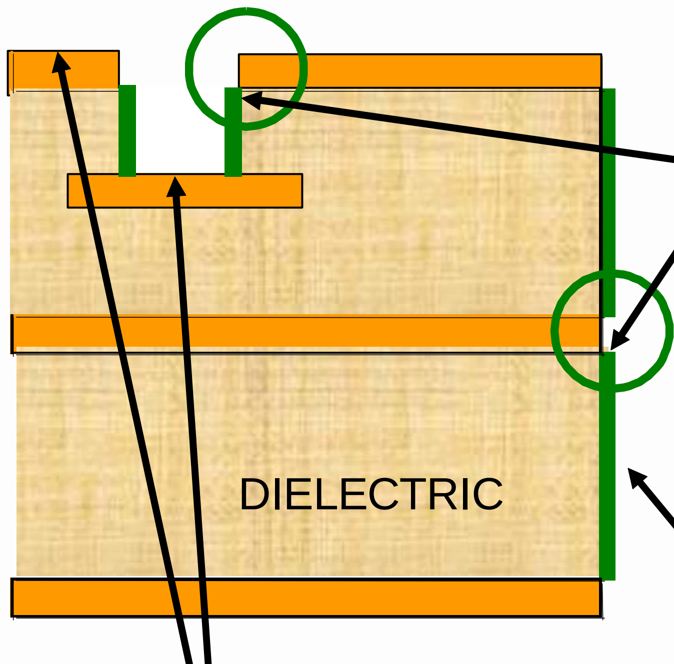
Inner Connect Defect Risk

Activation on Copper must be removed chemically with risk

Conductive Polymer

(needs no microetch)

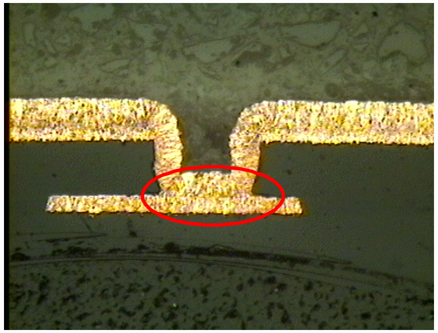
Complete Coverage of Micovias and Inner Layers

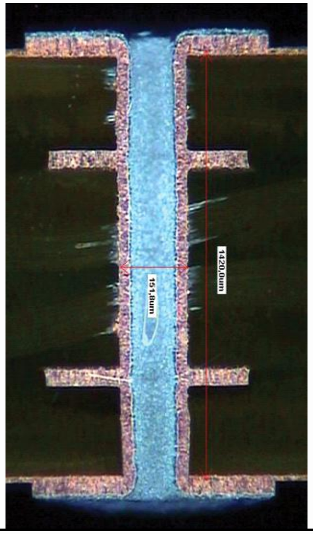


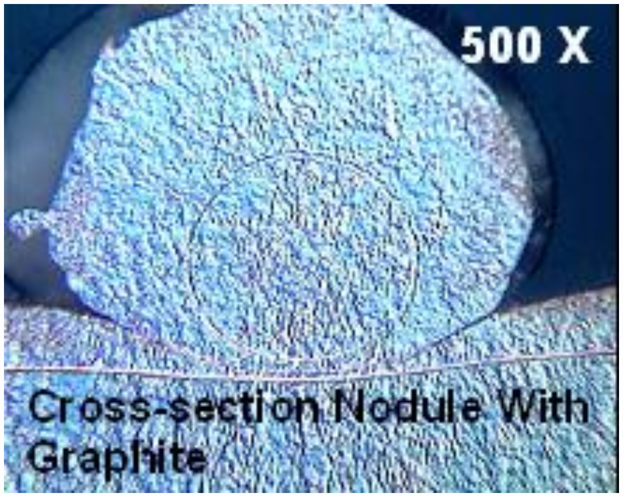
No Etch removal of copper at critical points

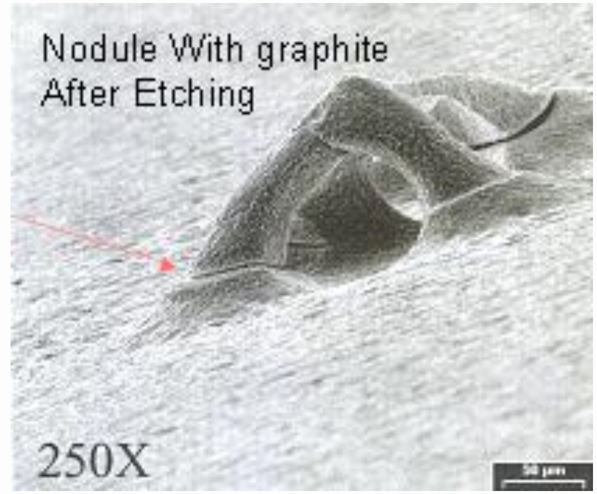
Conductive Polymer (only on dielectric)

No material deposited on Via capture pad or surface copper







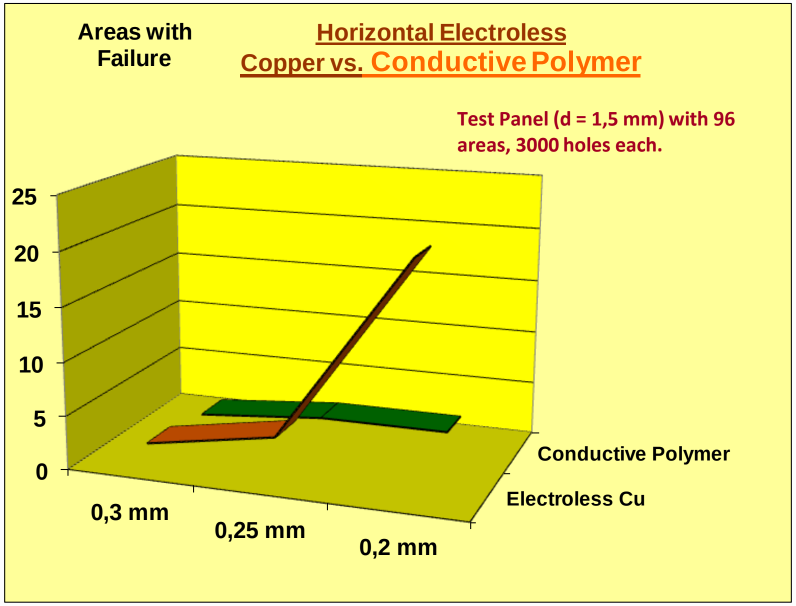


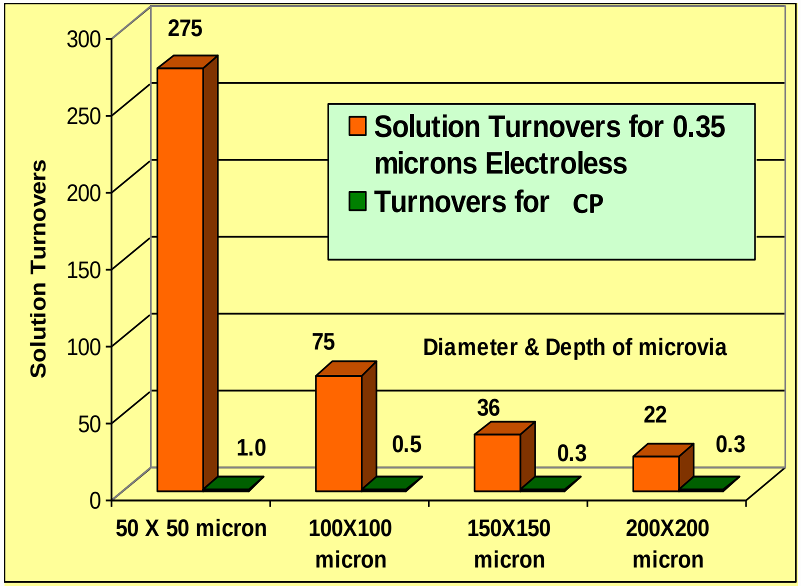
Nodules generated on copper surface with graphite, resulting in rough copper plating

- **The post-etching is needed in non-selective process**
  - There is negative etchback issue from over etching
  - Add a waste etchant solution treatment

- **Roller residues from carbon or graphite often cause rough deposits and quality issue in line manufacturing**

Process Reliability

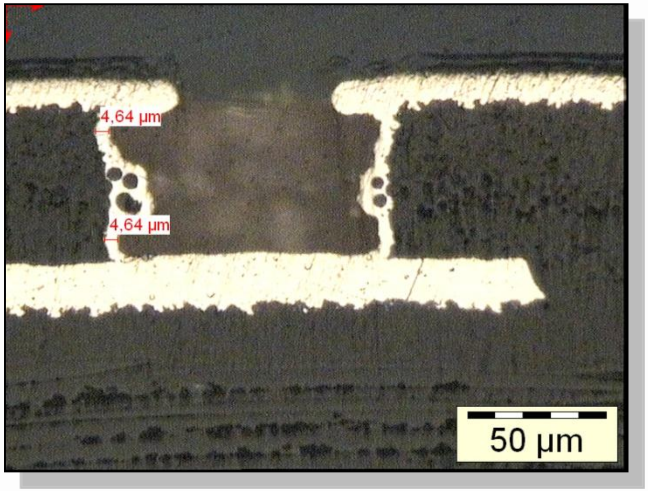


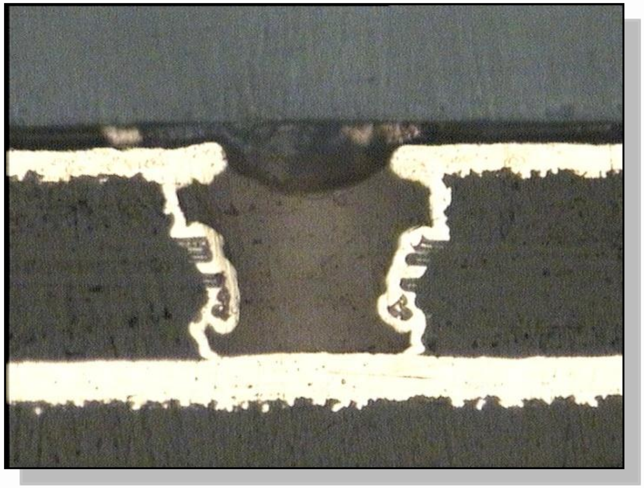


WHY is Conductive Polymer better for Microvias?

1. Easy to Conveyorize
2. Low Viscosity of Process Solutions
3. Chemical Bond to Dielectric Material
4. No H_2 Formation During Plating Process
5. Minimal Solution Exchange Required to Deposit Conductive Polymer

Glass fibre coverage





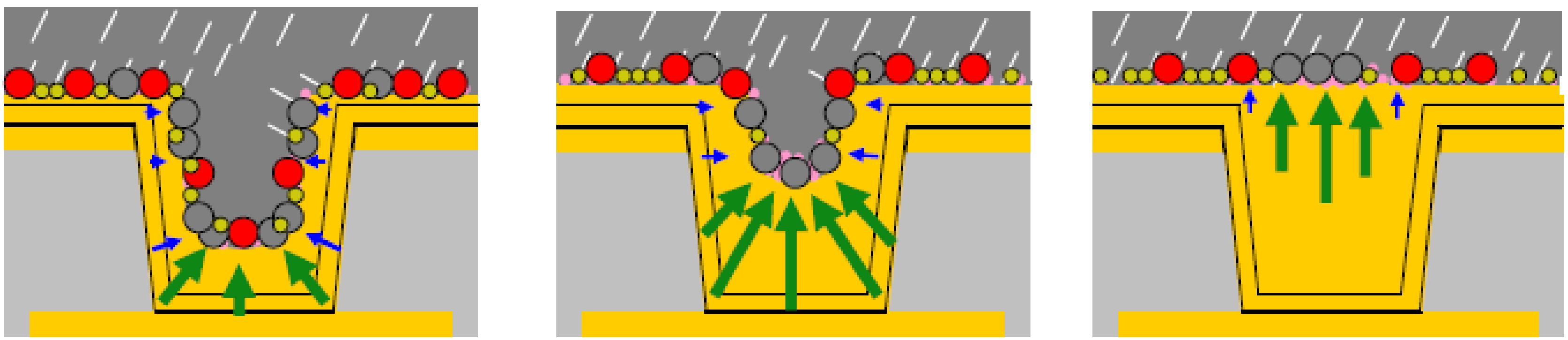
Copper Coverage after Initial Via-Fill Plating at 2 ASD for 10 minutes

- With a high copper and a low acid concentration, the initial copper plating starts relative easy.
- Conductive Polymer help a good copper coverage on glass and resin.
- A copper layer is formed and the adsorption/desorption of the inhibitor/accelerator system can take place.

Via- Filling mechanism

Innovative Via-Filling

- Inhibitor/Suppressor + Chloride suppresses plating rate
- Brightener / Activator
- Leveler



- Inhibitor/Suppressor
- Brightener/Activator
- Leveler

<u>Cu^{2+} concentration</u>
Higher concentration support better filling performance

<u>H^{+} concentration</u>
Enhance conductivity of solution

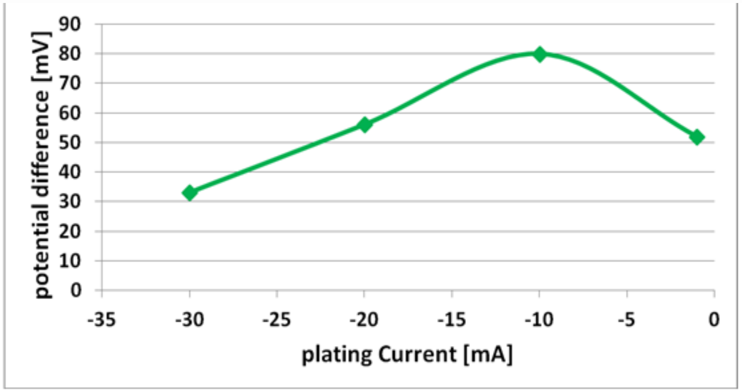
<u>Cl^{-} concentration</u>
Ingredient for brightener & carrier intermediates

<u>Carrier</u>
Formation of diffusion layer, reduce surface tension

<u>Accelerator</u>
Grain refiner for copper deposit

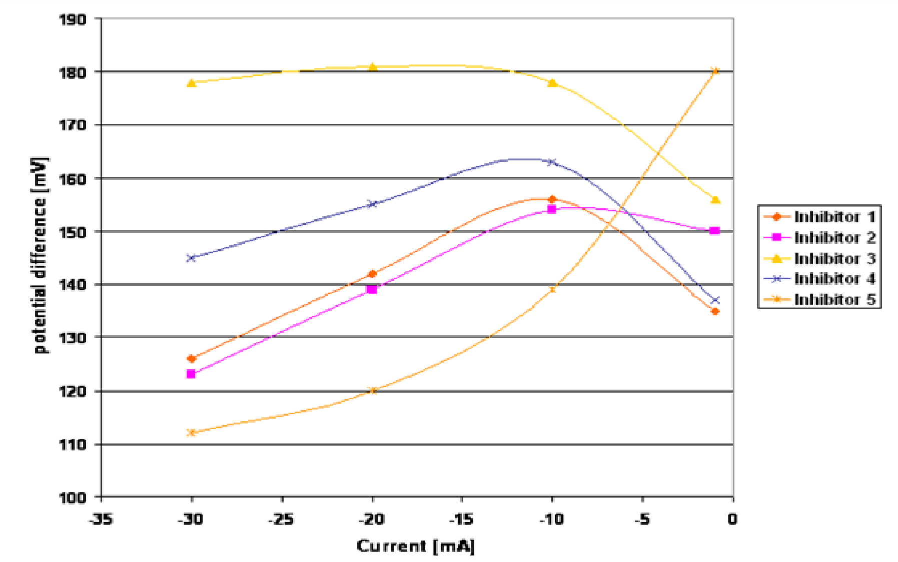
<u>Leveler</u>
Provide micro-leveling effect for copper deposition

Electrochemical Study



Best Plating Window

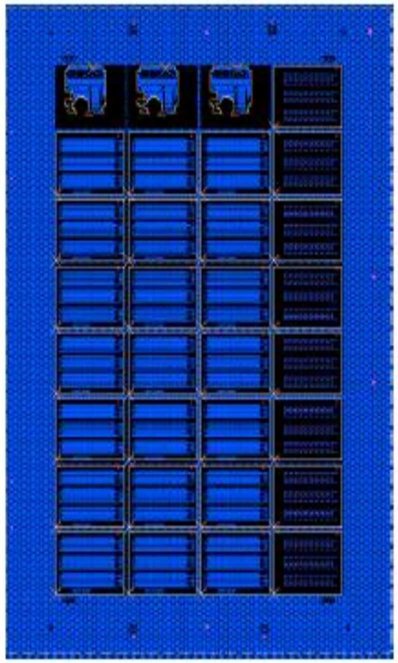
- Additive set had the biggest influence on plating between -10 mA to -20mA.
- The best current density range for plating with the development solution is in the range of 1 to 2 ASD.

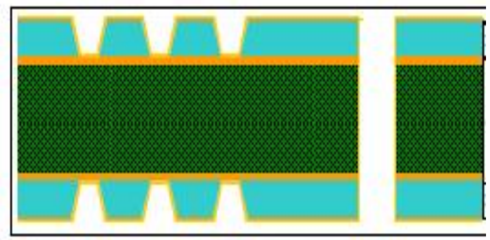


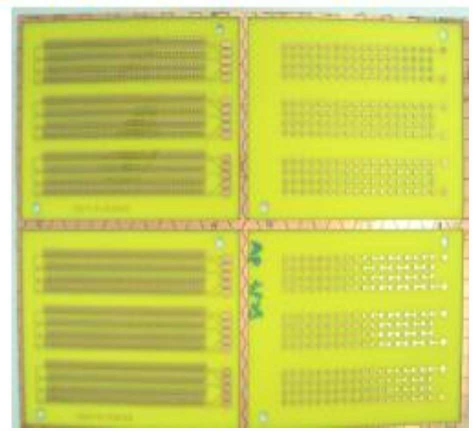
Testing with different inhibitor/accelerator systems.

- The inhibitor systems 1, 2 and 4 have a similar curve.
- Inhibitor 3 system shows conformal filling in the working window of 1 to 2 ASD.
- Inhibitor 5 gives good filling but the plating time is lower and the overburden is higher.

Test Vehicle Description







It is a 4 layer daisy chain design with 100 and 125 μm via and 250, 300 and 350 mm through hole. Core was 500 μm (20mil) 1/1 with 1080PP with 65% RC. Final HDI layer dielectric thickness was approximately 60 μm. There was no control on direct laser drill as the intention was to check the coating performance if micro-via quality was poor. Example of poor quality is overhang and large glass fiber protrusion.

Plating Tool Type

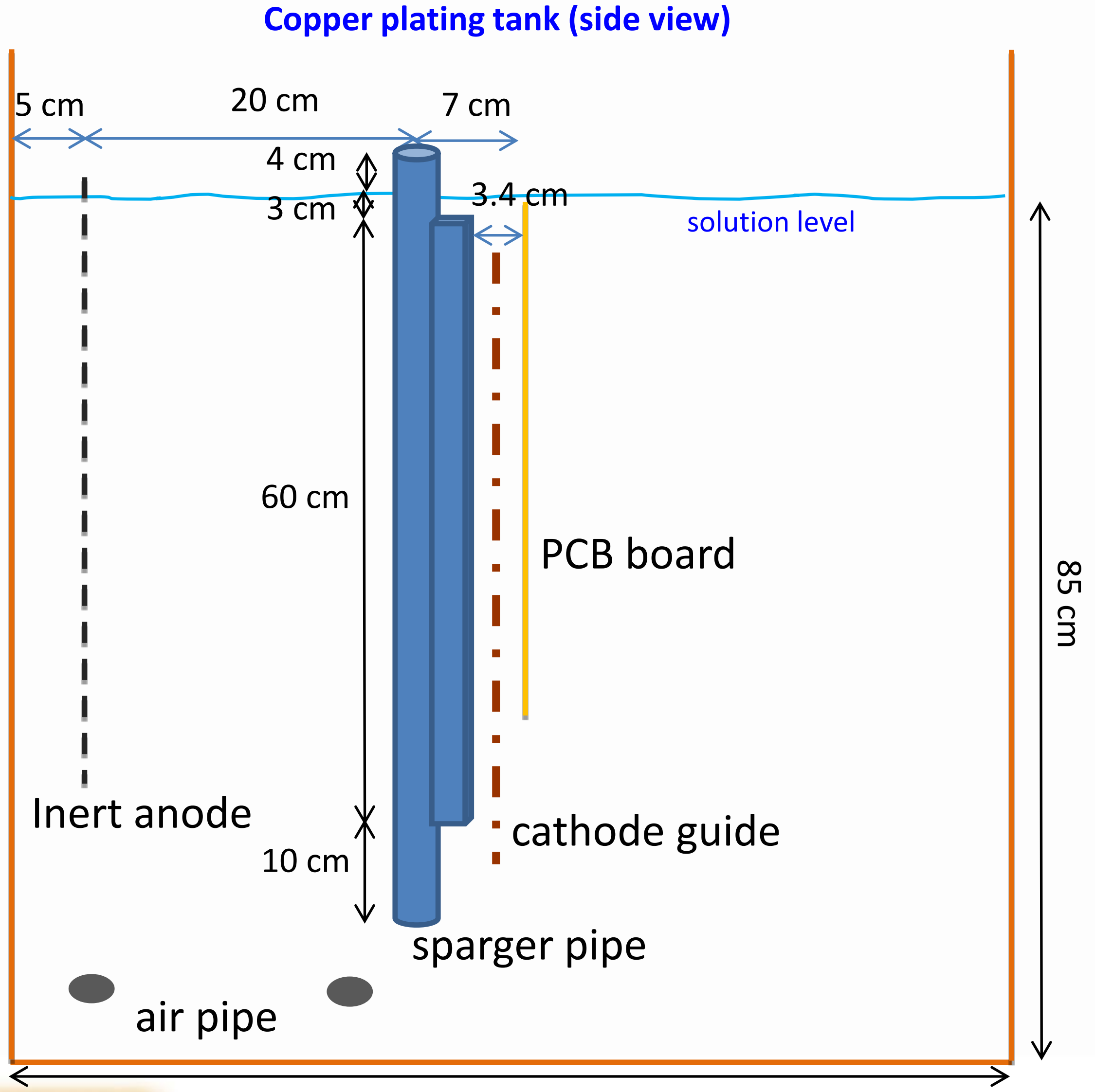
Plating tool configuration A - Low Flow System

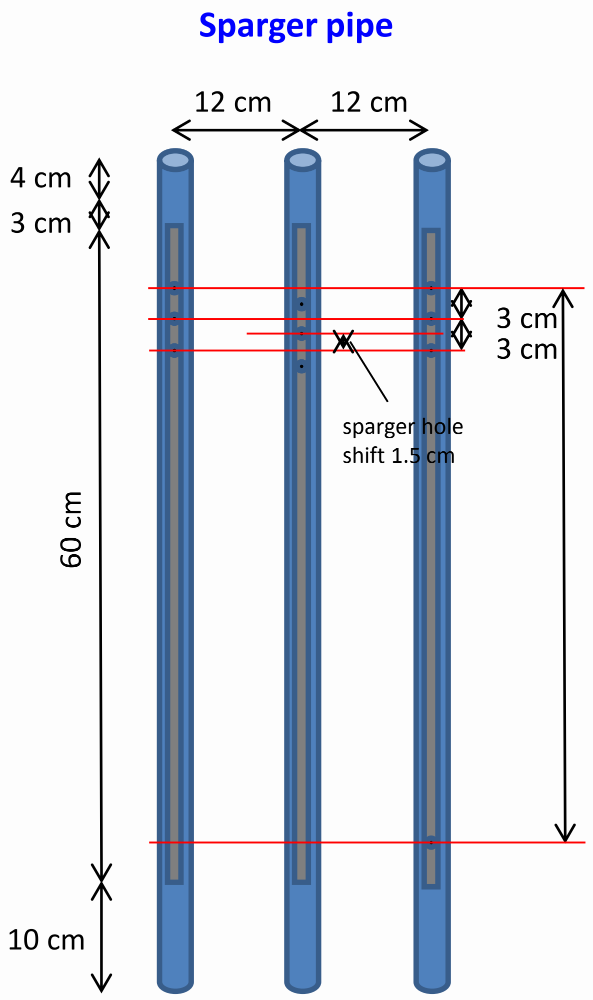
- Immersion type, where the boards are moving between two sparger systems on both side.
- The air agitation is optional; however, the flow rate of the solution could be adjusted from low to high, depending on the preference of the hydrodynamic flow required for the additive.
- In this set up the additive control becomes the predominate factor for via-filling, rather than solution flooding.

Plating tool configuration B -High Flow System

- Strong flooding design where the solution level is maintain under a high flow pressure.
- It helps the solution exchange within the micro via by forced flooding. Via-fill mechanism is dominated by hydrodynamic flow.

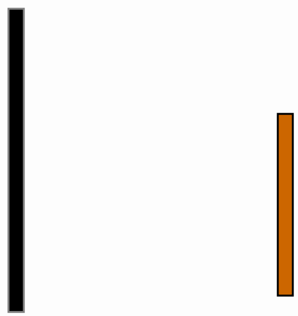
Plating Tool – Type A





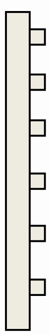
Plating Tool – Type B

Plating line side view



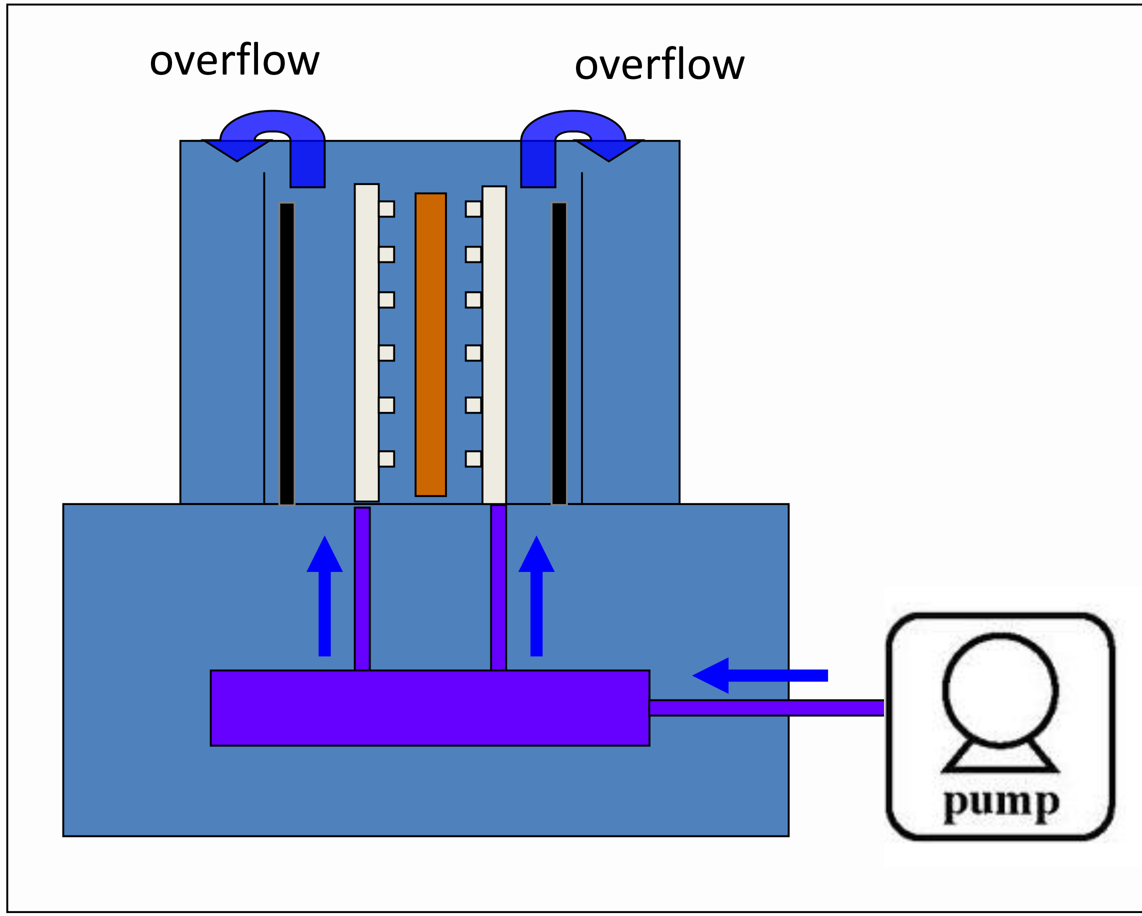
Anode (PP bags)

Cathode (PCB)



Eductor (11 ~12 nozzles/bar)

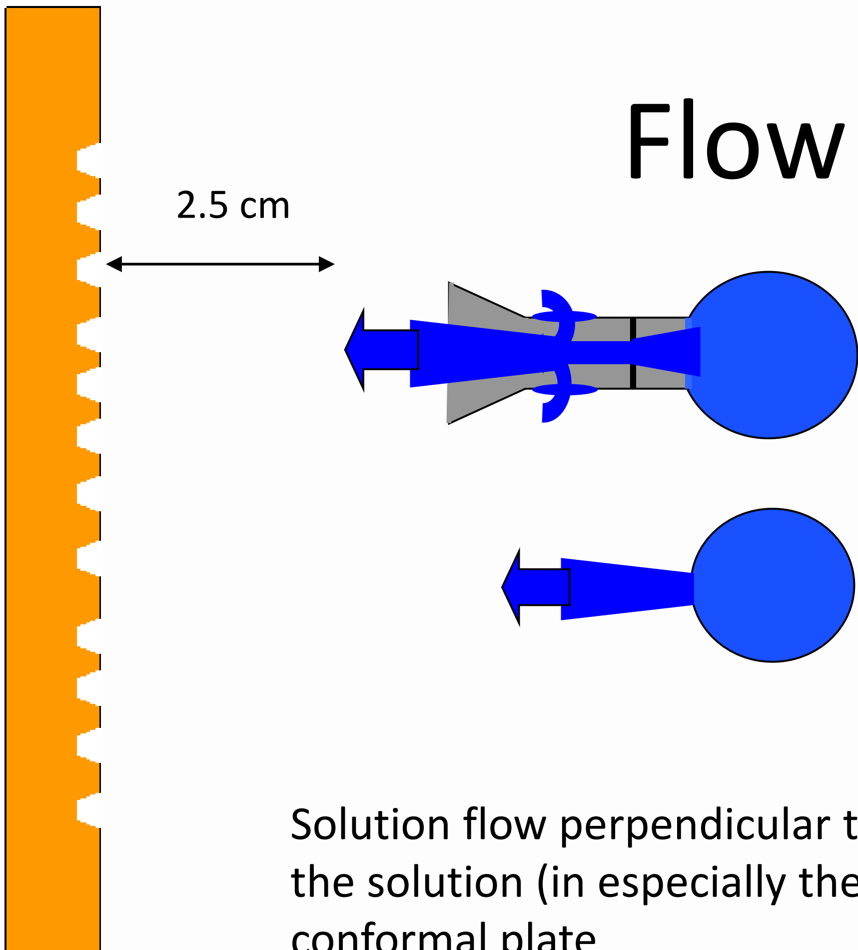
1 set has 8 bars, 1 plating side has 6 sets



No air agitation

Hydrodynamic Study

Flow Rate Effect



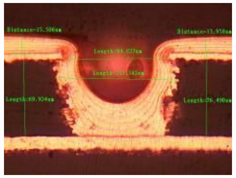
pipes with eductors

or

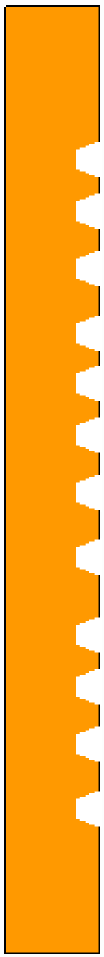
pipes without eductors

Cathode
with vias

Solution flow perpendicular to the surface exchanges the solution (in especially the bigger) vias resulting in conformal plate

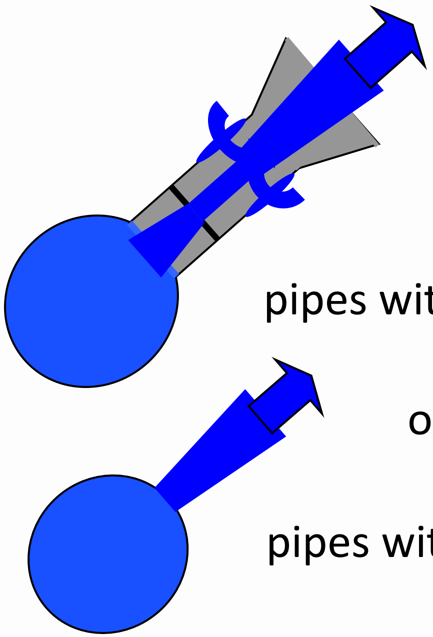


Flow Rate Effect



Cathode with vias

Little solution agitation at surface; copper ion diffusion into vias is limited

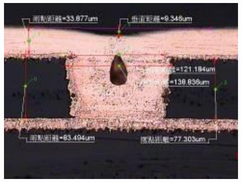


pipes with eductors

or

pipes without eductors

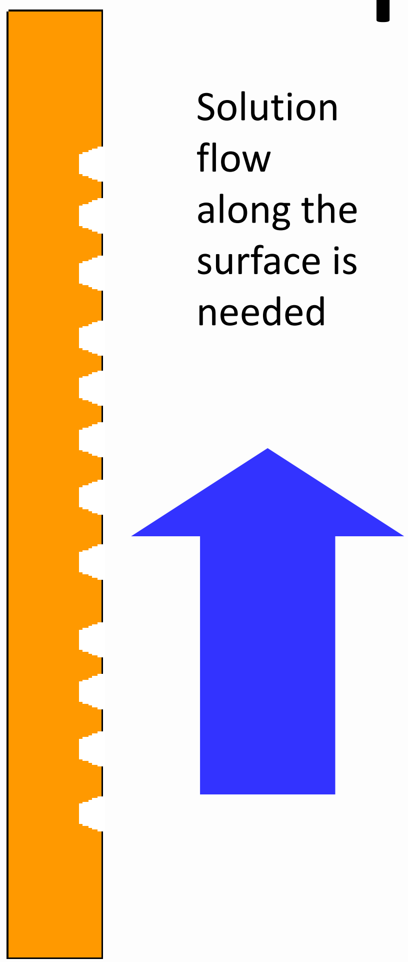
Pipe openings turned away from surface resulting in good fill, butt centre / top voids.



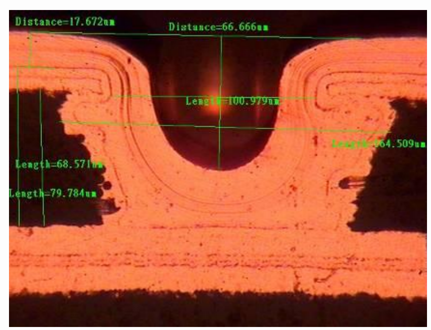
Flow Rate Effect

Air agitation would have supplied the right solution flow along the surface. This does not add fresh leveler into the vias and provides good copper ion diffusion into them.

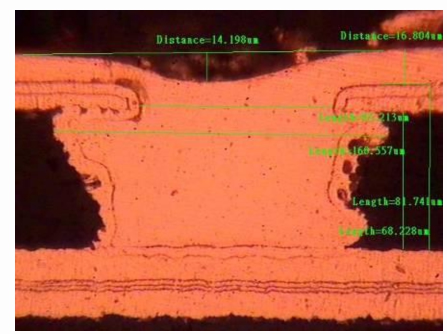
Solution flow along the surface is needed



Cathode with vias



panel plated in AEL tool



panel plated in haring cell with air agitation

Sparger Flowrate Profile (use of High flowrate)

Higher flowrate can enhance the solution exchange inside the BMV (Blind Micro-Via) especially at the BMV bottom or the deep BMV.

Higher flowrate is required for the BMV will poor laser drilling, the solution exchange is generally poor with overhang or glass fiber protrusion.

Higher flowrate may cause the strong solution turbulence inside the BMV that cause the unstable diffusion layer (of the electroplating chemistry). The brightener (accelerator) may be “washed” away and cannot perform the bottom-up BMV filling reaction. At the same time, the Leveler flush into the BMV (as well as the surface copper) that suppress the copper growth inside the BMV.

Too high flowrate (keep for the whole plating period) may cause larger dimple.

Generally speaking,

- deep BMV needs higher flowrate
- at the beginning of the plating needs higher flowrate

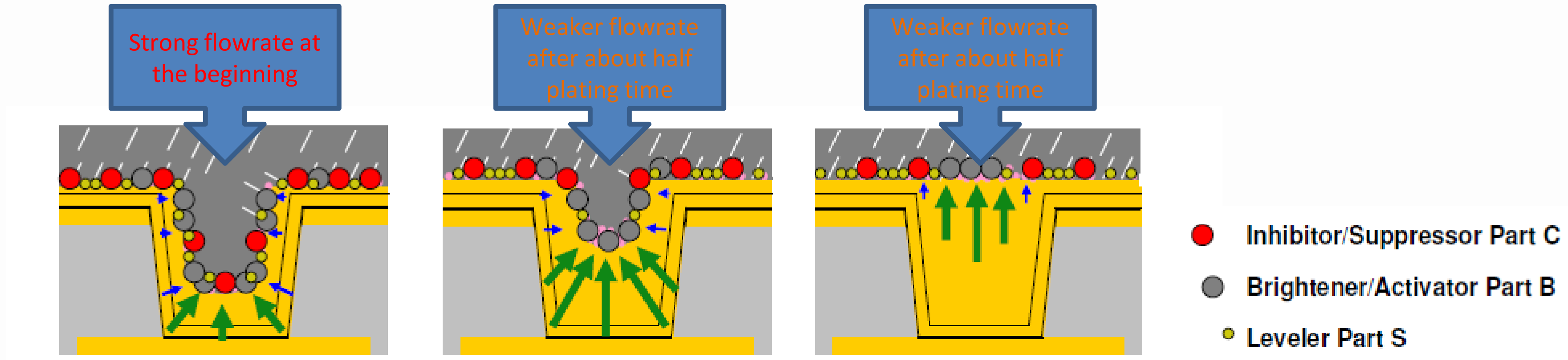
Sparger Flowrate Profile (use of Low flowrate)

Low flowrate can give more stable diffusion layer (of electroplating chemistry), the brightener (accelerator) is more stable inside the BMV and stick on the hole wall copper and give bottom-up copper plating.

Low flowrate can be used for the shallow BMV (e,g. 50 um depth).

Low flowrate is more suitable for the larger diameter BMV, as the solution exchange is already easier. If flowrate is high, the brightener in the diffusion will be unstable → less bottom-up plating→ larger dimple.

Low flowrate is more suitable to used after half of the total plating time.

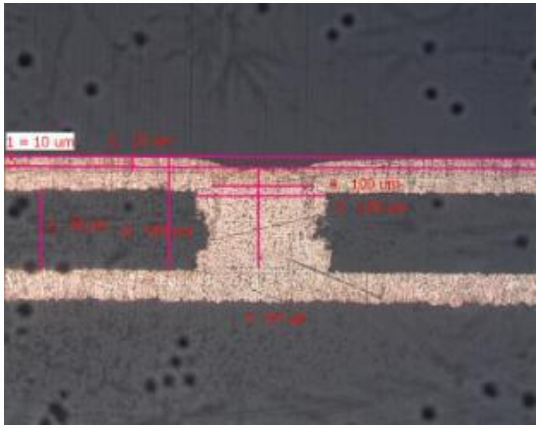


Current Density Profile Study

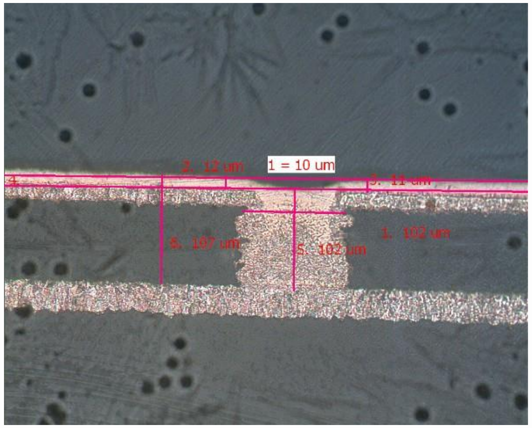
Flash panel layer has the best conductivity among all the conductive layers

Flash panel layer may starts with 1.5 ASD. And keep the same current density plate to the end.

On the other hand, to shorten the plating time or increase the surface copper thickness (according to the production specification), ramp current can be applied.



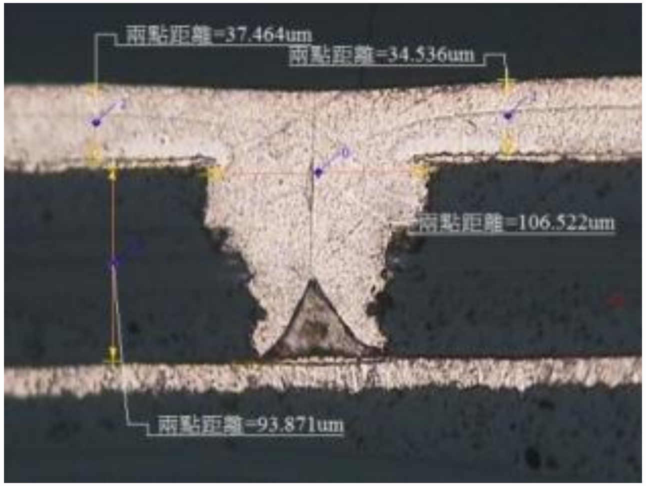
1.5 ASD x 60 min



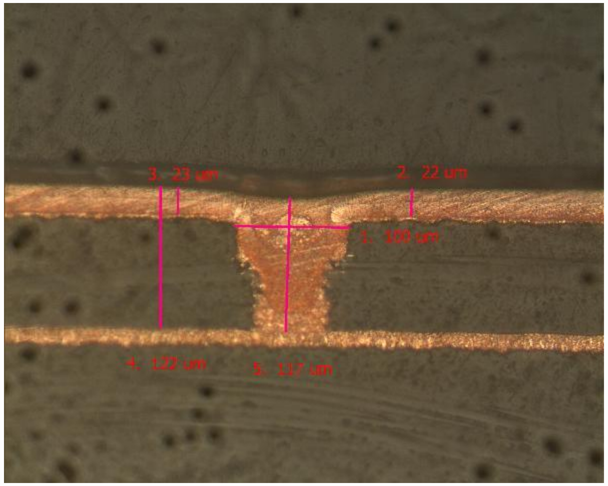
1.5 ASD x 40 min +
2.5 ASD x 10 min
Total 50 min

Current Density Profile (cont')

For direct metallization seeding, starts with 3 ASD x 5 min is recommended, the higher current density at the beginning can overcome the resistant barrier of the conductive layers. Longer high current density is not recommended because the surface copper and BMV top corner will plate too thick copper that increase the chance of void or liquid inclusion. The following is the example for 4 mil diameter/4 mil depth BMV.



3 ASD x 20 min (@ 12000 L/hr) +
2 ASD x 20 min (@ 10000 L/hr) +
4 ASD x 17 min (@ 7000 L/hr)

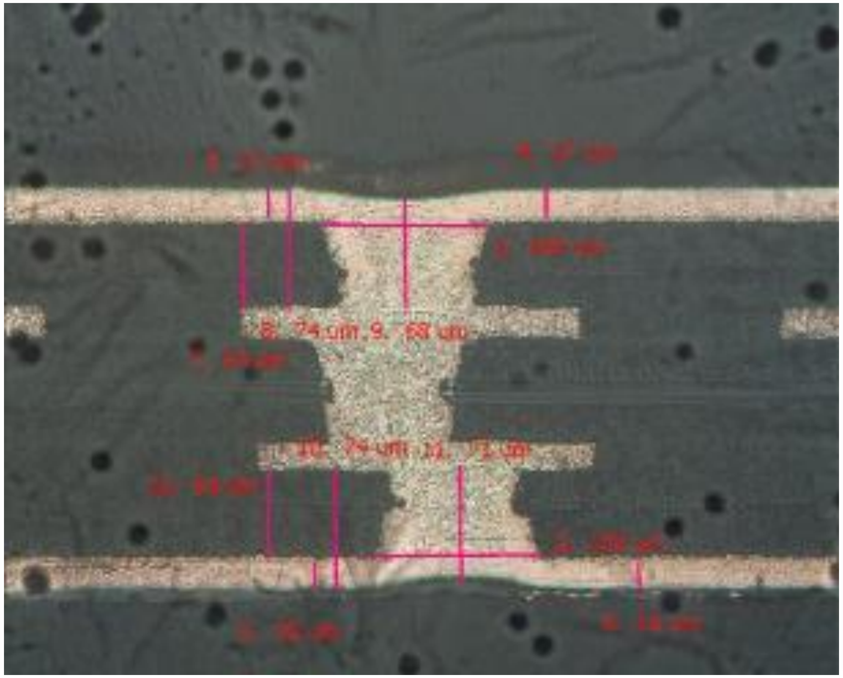


3 ASD x 5 min (@ 12000 L/hr) +
1.2 ASD x 50 min (@ 12000 L/hr) +
1.5 ASD x 35 min (@ 7000 L/hr)

Via-Filling Performance at Tool A

Conductivity Layer	Direct Metallization
Current density	1.7 ASD
Plating time	57 min
Sparger flowrate (for every 2 m length)	10000 L/hr

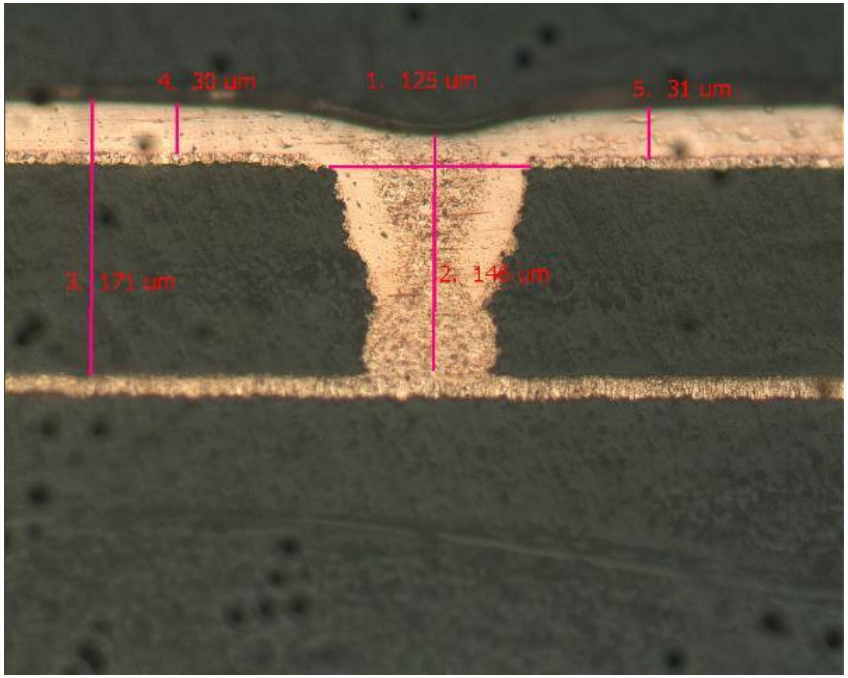
Customer “C” test board
∅4 mil
Depth: 2 mil
Surface copper: 16 um
Dimple: ~5 um



Via-Filling Performance at Tool A

Conductivity Layer	Direct Metallization
Current density	3→ 1.2 → 1.7 ASD
Plating time	120 min
Sparger flowrate (for every 2 m length)	12000 → 8000 L/hr

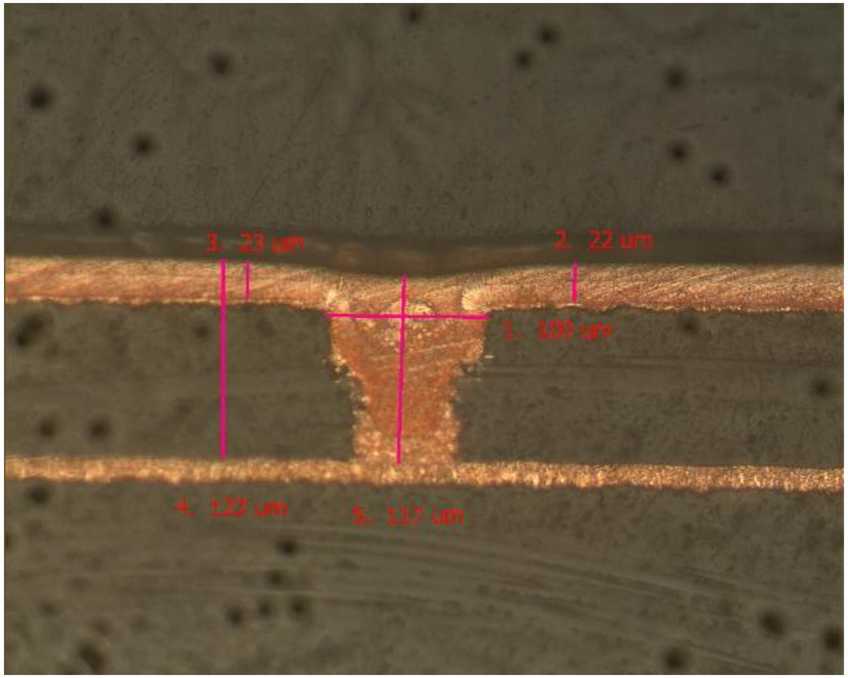
Customer “C” (special application)
∅135 um
Depth: 5 mil
Surface copper: ~30 um
Dimple: <25 um



Via-Filling Performance at Tool A

Conductivity Layer	Direct Metallization
Current density	3→1.2 → 1.5 ASD
Plating time	90 min
Sparger flowrate (for every 2 m length)	12000 → 7000 L/hr

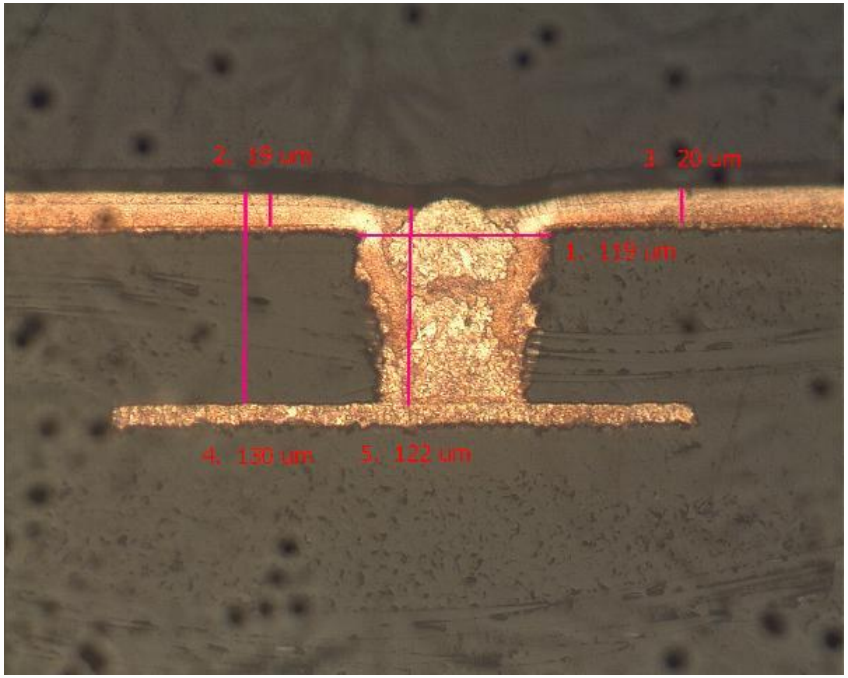
Customer “C” (special application)
∅4 mil
Depth: 92 um
Surface copper: 16 um
Dimple: ~13 um



Via-Filling Performance at Tool A

Conductivity Layer	Direct Metallization
Current density	3→ 1.2 → 1.5
Plating time	85 min
Sparger flowrate (for every 2 m length)	12000 → 7000 L/hr

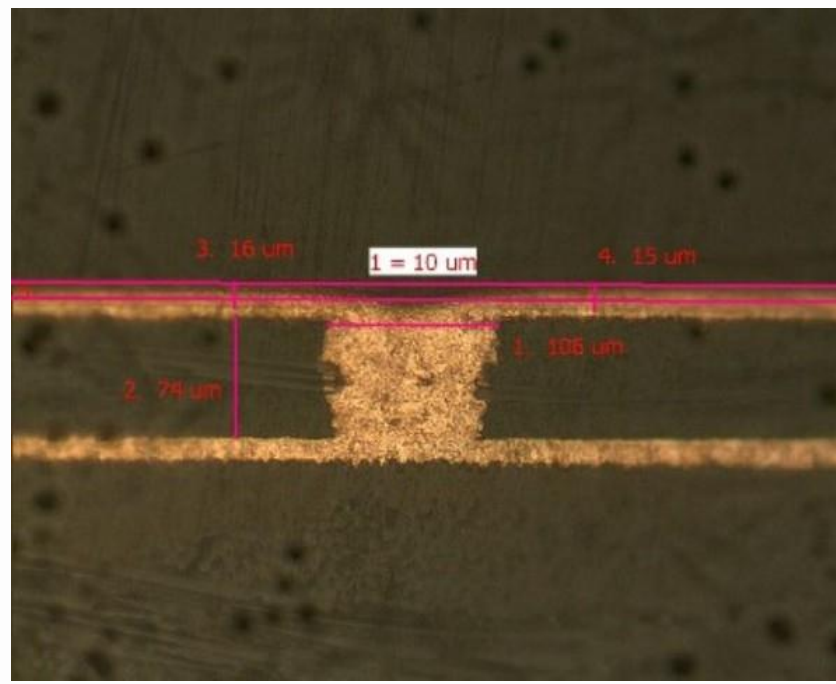
Customer "D" test board
∅4 mil
Depth: 4 mil
Surface copper: 19 um
Dimple: 8 um



Via-Filling Performance at Tool A

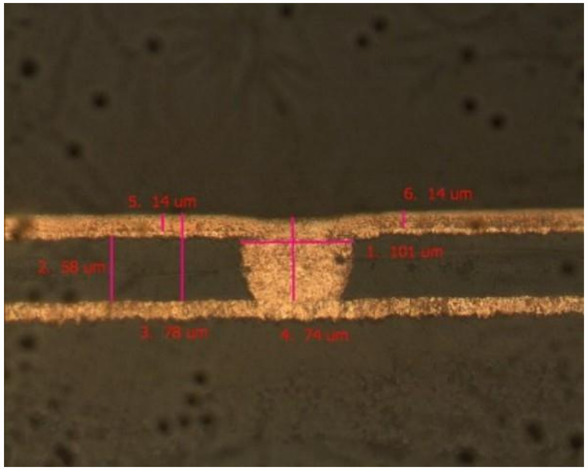
Conductivity Layer	Direct Metallization
Current density	3→ 1.5→ 2.2 ASD
Plating time	45 min
Sparger flowrate (for every 2 m length)	10000→ 8000 → 5000 L/hr

∅4 mil
Depth: 3 mil
Surface copper: 13 um
Dimple: 10 um

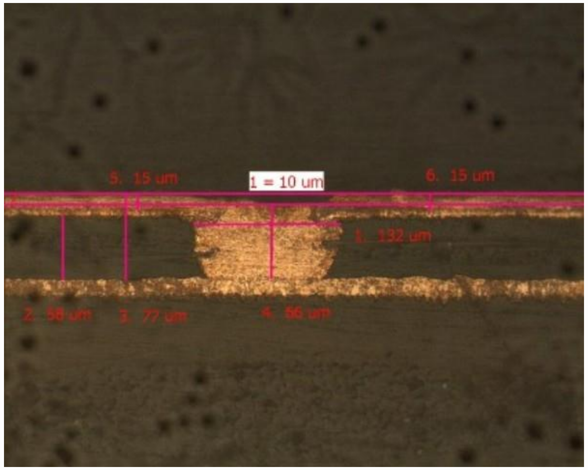


Via-Filling Performance at Tool A

Conductivity Layer	Direct Metallization
Current density	3→1.5→2.2 ASD
Plating time	45 min
Sparger flowrate (for every 2 m length)	10000→ 8000→ 5000 L/hr



∅4 mil
Depth: 2 mil
Surface copper: 14 um
Dimple: 1 – 4 um

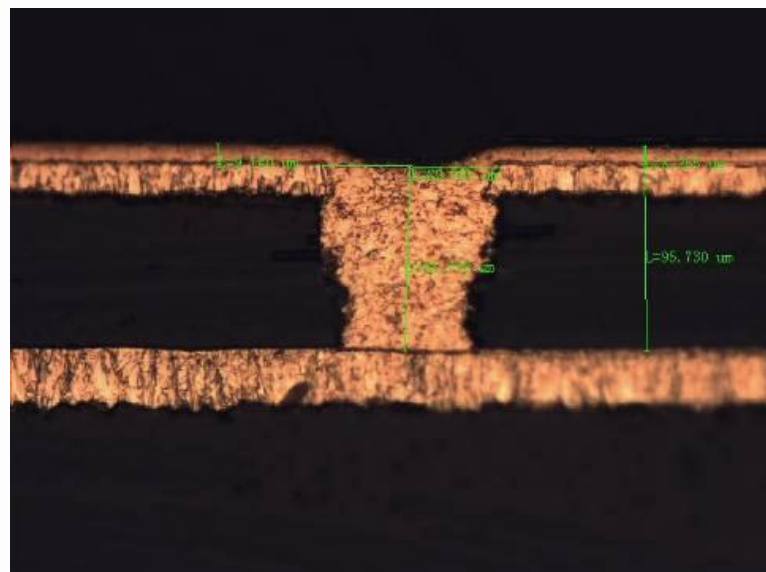


∅5 mil
Depth: 2 mil
Surface copper: 15 um
Dimple: ~10 um

Via-Filling Performance at Tool A

Conductivity Layer	**Direct Metallization**
Current density	1.5 ASD
Plating time	50 min
Sparger flowrate	10 L/ft2

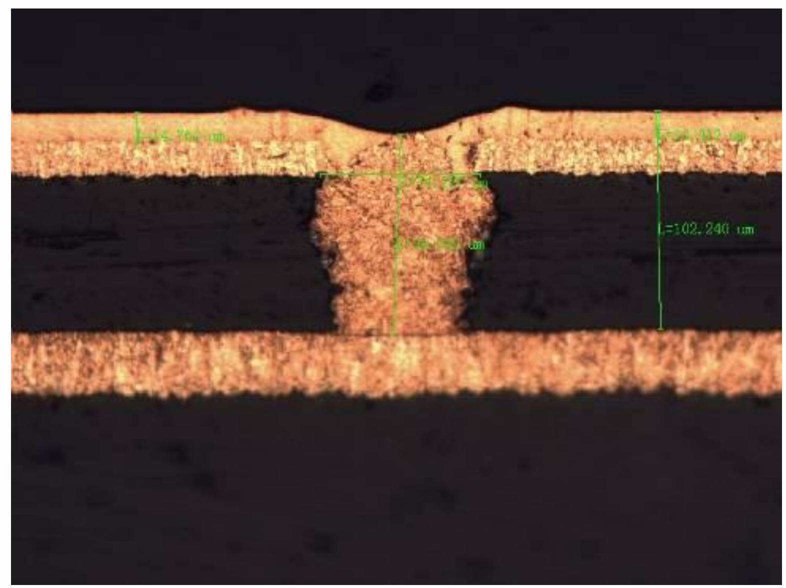
∅80 um
Depth: 85 um
Surface copper: 9 um
Dimple: <15 um



Via-Filling Performance at Tool A

Conductivity Layer	**Direct Metallization**
Current density	2.5 ASD
Plating time	40 min
Sparger flowrate	10 L/ft2

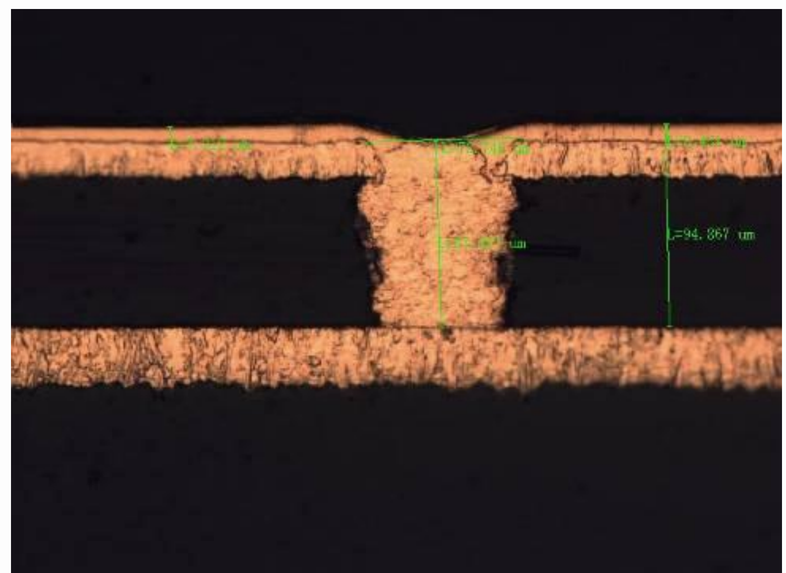
∅80 um
Depth: 85 um
Surface copper: 12 um
Dimple: <15 um



Via-Filling Performance at Tool A

Conductivity Layer	**Direct Metallization**
Current density	1.5→2→2.5 ASD
Plating time	30 min
Sparger flowrate	10 L/ft2

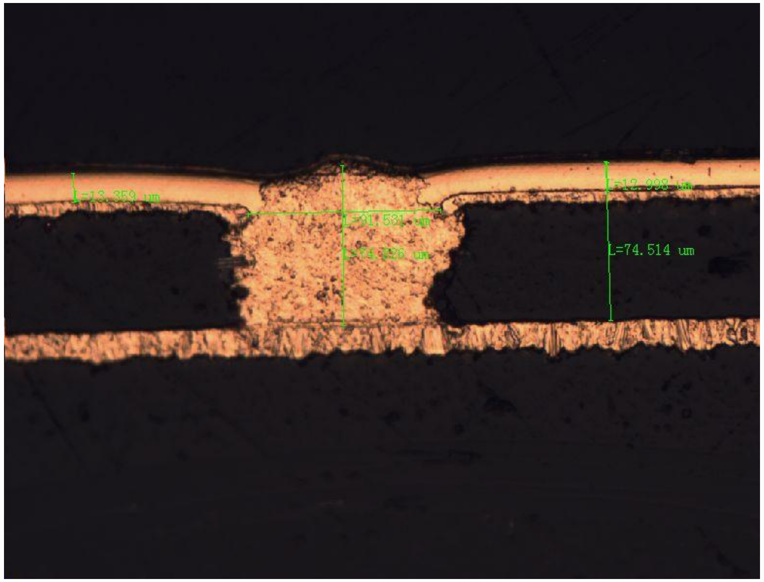
∅80 um
Depth: 85 um
Surface copper: 7 um
Dimple: <15 um



Via-Filling Performance at Tool A

Conductivity Layer	**Direct Metallization**
Current density	2.5→ 1.5
Plating time	60 min
Sparger flowrate	10 L/ft2

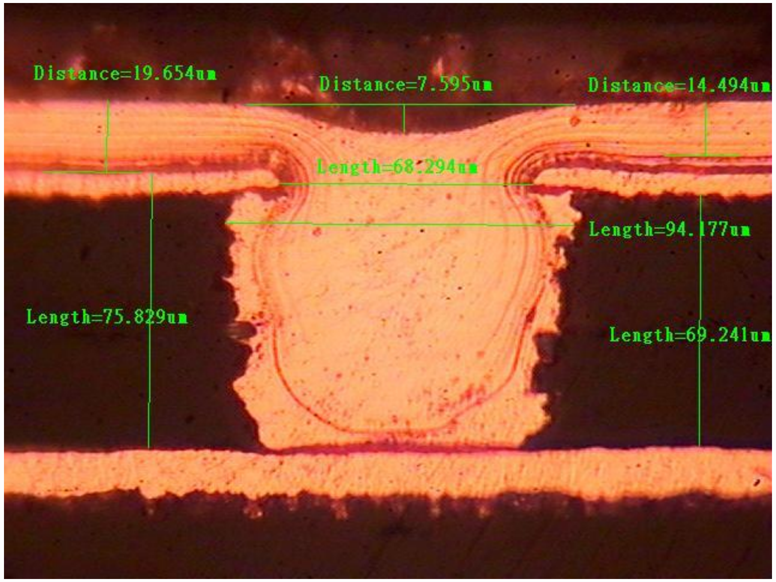
∅91 um
Depth: 60 um
Surface copper: 13 um
Dimple: ~0 um



Via-Filling Performance at Tool B

Conductivity Layer	Direct Metallization (with Flash)
Current density	2 ASD
Plating time	45 min
Sparger flowrate	0.2 bar

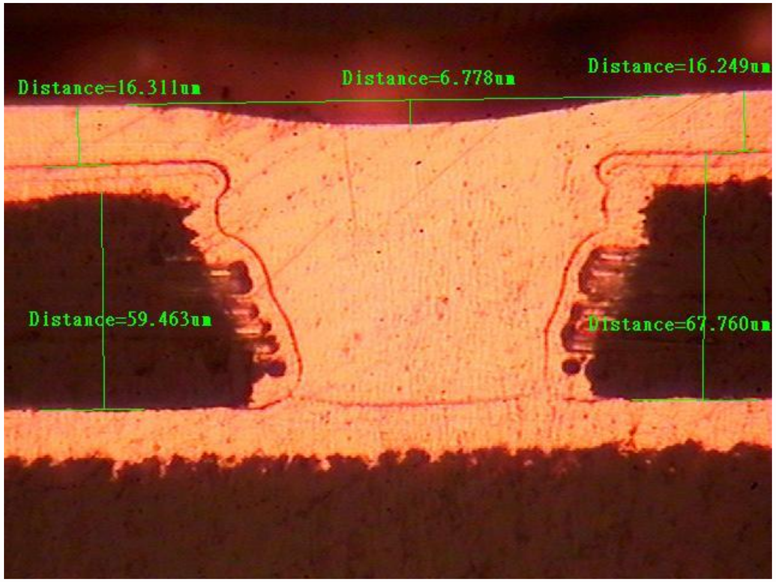
∅90 um
Depth: 75 um
Surface copper: 20 um
Dimple: <8 um



Via-Filling Performance at Tool B

Conductivity Layer	Direct Metallization (with Flash)
Current density	1.5 ASD
Plating time	60 min
Sparger flowrate	0.3 bar

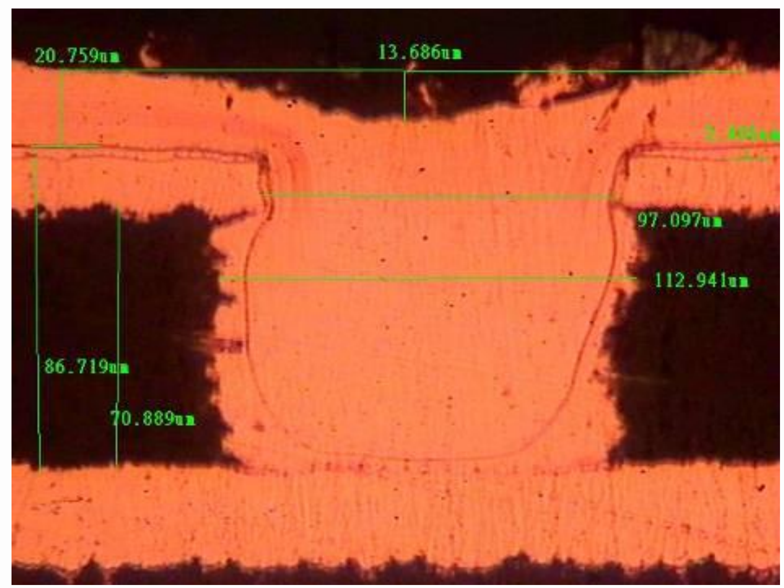
∅95 um
Depth: 65 um
Surface copper: 16 um
Dimple: <7 um



Via-Filling Performance at Tool B

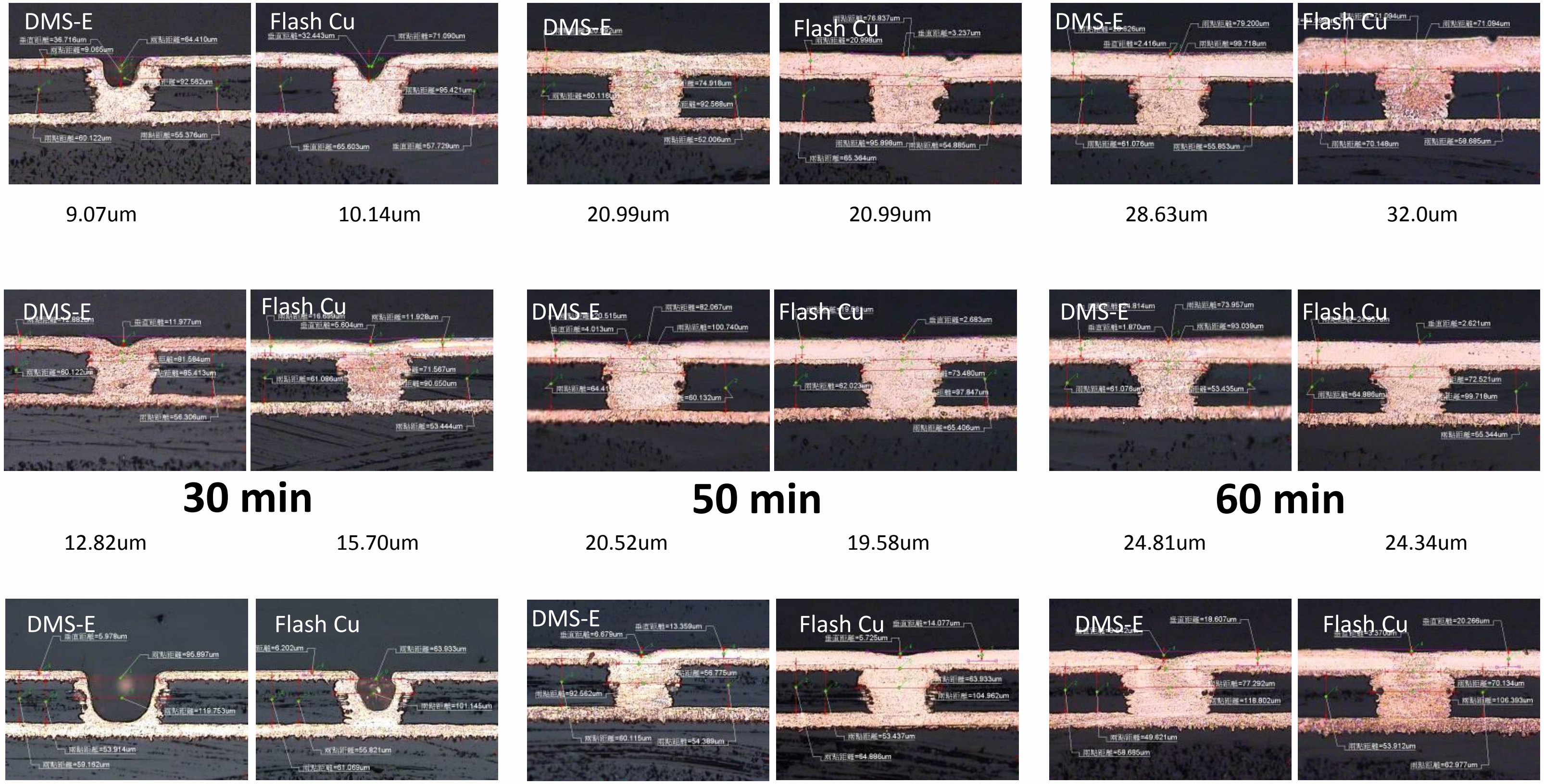
Conductivity Layer	Electroless Copper Flash
Current density	2.15 ASD (20 ASF)
Plating time	45 min
Sparger flowrate	0.1 bar

∅4 mil
Depth: 3 mil
Surface copper: 20 um
Dimple: ~13um



Via Open/Depth: 3/2 mil

Via open / depth: 3 mils / 2 mils



25 ASF

Plated Cu thk: 9.07um | 10.14um | 20.99um | 20.99um | 28.63um | 32.0um

20 ASF

30 min | **50 min** | **60 min**

Plated Cu thk: 12.82um | 15.70um | 20.52um | 19.58um | 24.81um | 24.34um

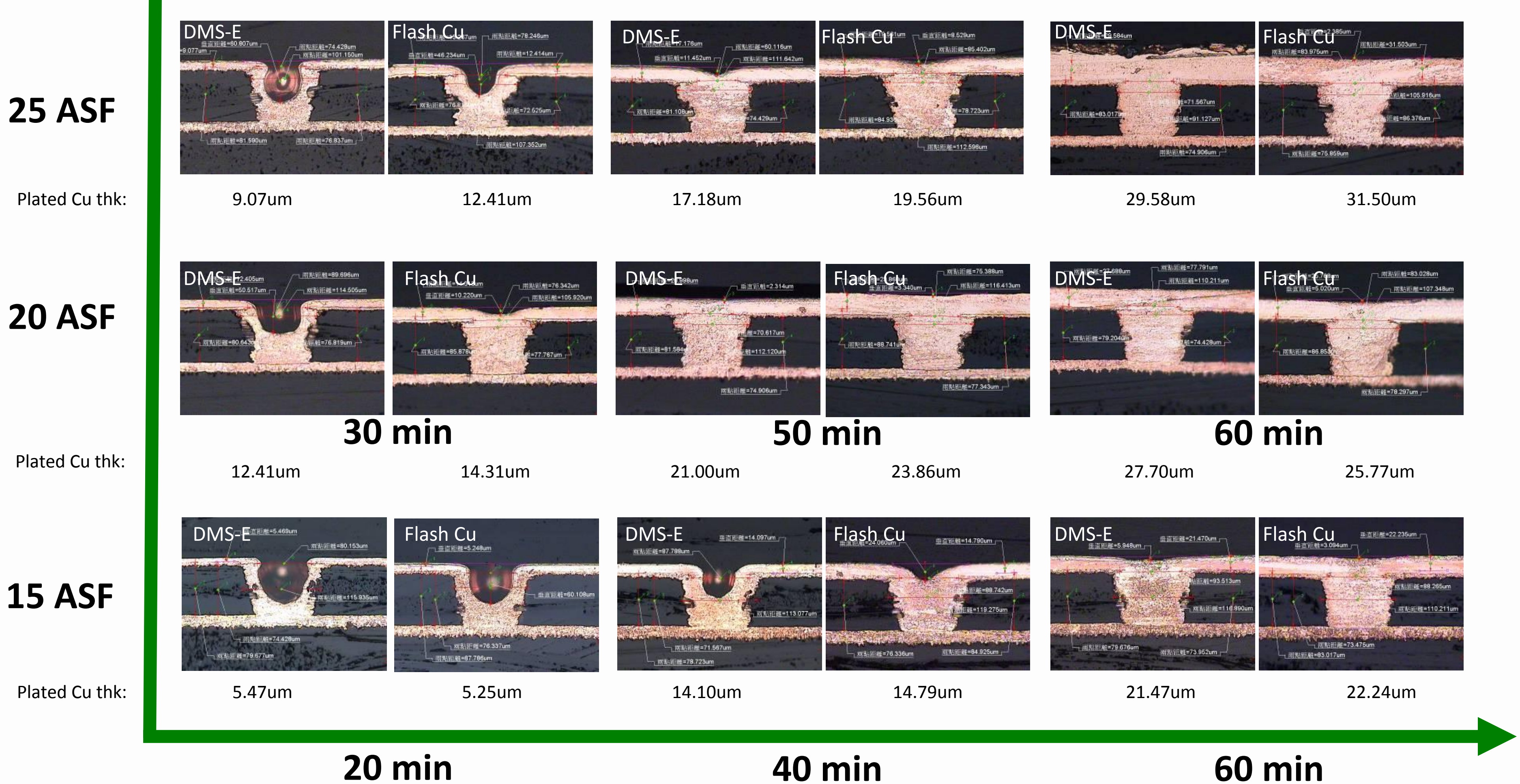
15 ASF

Plated Cu thk: 5.98um | 6.20um | 13.36um | 14.08um | 18.61um | 20.27um

20 min | **40 min** | **60 min**

Via Open/Depth: 3/3 mil

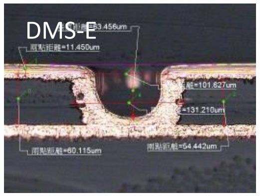
Via open / depth: 3 mils / 3 mils

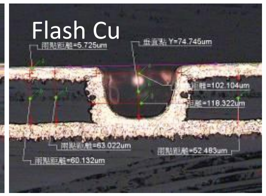


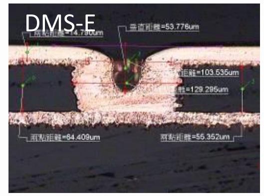
Via open / depth: 4 mils / 2 mils

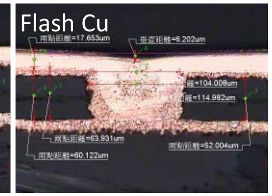
Via Open/Depth: 4/2 mil

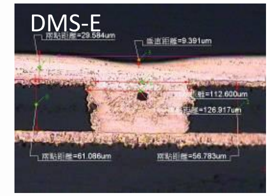
25 ASF

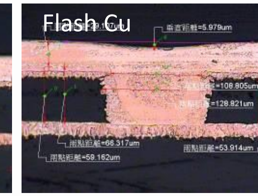






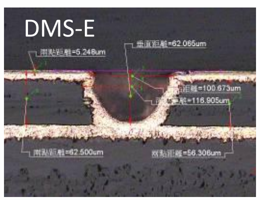


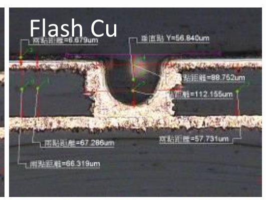


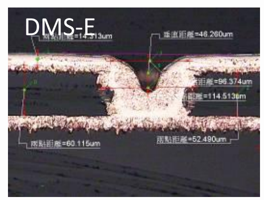


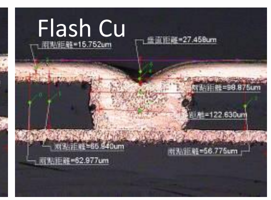
Plated Cu thk: 11.45um 5.73um 14.79um 17.65um 29.58um 29.12um

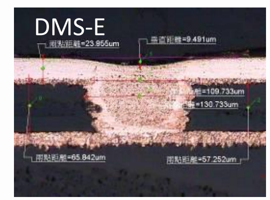
20 ASF

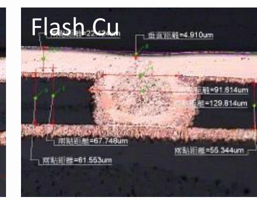






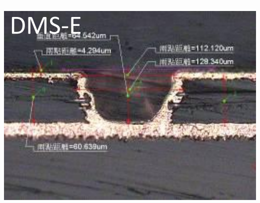


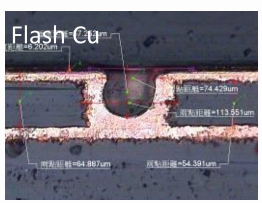


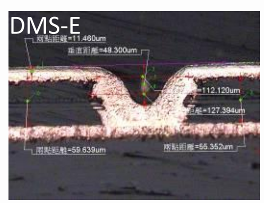


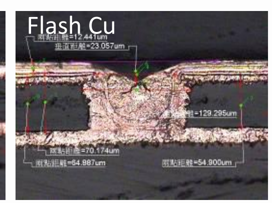
Plated Cu thk: 5.25um 6.68um 14.31um 15.75um 23.96um 22.42um

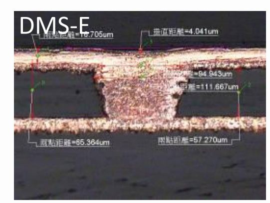
15 ASF

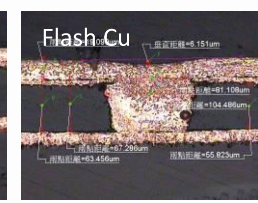










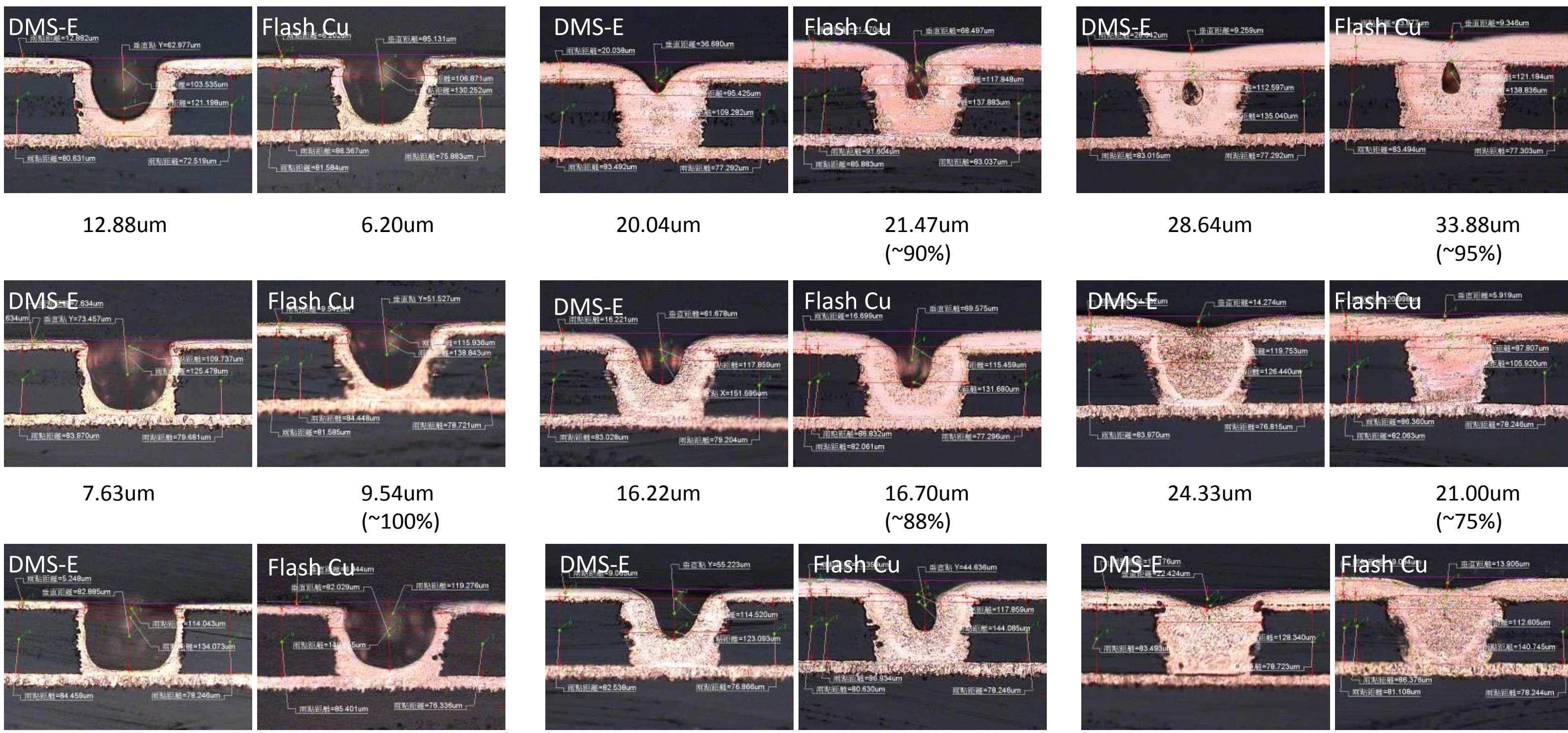


Plated Cu thk: 4.29um 6.20 um 11.46um 12.44um 16.71um 19.09um

20 min **40 min** **60 min**

Via Open/Depth: 4/3 mil

Via open / depth: 4 mils / 3 mils



	20 min DMS-E	20 min Flash Cu	40 min DMS-E	40 min Flash Cu	60 min DMS-E	60 min Flash Cu
25 ASF – Plated Cu thk:	12.88um	6.20um	20.04um	21.47um (~90%)	28.64um	33.88um (~95%)
20 ASF – Plated Cu thk:	7.63um	9.54um (~100%)	16.22um	16.70um (~88%)	24.33um	21.00um (~75%)
15 ASF – Plated Cu thk:	5.25um	6.94 um (~95%)	9.07um	13.36um (~95%)	17.18um	19.08um (~90%)

20 min 40 min 60 min

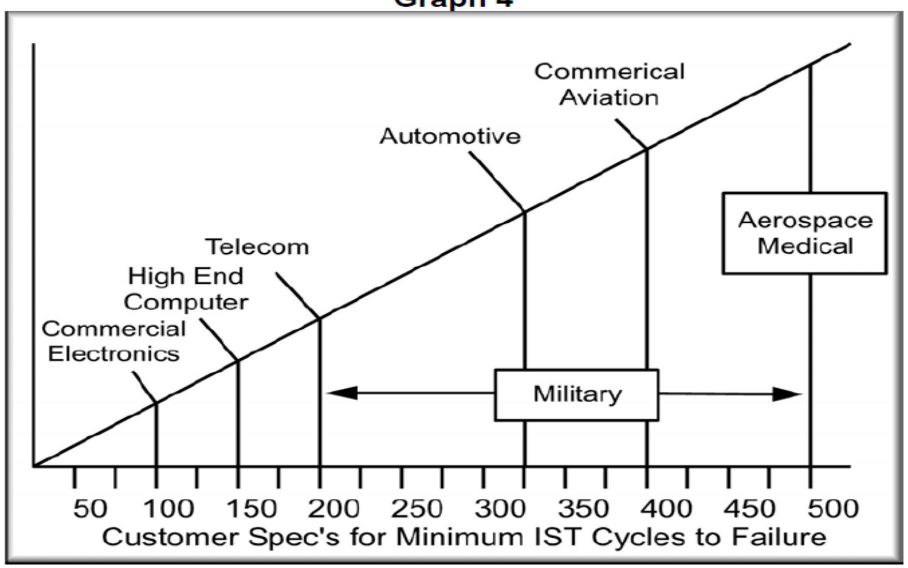
Samples were plated in different equipment build up Cu thickness. These panels were then multi-reflowed at 260+/0° C. Resistance change of daisy chain was less than 2% after 10X reflow as shown below.

			before reflow						after reflow(260℃ 10X Moto2)						change rate/ %					
			top			bottom			top			bottom			top			bottom		
			line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3	line 1	line 2	line 3
A	HDI daisy chain	Unit1	1.60	1.57	1.59	1.62	1.63	1.69	1.61	1.58	1.59	1.62	1.63	1.69	0.6%	0.6%	0.0%	0.0%	0.0%	0.0%
		Unit2	1.53	1.46	1.46	1.55	1.55	1.62	1.53	1.47	1.46	1.56	1.57	1.64	0.0%	0.7%	0.0%	0.6%	1.3%	1.2%
		Unit3	1.60	1.54	1.56	1.65	1.55	1.63	1.63	1.56	1.57	1.65	1.55	1.64	1.9%	1.3%	0.6%	0.0%	0.0%	0.6%
		Unit4	1.48	1.45	1.50	1.58	1.49	1.57	1.49	1.45	1.50	1.58	1.50	1.58	0.7%	0.0%	0.0%	0.0%	0.7%	0.6%
		Unit5	1.63	1.64	1.63	1.67	1.66	1.68	1.65	1.66	1.64	1.69	1.66	1.69	1.2%	1.2%	0.6%	1.2%	0.0%	0.6%
		Unit6	1.56	1.54	1.53	1.63	1.60	1.64	1.56	1.54	1.56	1.64	1.61	1.64	0.0%	0.0%	2.0%	0.6%	0.6%	0.0%
		Unit7	1.63	1.59	1.54	1.72	1.65	1.65	1.64	1.60	1.57	1.73	1.66	1.66	0.6%	0.6%	1.9%	0.6%	0.6%	0.6%
		Unit8	1.53	1.50	1.47	1.67	1.59	1.59	1.54	1.51	1.48	1.68	1.59	1.59	0.7%	0.7%	0.7%	0.6%	0.0%	0.0%
		Unit9	1.53	1.49	1.55	1.53	1.61	1.53	1.53	1.50	1.57	1.53	1.62	1.56	0.0%	0.7%	1.3%	0.0%	0.6%	2.0%
		Unit10	1.54	1.49	1.52	1.58	1.57	1.60	1.54	1.50	1.53	1.58	1.58	1.61	0.0%	0.7%	0.7%	0.0%	0.6%	0.6%
		Unit11	1.51	1.51	1.48	1.63	1.59	1.63	1.51	1.52	1.49	1.63	1.59	1.63	0.0%	0.7%	0.7%	0.0%	0.0%	0.0%
		Unit12	1.49	1.48	1.49	1.65	1.59	1.58	1.49	1.48	1.49	1.65	1.60	1.61	0.0%	0.0%	0.0%	0.0%	0.6%	1.9%
		Unit13	1.45	1.41	1.46	1.60	1.60	1.68	1.45	1.42	1.46	1.61	1.61	1.70	0.0%	0.7%	0.0%	0.6%	0.6%	1.2%
	through hole daisy chain	Unit14	0.53	0.54	0.55	N/A			0.54	0.54	0.56	N/A			1.9%	0.0%	1.8%	N/A		
		Unit15	0.58	0.55	0.55				0.58	0.56	0.56				0.0%	1.8%	1.8%			
		Unit16	0.54	0.55	0.54				0.55	0.56	0.55				1.9%	1.8%	1.9%			
		Unit17	0.55	0.56	0.54				0.56	0.56	0.54				1.8%	0.0%	0.0%			
		Unit18	0.55	0.55	0.54				0.55	0.55	0.55				0.0%	0.0%	1.9%			
		Unit19	0.56	0.55	0.53				0.55	0.55	0.54				-1.8%	0.0%	1.9%			
B	HDI daisy chain	Unit1	1.72	1.71	1.77	1.64	1.63	1.68	1.74	1.72	1.80	1.64	1.64	1.69	1.2%	0.6%	1.7%	0.0%	0.6%	0.6%
		Unit2	1.71	1.68	1.76	1.57	1.54	1.57	1.70	1.69	1.77	1.59	1.53	1.57	-0.6%	0.6%	0.6%	1.3%	-0.6%	0.0%
		Unit3	1.77	1.75	1.75	1.67	1.64	1.70	1.79	1.76	1.74	1.69	1.66	1.72	1.1%	0.6%	-0.6%	1.2%	1.2%	1.2%
		Unit4	1.73	1.75	1.74	1.60	1.56	1.63	1.71	1.76	1.77	1.61	1.59	1.64	-1.2%	0.6%	1.7%	0.6%	1.9%	0.6%
		Unit5	1.84	1.78	1.80	1.74	1.73	1.74	1.86	1.79	1.81	1.74	1.73	1.74	1.1%	0.6%	0.6%	0.0%	0.0%	0.0%
		Unit6	1.83	1.78	1.79	1.66	1.64	1.66	1.85	1.78	1.79	1.67	1.66	1.67	1.1%	0.0%	0.0%	0.6%	1.2%	0.6%
		Unit7	1.81	1.79	1.87	1.73	1.65	1.66	1.83	1.79	1.88	1.73	1.65	1.67	1.1%	0.0%	0.5%	0.0%	0.0%	0.6%
		Unit8	1.82	1.78	1.86	1.65	1.57	1.58	1.83	1.80	1.88	1.67	1.59	1.60	0.5%	1.1%	1.1%	1.2%	1.3%	1.3%
		Unit9	1.71	1.75	1.76	1.80	1.77	1.78	1.72	1.76	1.77	1.81	1.78	1.78	0.6%	0.6%	0.6%	0.6%	0.6%	0.0%
		Unit10	1.82	1.74	1.77	1.71	1.69	1.65	1.83	1.75	1.77	1.70	1.69	1.66	0.5%	0.6%	0.0%	-0.6%	0.0%	0.6%
		Unit11	1.86	1.84	1.86	1.71	1.69	1.77	1.86	1.84	1.86	1.71	1.70	1.77	0.0%	0.0%	0.0%	0.0%	0.6%	0.0%
		Unit12	1.88	1.82	1.89	1.72	1.65	1.64	1.88	1.83	1.90	1.72	1.65	1.65	0.0%	0.5%	0.5%	0.0%	0.0%	0.6%
		Unit13	1.86	1.80	1.85	1.70	1.64	1.68	1.85	1.80	1.85	1.71	1.66	1.70	-0.5%	0.0%	0.0%	0.6%	1.2%	1.2%
	through hole daisy chain	Unit14	0.69	0.68	0.69	N/A			0.70	0.68	0.69	N/A			1.4%	0.0%	0.0%	N/A		
		Unit15	0.69	0.67	0.67				0.70	0.67	0.67				1.4%	0.0%	0.0%			
		Unit16	0.68	0.67	0.67				0.68	0.68	0.67				0.0%	1.5%	0.0%			
		Unit17	0.69	0.68	0.66				0.69	0.68	0.67				0.0%	0.0%	1.5%			
		Unit18	0.69	0.69	0.70				0.69	0.70	0.70				0.0%	1.4%	0.0%			
		Unit19	0.72	0.70	0.69				0.72	0.70	0.69				0.0%	0.0%	0.0%			

IST Test Pass Over 500 Cycles

IST Minimum Requirements by Industry – *IST testing is used in a number of industries. The graph below shows the typical minimum IST cycles to failure of coupons tested "As Received" (no preconditioning).*

Typical Minimum Requirement by Industry
Graph 4



Ref: PWB Interconnect Solutions Inc.

Observations and Considerations:

1. There were some "quality control" issues noted in this test set. One coupon arrived with an open on S1 and another with a short between P2/S2. Both defects were repaired. Reliability testing is best preformed on coupons that are free of quality related defects.
2. The IST cycles to failure mean of 293 may be somewhat lower than the average achieved testing similar coupons. The average of 20,781 coupons fabricated on a mid-range Tg material with a thickness between .062' and .093" was 570 IST cycles to failure. A thinner coupon would be expected to surpass 570 cycles to failure.

Ref: PWB Interconnect Solutions Inc.

Features	Benefits
• Super Fills Blind Microvias (BMV)	• Higher productivity • Fewer process steps • Improved process yields
• Strong Filling Performance	• Exceptionally good filling ▪ Typically >100% & dimple < 5um • Minimal surface copper deposited (<15um)
• Short Plating Time for Via Fill (40-60 mins)	• High productivity • Lower labor cost
• Panel or Pattern Plate Processing Capability	• Process flexibility • Low surface copper thickness with excellent fill
• Insoluble anode	• Fast start up without dummy plating • Maintenance free
• No Pre-dip Bath	• No extra bath maintenance
• "All in one" system	• Accurate CVS control of plating bath additive
• Via Fill Process directly after Direct Metallization	• No additional flash copper plating
• Compatible with different equipment configuration	• Drop-in process for existing production lines • Low start-up cost

THE END!