Electronic Materials

INTERLINK™ 9200 Cu TSV

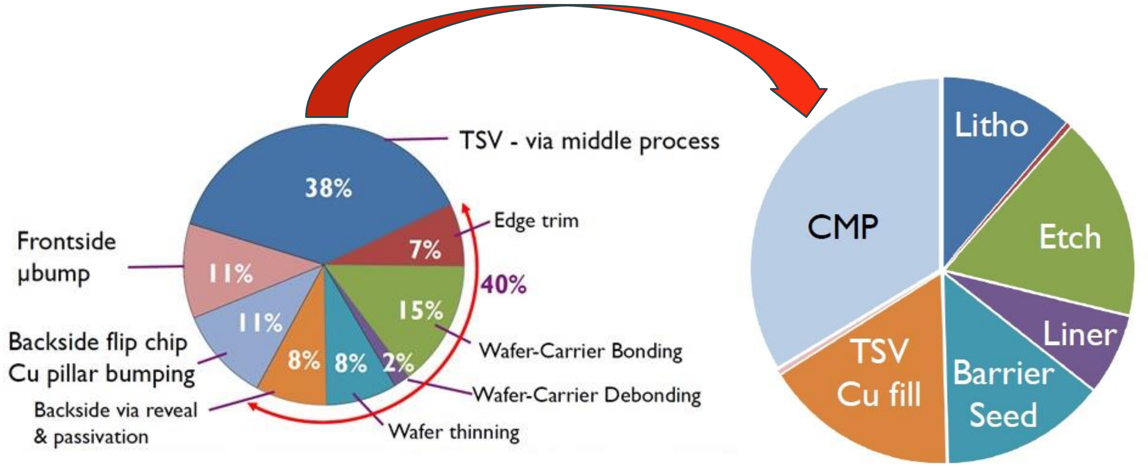
Advanced Packaging Technologies

Outline

- Introduction: TSV for 2.5D and 3D Packaging
- INTERLINK™ 9200 Cu TSV
  - Formulation
  - Mechanism of bottom-up fill Cu deposition
- Segment Plating Results
  - 5x55 µm via-middle
  - 10x100 µm via-last
  - High aspect ratio – next-generation devices
- 300 mm Plating Results
- INTERLINK™ 9200 Process Window and Stability
- Conclusions

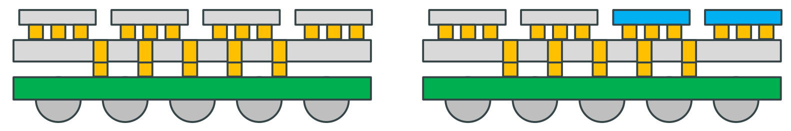
Introduction: TSVs for 2.5D and 3D Packaging

- High performance devices
- Low latency between dies
- Maximum I/O density
- Decreased power consumption
- High costs for CMP and via filling



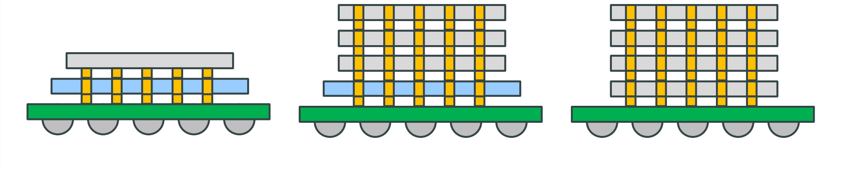
Interposers: 2.5D

- Able to use existing die layouts
- Can combine high yield die processes already in place
- Bridge to true 3D design



Die-stacking: 3D

- New die design layout/rules needed
- Smallest device layout, highest performance



INTERLINK™ 9200 Cu TSV

INTERLINK™ 9200 Cu TSV *Formulation*

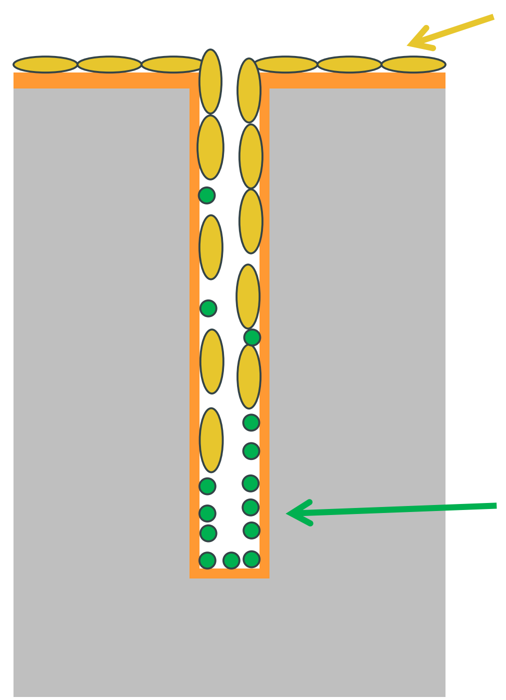
INTERLINK™ 9200 Cu TSV Formulation (For Catholyte Chamber)			
Product Name	*Function*	*Target*	*Range*
INTERLINK™ 9200 Accelerator	De-polarizer, accelerates Cu plating & allows bottom-up fill	3 mL/L	2.5 – 3.5 mL/L
INTERLINK™ 9200 Suppressor	Polarizer that slows Cu plating and provides wetting of vias	6 mL/L	2 – 8 mL/L
INTERLINK™ 9200 Leveler	Sidewall polarizer, slows rate of Cu plating	3.5 mL/L	3 – 4 mL/L
INTERLINK™ 9200 Electrolyte	Source of Cu ions, provides pH adjustment and bath conductivity	60 g/L Cu^{2+}; 10 g/L H_2SO_4; 80 ppm Cl^-	Cu^{2+}: +/- 5%; Acid, Cl^-: +/- 10%

INTERLINK™ 9200 Cu TSV Formulation (For Anolyte Chamber)			
Product Name	*Function*	*Target*	*Range*
INTERLINK™ 9200 Anolyte	Electrolyte designed to work with Cu anode in the Anolyte Chamber	60 g/L Cu^{2+}; 0.3 g/L H_2SO_4; 80 ppm Cl^-	Cu^{2+}: +/- 5%; Acid, Cl^-: +/- 10%

- INTERLINK™ 9200 Cu TSV uses a 3-component additive system (Accelerator, Suppressor, Leveler), with membrane in the plating cell, to deposit Cu in 2.5D & 3D TSV packaging applications
- Additive components specially formulated to allow for rapid, defect-free bottom up filling performance within 10x100 µm and 5x50 µm TSV features
- Target dosing can be modified to achieve optimized performance on a specific wafer type and pattern layout

INTERLINK™ 9200 Cu TSV

Mechanism of Bottom-up Fill



Suppressor:

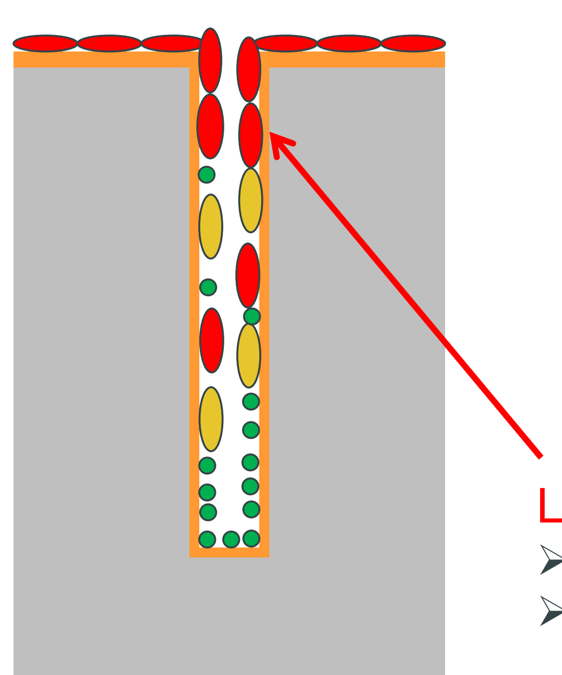
- Used to lower surface tension of plating bath, allowing proper wetting of TSV vias and wafer surface, reducing surface defects
- Weaker suppressor preferred to allow stronger polarizing leveler to polarize via sidewalls
- Suppressor also can compete with accelerator adsorption to the surface, supporting the leveler and offering additional Cu deposition control

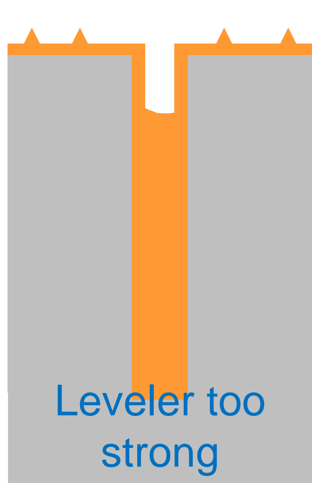
Accelerator:

- Needed to initiate bottom-up filling at via bottom
- Relatively low dosing needed to maintain bath stability
- Higher doses needed for rapid via filling
- Dosing set by balance between stability and plating rate

INTERLINK™ 9200 Cu TSV

Mechanism of Bottom-up Fill





Leveler:

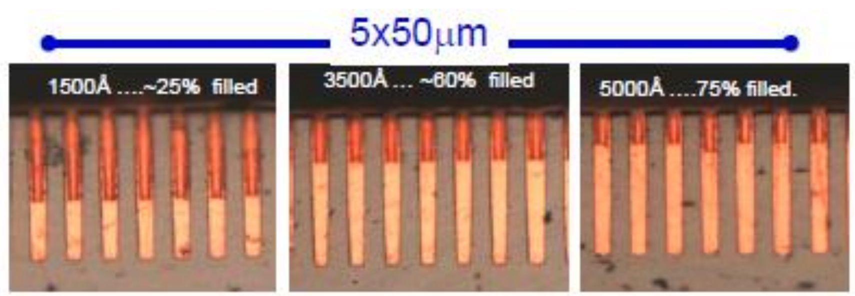
- Used to polarize field area as well as via sidewalls
- Strong polarizing leveler used to minimize Cu deposition on wafer field area and on upper via sidewalls
- Leveler required to prevent plating defects such as pinch-off voids and surface nodules
- Too strong of leveler causes doping of deposited Cu, surface defects, as well as preventing top of via filling

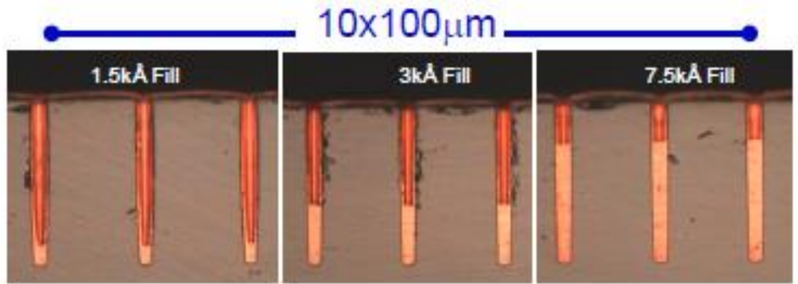
INTERLINK™ 9200 Segment Plating Results

INTERLINK™ 9200 Segment Plating Results

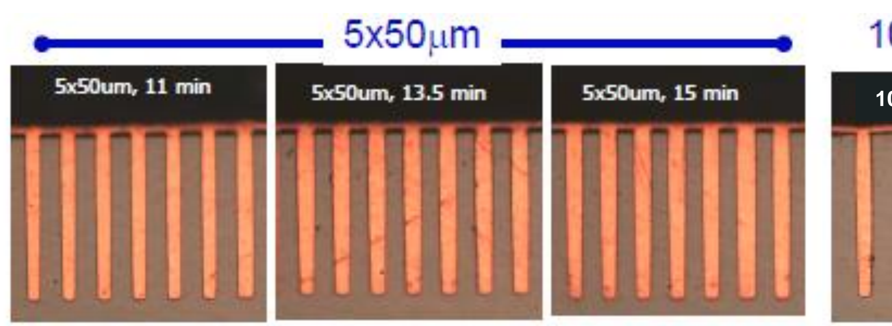
Partial and Full Fill on 5x55 µm and 10x100 µm Test Wafers

- Partial Filling Sequences: Strong polarization at via opening ➔ ideal filling profile





- Via filling speed tests: Rapid filling capability
  - Plating Cycle times ~15 min (5x50 µm), and ~55 min (10x100 µm) demonstrated in segment level test (wafer dependent)
- Full Filling Sequences: Low overburden thickness, smooth deposits



10x100µm

10x100um, 55 min

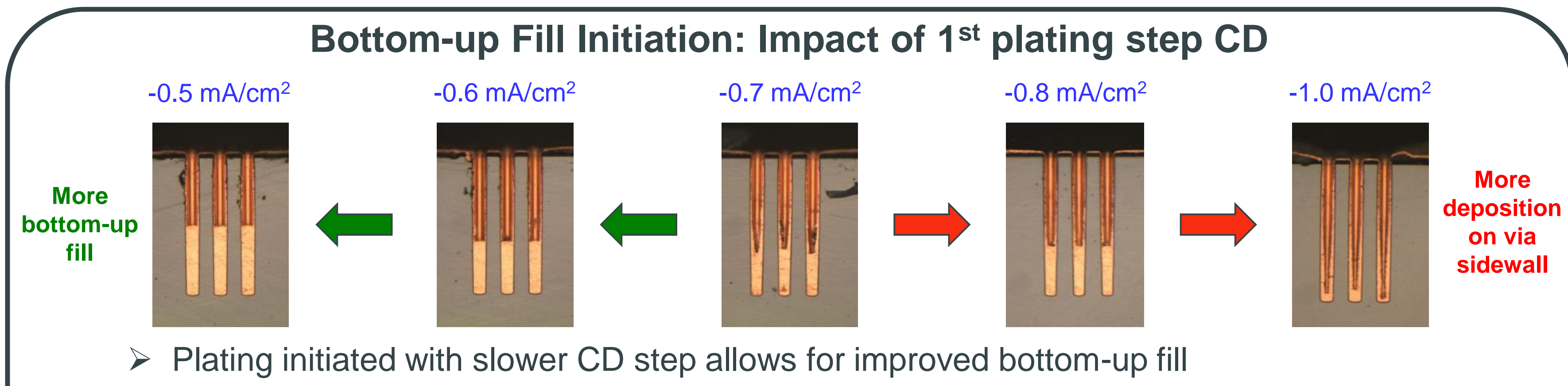
Overburden

0.80um OB for 1.5um Cu deposit

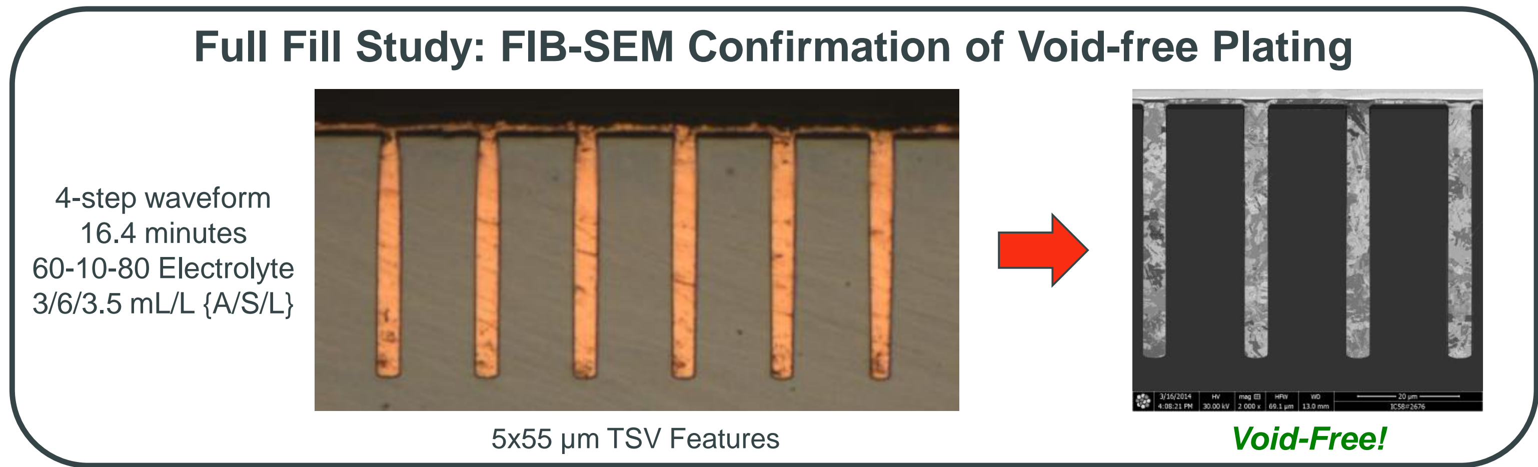
$R_a \leq 10$nm

INTERLINK™ 9200 Segment Plating Results

Initial Plating Rate and Full Fill Void Inspection



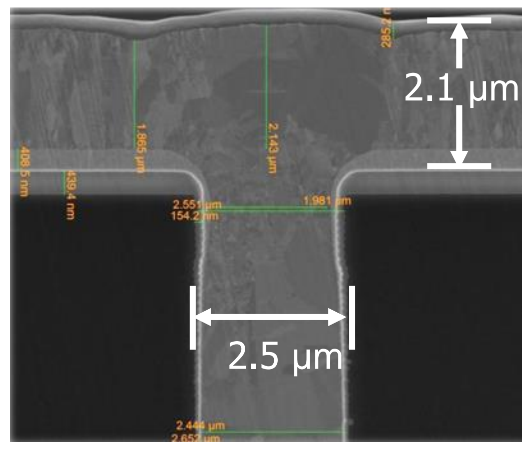
- Plating initiated with slower CD step allows for improved bottom-up fill
- Plating too fast initially does not allow enough time for Cu diffusion to bottom of the via
- Balance of Additive concentration and plating waveform to optimize fill time/performance



INTERLINK™ 9200 Segment Plating Results

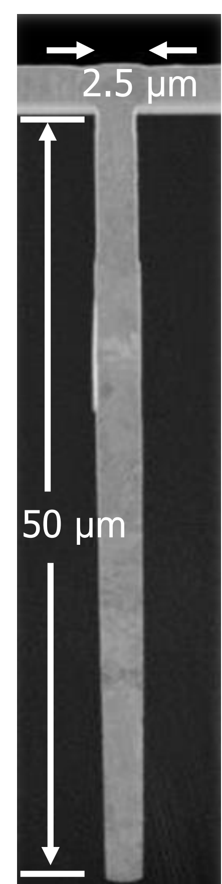
Extension to Next-Generation Applications

- INTERLINK™ 9200 can be extended into future generation applications including TSV features with an aspect ratio of 20:1 (2.5x50 μm)
- Bottom-up fill is maintained with challenging aspect ratio, TSV vias are void-free as confirmed by FIB-SEM
- Cu plating still occurs mostly in-via, with minimal overburden



Images provided courtesy of Applied Materials

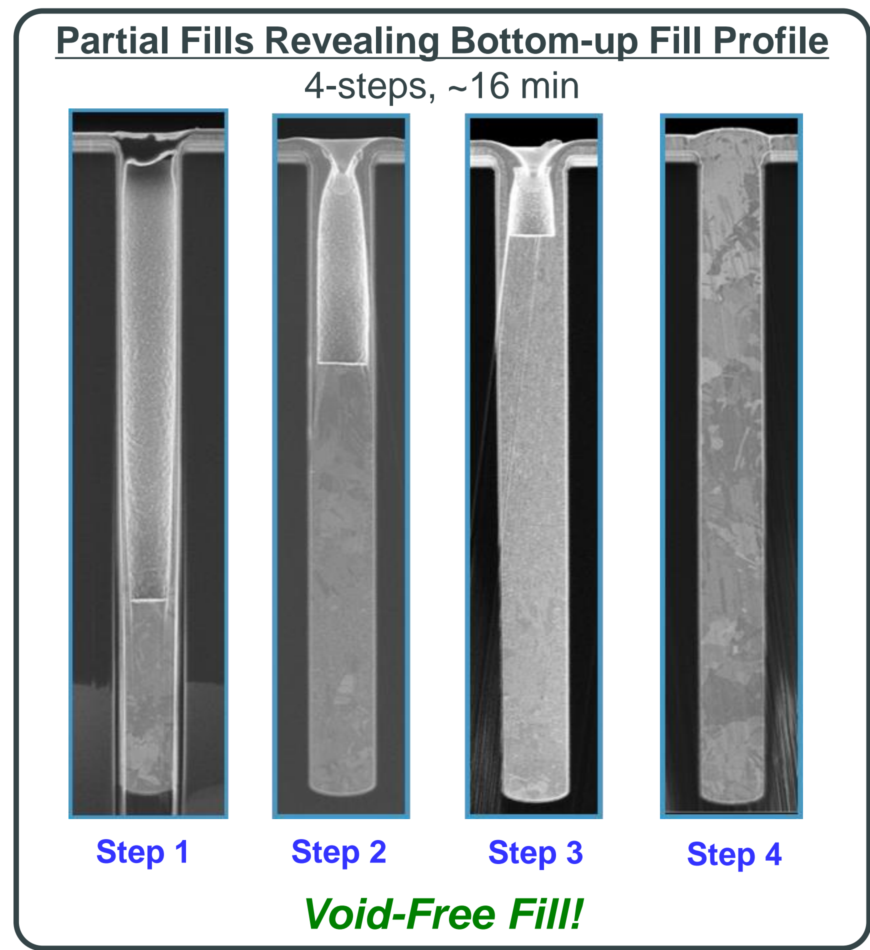
4-step plating waveform
Void-free fill



INTERLINK™ 9200: 300 mm Plating Results

INTERLINK™ 9200: 300 mm Plating Results

Partial and Full Fill on 5x55 µm Test Wafers



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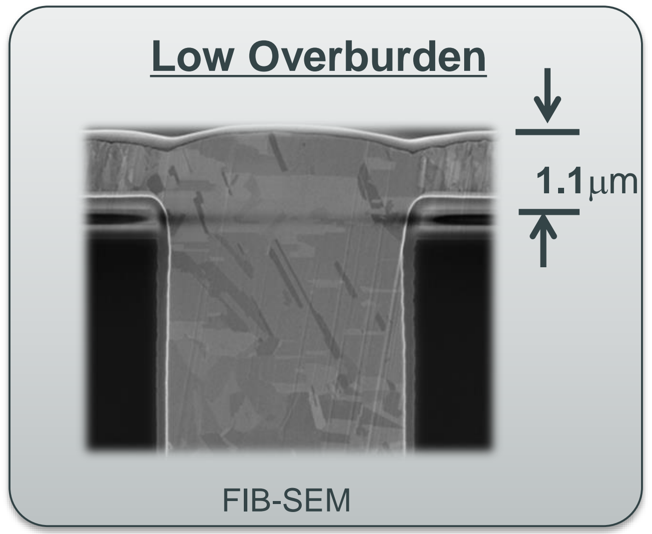
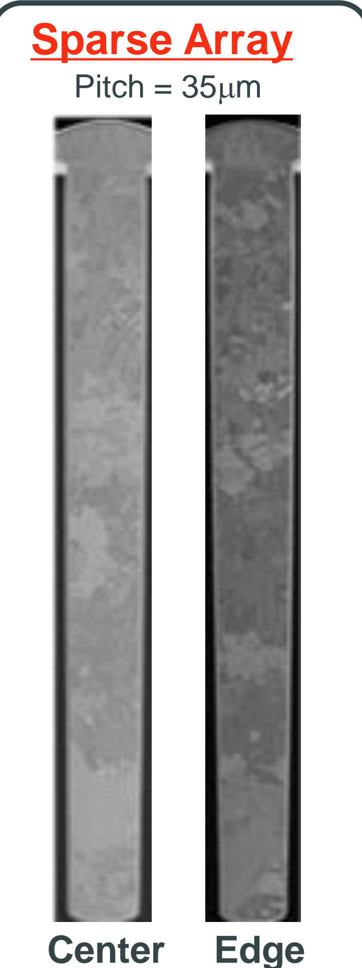


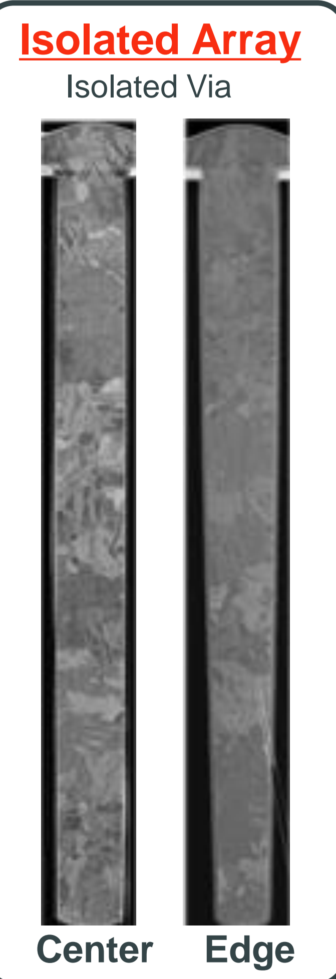
- Strong sidewall suppression during deposition prevents voiding at the top of the via
- Low total overburden of ~1 um minimizes CMP processing
- Fill times of less than 20 min.

INTERLINK™ 9200: 300 mm Plating Results

Center-to-Edge Effects on 5x55 μm Test Wafers

- Uniform plating overburden from center to edge of wafers
- Same via filling rates independent of via pitch, allowing for flexible die layout
- Small changes in via over-bump with pitch, minimizing CMP issues





Images provided courtesy of Applied Materials

INTERLINK™ 9200: 300 mm Plating Results

Partial and Full Fill on 10x100 µm Test Wafers

Partial Fills Revealing Bottom-up Fill Profile

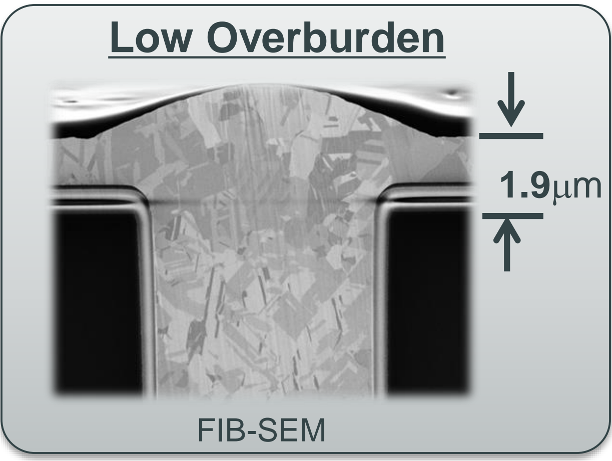
5-steps, ~55 min

Step 1 Step 2 Step 3 Step 4 Step 5

Void-Free Fill!

Images provided courtesy of Applied Materials

Low Overburden



FIB-SEM

- Bottom-up filling with strong suppression of sidewalls and via opening
- Minimal overburden of ~1.5-2 µm reduces CMP processing time
- Fill times of less than 60 min. achieved

INTERLINK™ 9200 Process Window and Stability

INTERLINK™ 9200 Process Window and Stability

5x55 µm Test Wafer at Segment Level

		[Accelerator]		
		-25 %	Target	+25%
[Leveler]	-25%			
	Target			
	+25%			

- Aggressive filling time enables better centering of chemistry dosing
- Target leveler dosing exhibits void-free full filling with wide accelerator window
- Low leveler content exhibits voiding at via bottoms – not enough sidewall polarization

- 4 step plating cycle
- 16.5 min. fill time

Membrane segment plater, 700 mL catholyte chamber, 1 L anolyte chamber

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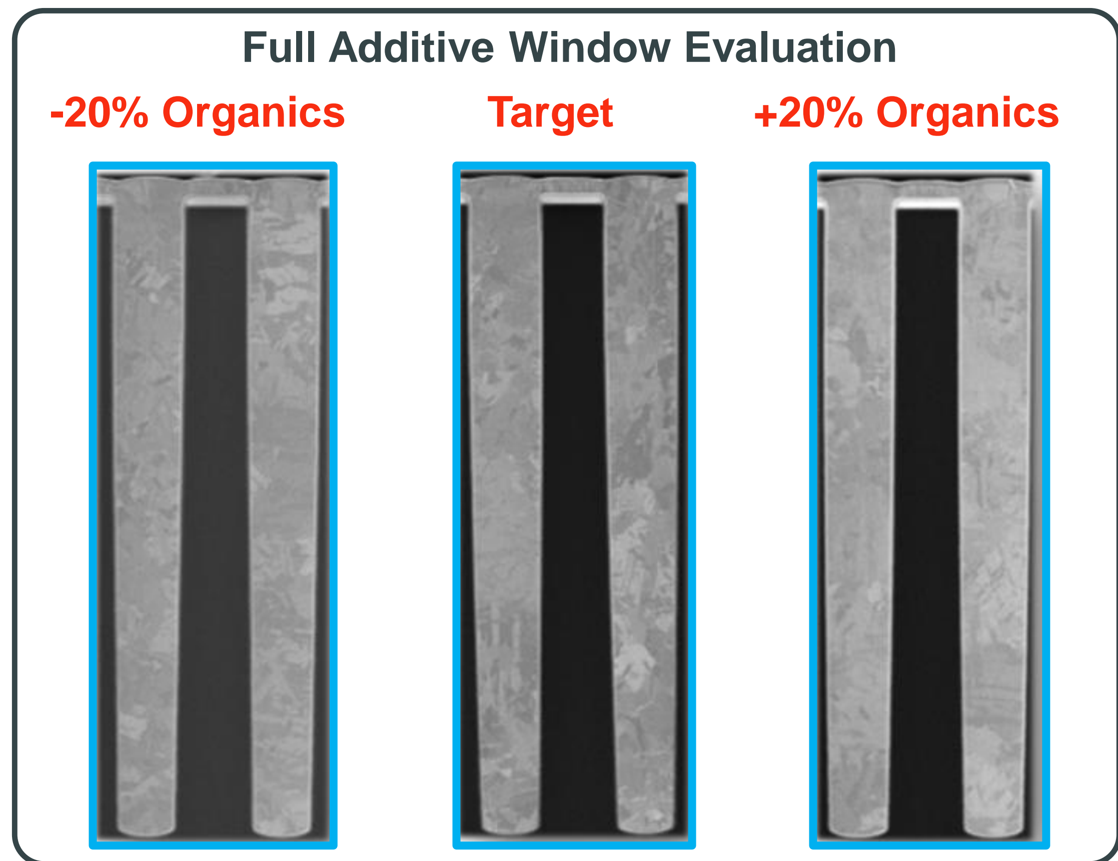
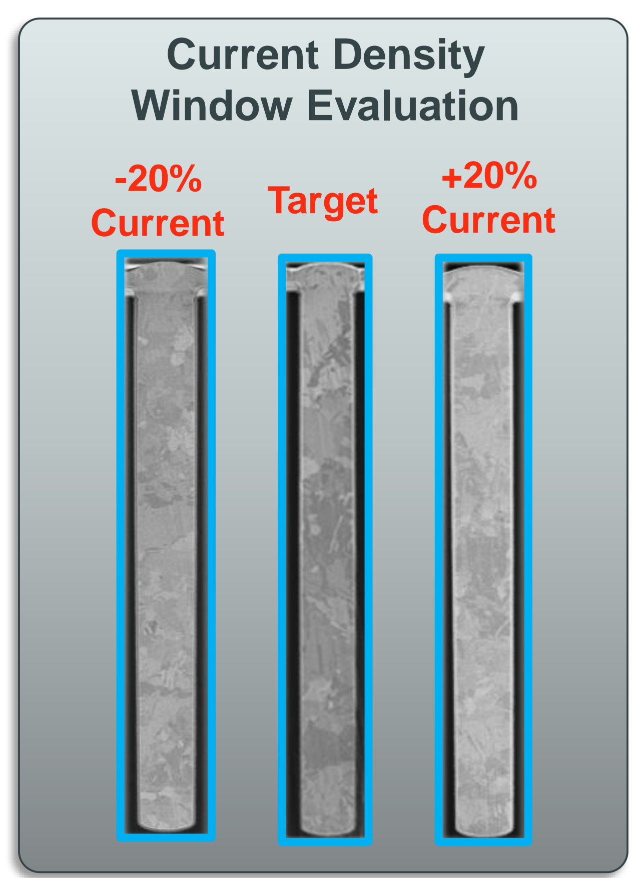
INTERLINK™ 9200 Process Window and Stability

5x55 µm Test Wafer at Tool Level





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- INTERLINK™ 9200 displays a wide additive and current density process window

INTERLINK™ 9200 Process Window and Stability

10x100 µm Test Wafer at Segment Level

[Leveler]		[Accelerator]		
		-66 %	Target	+66%
	-42%			
	Target			
	+42%			

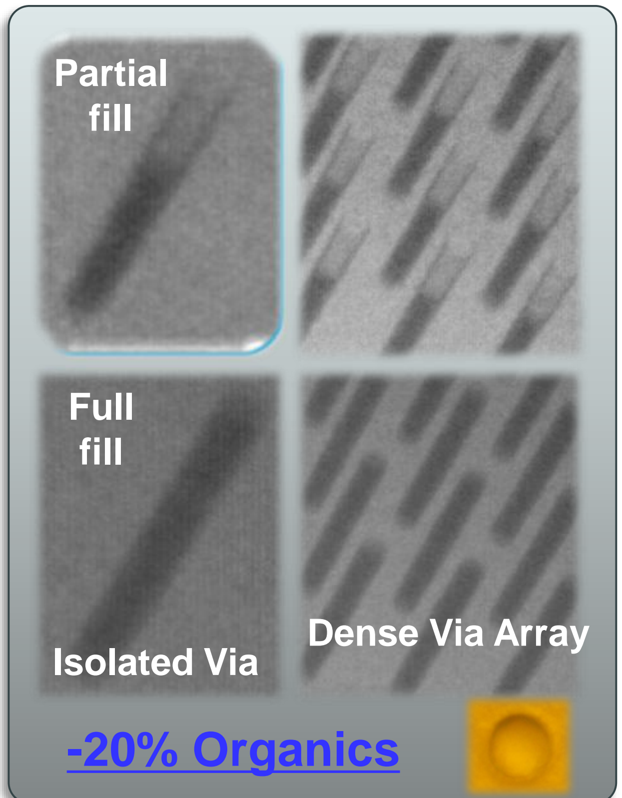
- Increased accelerator content within a leveler dosing increases fill rate
- Increased leveler content slows fill speeds and increases time for full fill
- Target dosings give rapid void-free filling of vias

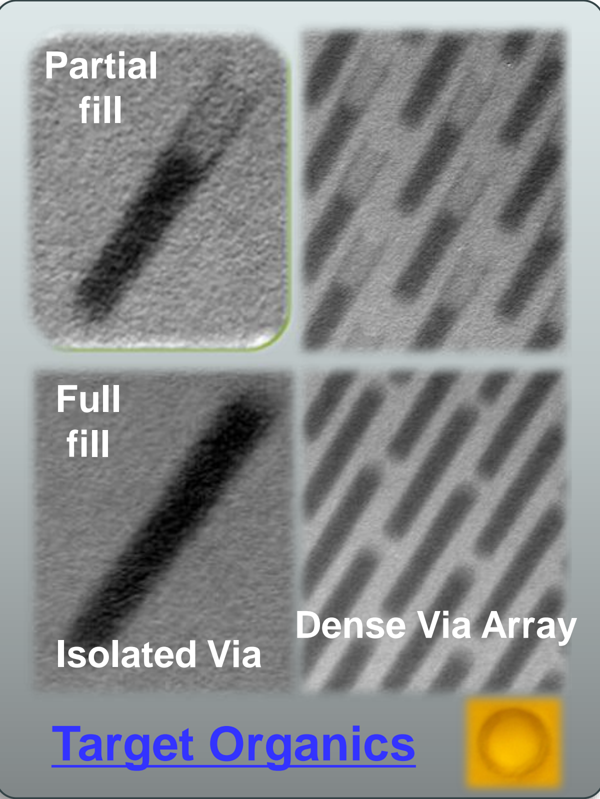
- 4 step plating cycle
- 56 min. fill time

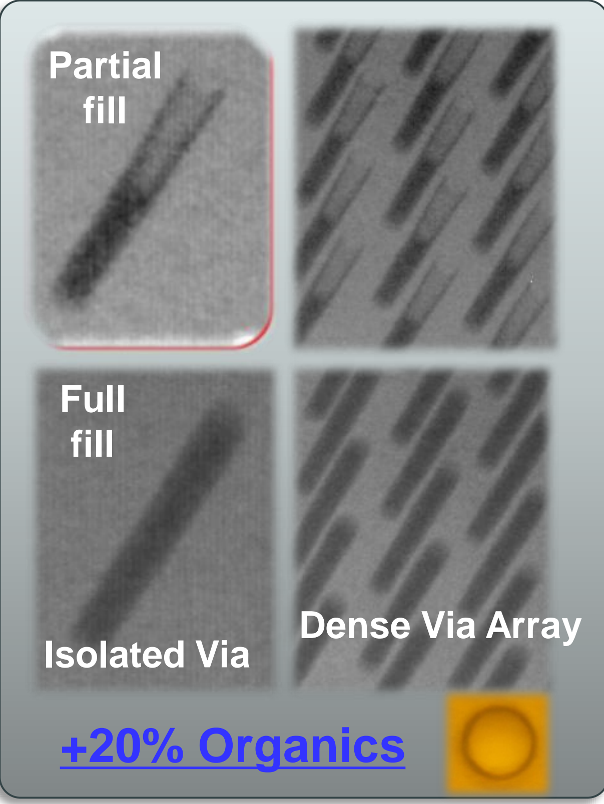
Membrane segment plater, 700 mL catholyte chamber, 1 L anolyte chamber

INTERLINK™ 9200 Process Window and Stability

10x100 µm Test Wafer at Tool Level







Images provided courtesy of Applied Materials

- Void-free filling with a wide ±20% organic dosing window
- Similar fill speeds between via pitches across dosing window

INTERLINK™ 9200 Process Window and Stability

Fill Performance Throughout Electrolytic Aging

10 × 100 µm Via Filling Stability

0.1 days	6 days	10 days	13 days	27 days	39 days
0 Ahr/L	10 Ahr/L	15 Ahr/L	20 Ahr/L	30 Ahr/L	40 Ahr/L

Steady-State

Center / Edge (shown for each time point)

Images provided courtesy of Applied Materials

- ➤ Greater than 40 Ahr L^{-1} bath life with both 10 × 100 µm and 5 × 50 µm vias
- ➤ Equivalent of ~10,000 5 × 50 µm wafers or ~4,000 10 × 100 µm wafers

Conclusions

- INTERLINK™ 9200 was developed to provide fast bottom-up fill of Cu into TSV features of 10x100 µm down to 5x50 µm and 2.5x50 µm
- Fill times of ~55 min for 10x100 µm features and ~16 min for 5x50 µm features achieved at the 300 mm tool level
- INTERLINK™ 9200 has shown a wide process window of ±20% for both the additives and the plating rate
- INTERLINK™ 9200 shows stable plating performance at the 300 mm tool level up to 40 Ahr/L

Thank You

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