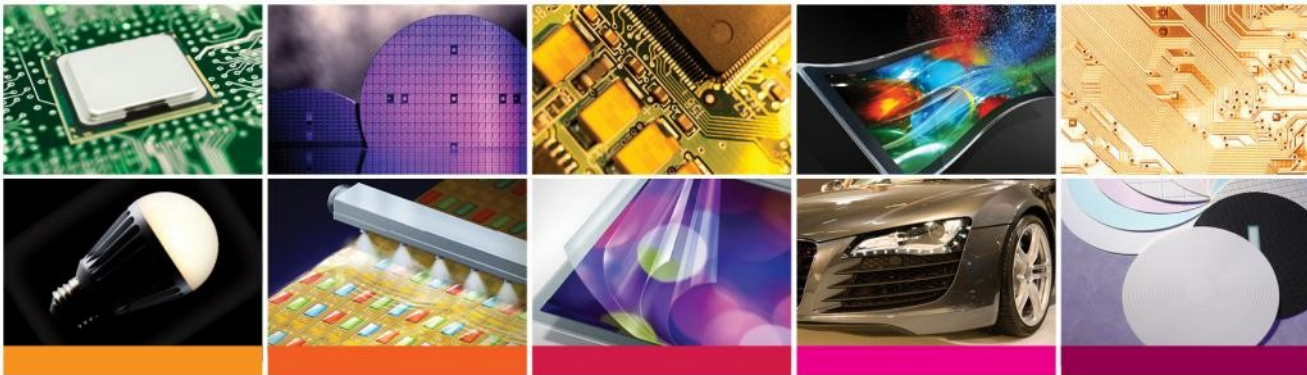


Presented at 2016 IMAPS  
Device Packaging

## Electronic Materials



# Evaluation of Cu Pillar Chemistries

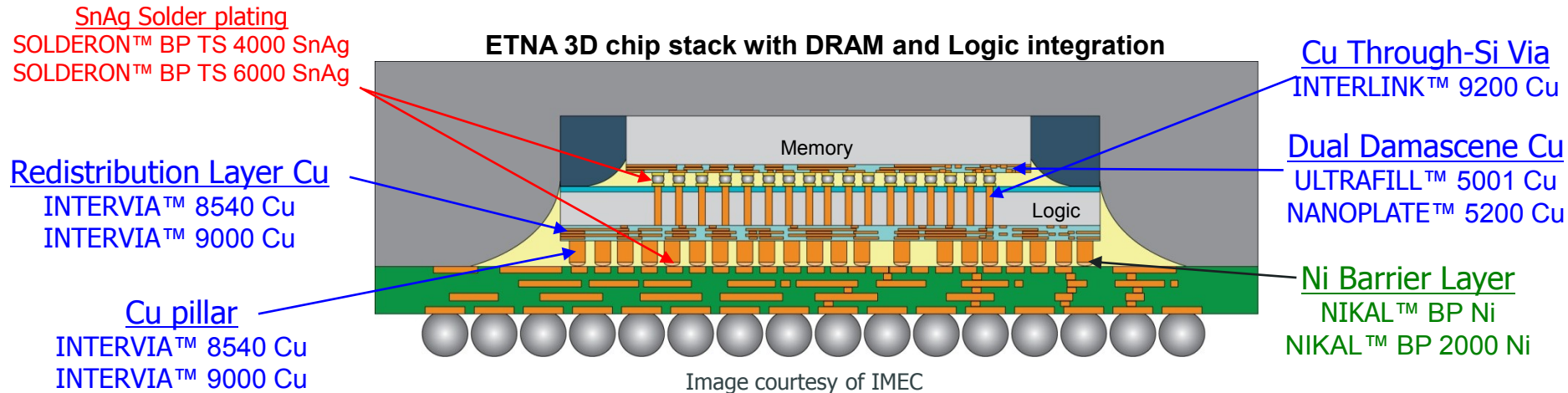
iMAPS Device Packaging Conference – Spring 2016

Matthew Thorseth, Mark Scalisi, Inho Lee, Sang-Min Park, Yil-Hak Lee, Jonathan Prange, Masaaki Imanari, Mark Lefebvre, Jeff Calvert

# Outline

- Introduction
- Cu Pillar Plating with INTERVIA™ Cu Products
  - RDL
  - Pillars
  - Solder integration
- Next generation performance
  - Megapillars
  - 50 μm pillars

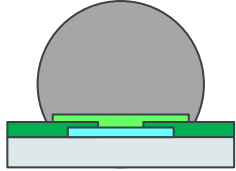
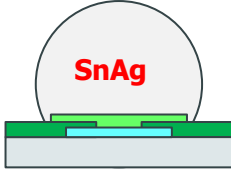
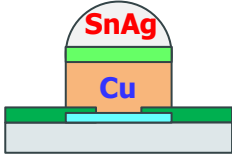
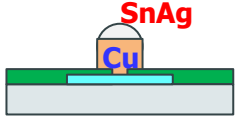
# Background and Introduction



- **Solders** – Used for electrical joint formation, previously had been SnPb, shift to SnAg due to environmental concerns
- **Copper** – Conductor used to carry signals throughout the chip package
- **Nickel** – Used mainly as a seed & barrier layer to prevent intermetallic mixing at metal/metal interfaces

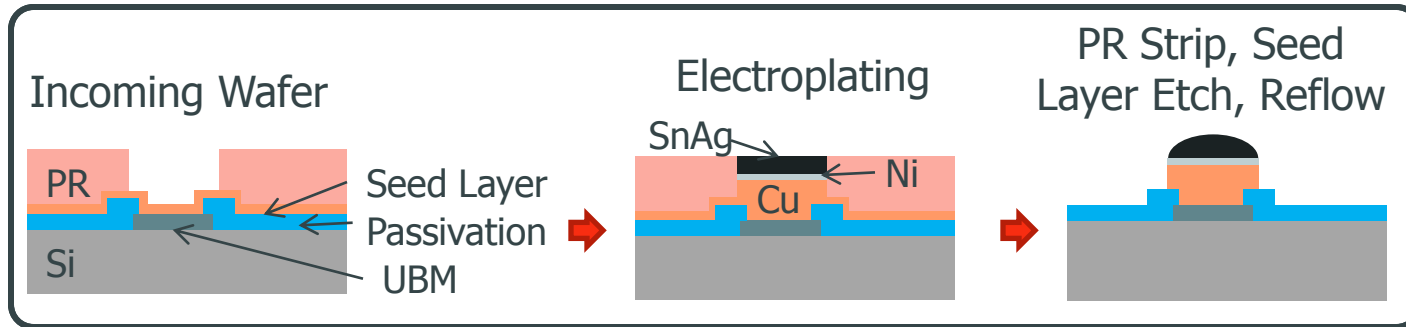
# Background and Introduction

## Technology Trend in Packaging

	SnPb C4 Bump	Pb-Free C4 Bump	Cu Pillar + Pb-free Cap	Cu $\mu$ -Pillar + Pb-free Cap
Structure				
Diameter	75 – 200 $\mu\text{m}$	75 – 150 $\mu\text{m}$	50 – 100 $\mu\text{m}$	10 – 30 $\mu\text{m}$
Products	SOLDERON™ BP + NIKAL™ BP Ni <b>NIKAL™ BP 2000 Ni</b>	SOLDERON™ BP TS 4000 SnAg <b>SOLDERON™ BP TS 6000</b> SnAg + NIKAL™ BP Ni <b>NIKAL™ BP 2000 Ni</b>	INTERVIA™ 8540 Cu <b>INTERVIA™ 9000</b> Cu + NIKAL™ BP Ni <b>NIKAL™ BP 2000 Ni</b> + SOLDERON™ Products	INTERVIA™ Cu Products + NIKAL™ Products + SOLDERON™ Products



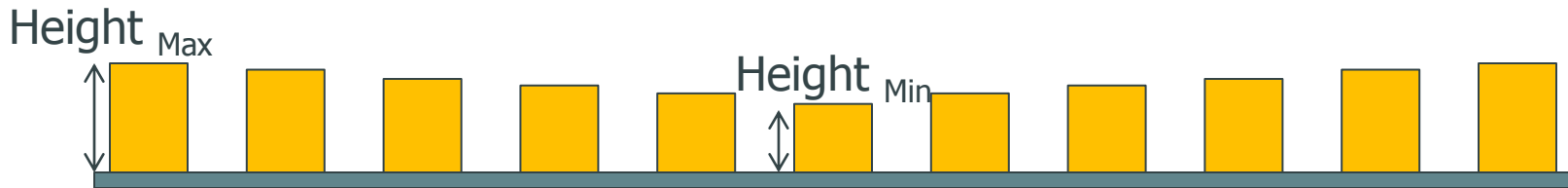
# Process Flow and Design Goals



Design Goal	RDL Target	20 $\mu\text{m}$ Pillar Target	50 $\mu\text{m}$ Pillar Target	200 $\mu\text{m}$ Pillar Target
%WID Uniformity	< 5%	< 5%	< 5%	< 10%
%TIR Doming	-5% to 5%	-5% to 5%	-5% to 5%	-5% to 5%
<b>Plating Rate</b>	<b>2 to 12 ASD</b>	<b>4.5 to 12 ASD</b>	<b>4.5 to 18 ASD</b>	<b>20 to 40 ASD</b>
Total Doping (C,N,O,S,Cl)	< 20 ppm	< 20 ppm	< 20 ppm	< 20 ppm
Solder Compatibility	Void-free w/o Ni Barrier	Void-free w/o Ni Barrier	Void-free w/o Ni Barrier	Void-free w/o Ni Barrier

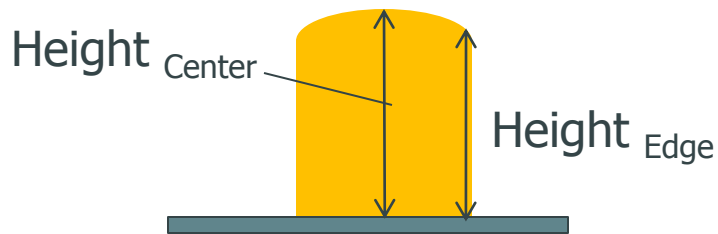
# Definitions

## Within-die (WID) Co-planarity

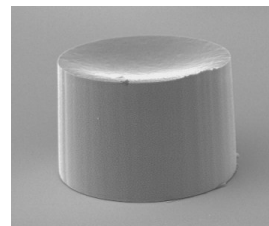


$$\%WID = \frac{1}{2} \left[ \frac{Height_{Max} - Height_{Min}}{Height_{Avg}} \right] \times 100$$

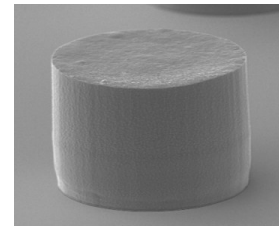
## Total Indicated Runout (TIR)



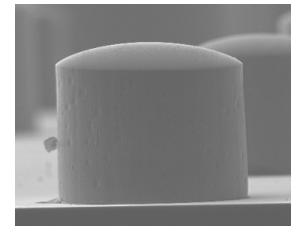
$$\%TIR = \frac{Height_{Center} - Height_{Edge}}{Height_{Max}} \times 100$$



**Dished (-TIR)**





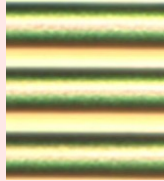





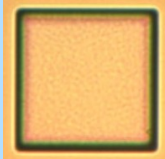

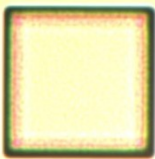
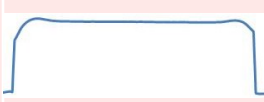
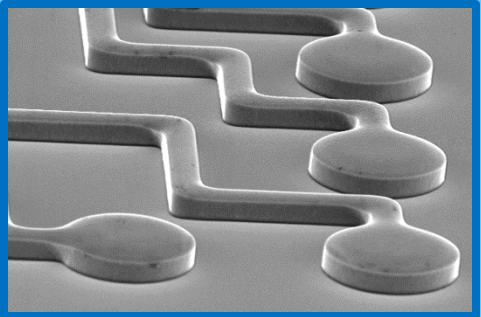
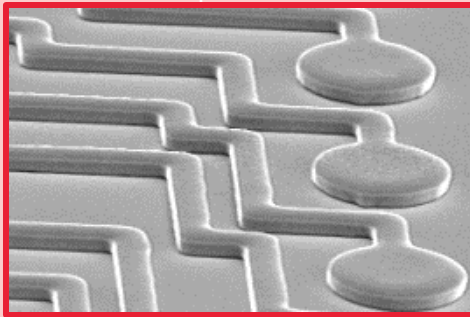
**Flat (0 TIR)**



**Domed (+TIR)**

**300 mm Data**  
**INTERVIA™ Copper**  
**Chemistry**

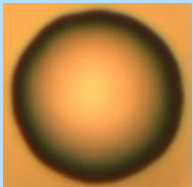

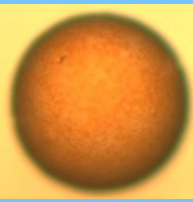

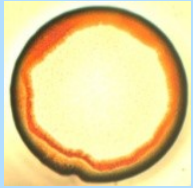

# Redistribution Layer Pattern Plating at 4.5 ASD



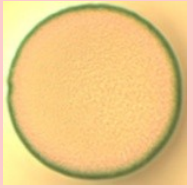

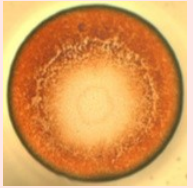

	INTERVIA™ 8540 Cu Images		INTERVIA™ 9000 Cu Images	
Feature Size	Optical Image	Profile	Optical Image	Profile
5/5 μm line/space comb				
50/50 μm line/space comb				
100 μm square pad				
50 μm bond pad with 10 μm lines				

➤ Similar plating performances between chemistries, with slightly less domed profiles with INTERVIA™ 9000 Cu



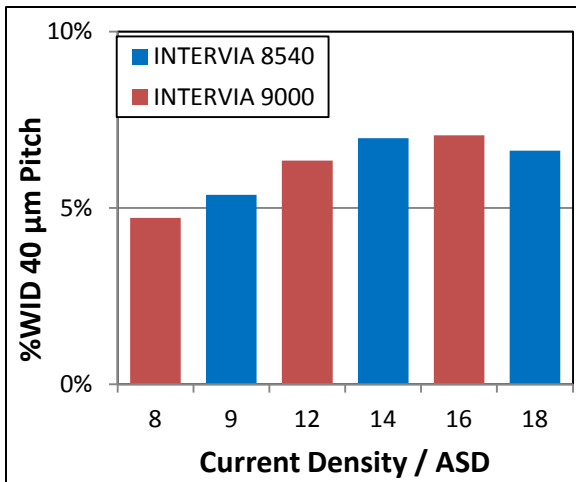
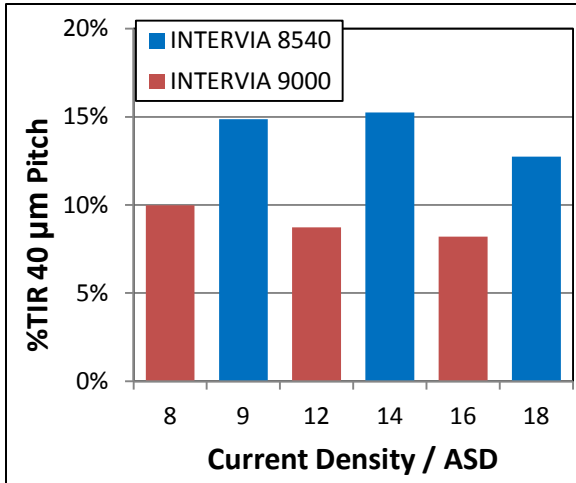
# Pillar Plating Performance Across Feature Sizes

INTERVIA™ 8540 Cu Images		
Pillar Size and Plating Rate	Optical Image	Profile
20 μm pillar at 8 ASD		
50 μm pillar at 14 ASD		
75 μm pillar at 14 ASD		

INTERVIA™ 9000 Cu Images		
Pillar Size and Plating Rate	Optical Image	Profile
20 μm pillar at 8 ASD		
50 μm pillar at 14 ASD		
75 μm pillar at 14 ASD		

➤ INTERVIA™ 9000 Cu pillars have lower doming across all pillar types

# INTERVIA™ 8540 Cu vs. INTERVIA™ 9000 Cu 20 μm diameter micropillars

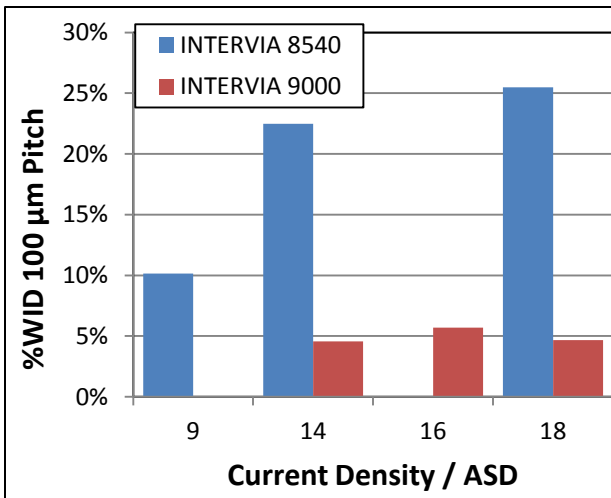
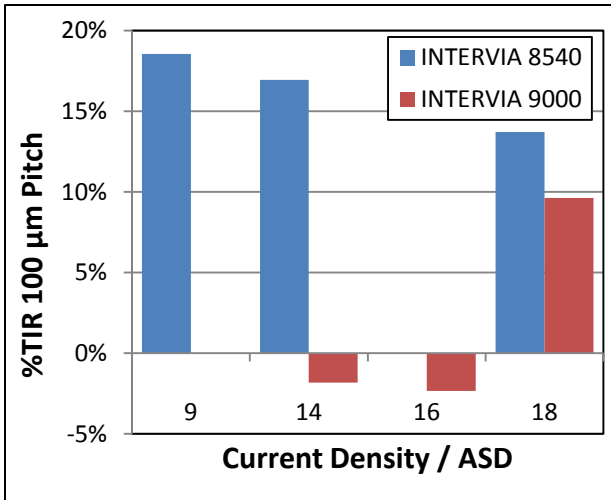


INTERVIA™ Cu 8540 Images		
Current Density / ASD	Optical Image	Profile Dense Pitch
9		
14		
18		

INTERVIA™ Cu 9000 Images		
Current Density / ASD	Optical Image	Profile Dense Pitch
8		
12		
16		

# INTERVIA™ 8540 vs. INTERVIA™ 9000

## 50 μm diameter pillars

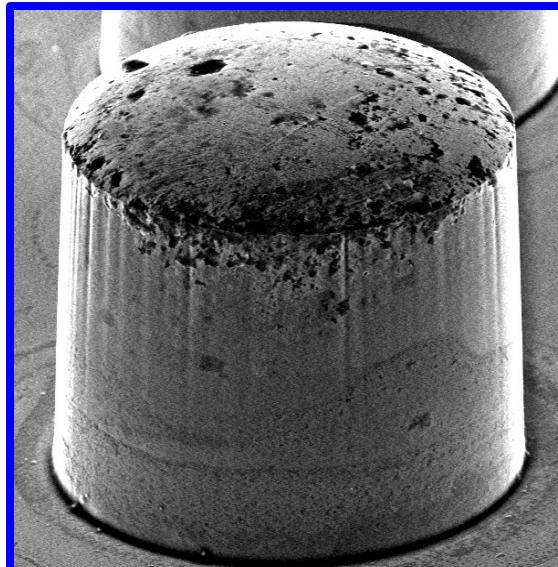


INTERVIA™ 8540 Images		
Current Density / ASD	Optical Image	Profile Dense Pitch
9		
14		
18		

INTERVIA™ 9000 Images		
Current Density / ASD	Optical Image	Profile Dense Pitch
14		
16		
18		

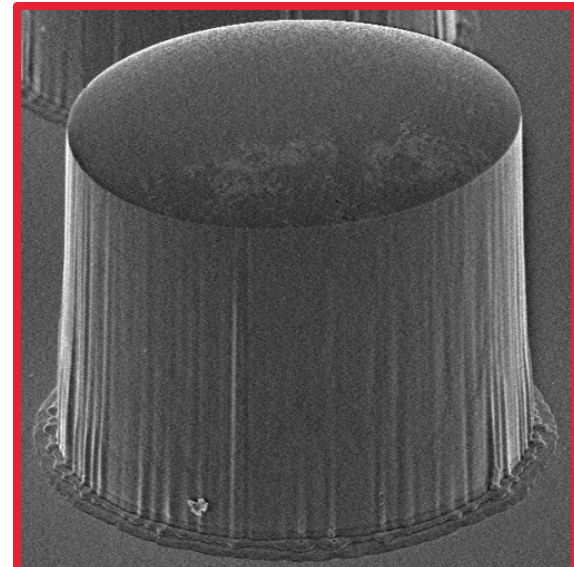
# INTERVIA™ Cu Megapillar Plating – Segment Level

INTERVIA™ 8540 Cu



WID = 3.5%  
TIR > 10.3%

INTERVIA™ 9000 Cu



WID = 4.0%  
TIR = 5.0%

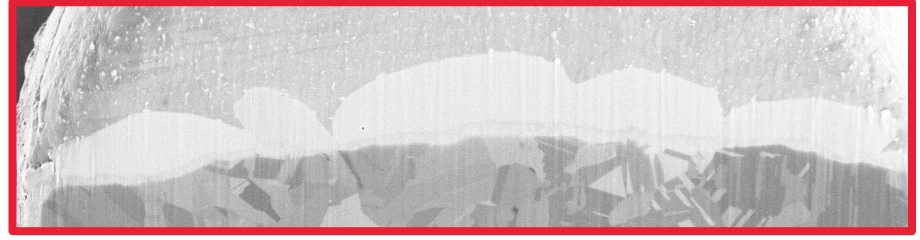
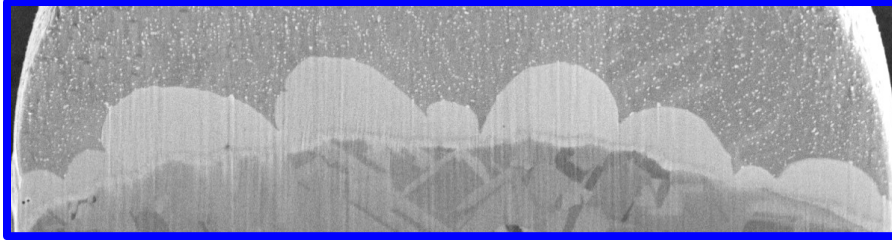
18.5 ASD Avg.  
Plating Rate

# Solder Integration with INTERVIA™ Cu on 20 μm Pillars

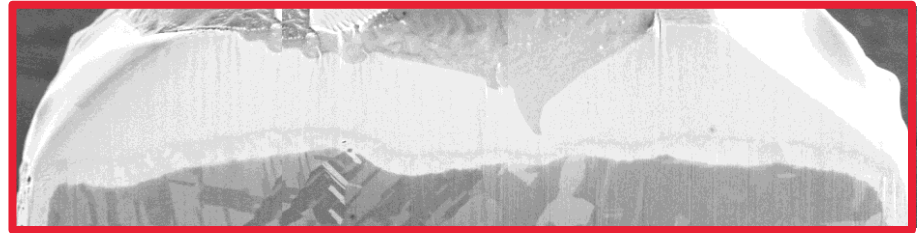
**INTERVIA™ 8540 Cu**

1 Reflow

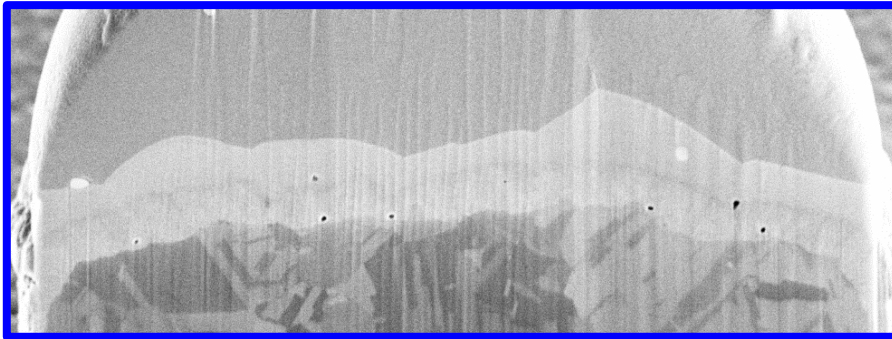
**INTERVIA™ 9000 Cu**



10 Reflows



High Temperature Storage at 150°C for 125 hr.



➤ Minimal voiding at SnAg-Cu interface after multiple reflows and HTS

# INTERVIA™ 9000 Cu Integration with Ni and SnAg

## 20 µm Ø Pillar, 9 ASD, 1x Reflow

Solderon™ BP  
TS 6000 SnAg

Solderon™ BP  
TS 6000 SnAg

NIKAL™ BP Ni

INTERVIA™ 9000

INTERVIA™ 9000

w/o Ni

w/ 2 µm Ni

## 50 µm Ø Pillar, 9 ASD, 1x Reflow

Solderon™ BP  
TS 6000 SnAg

Solderon™ BP  
TS 6000 SnAg

NIKAL™ BP Ni

INTERVIA™ 9000

INTERVIA™ 9000

w/o Ni

w/ 2 µm Ni

- Excellent Compatibility with NIKAL™ BP Nickel and SOLDERON™ BP TS 6000 Tin-Silver in both 20 µm and 50 µm Ø sizes
- Organic doping (C, O, N, S, Cl) of <20 ppm as measured by SIMS

## INTERVIA™ Cu Deposit Summary

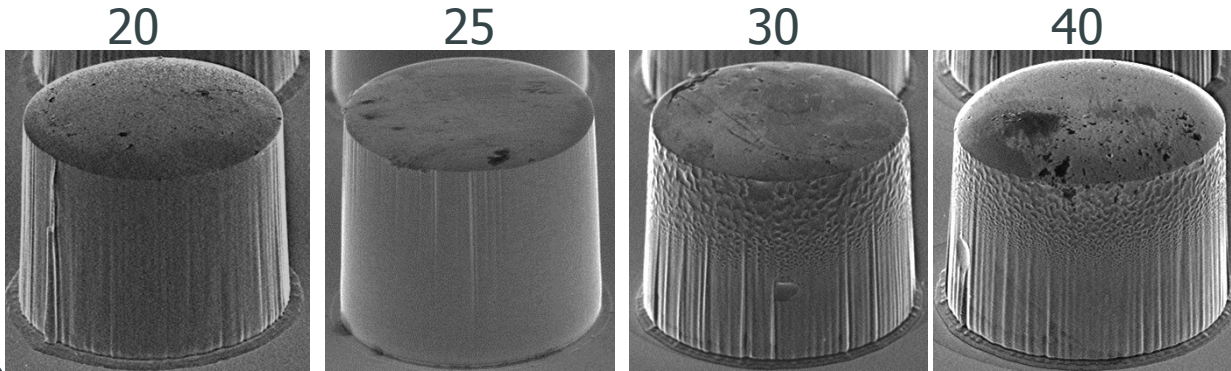
- INTERVIA™ 8540 and 9000 Copper Chemistry deposits have excellent WID uniformity with superior integration with solder materials
- Both plating baths deposit pure Cu across a wide range of applications, including RDL, micropillar, pillar, and megapillars
- INTERVIA™ 9000 Cu deposits are flatter than INTERVIA™ 8540 Cu
- Plating rates of at least 18 ASD ( $4 \mu\text{m min}^{-1}$ ) are achievable with INTERVIA™ 9000 Cu plating baths
- Both chemistries deposit Cu with robust Cu-solder interfaces with minimal interfacial voiding, even after HTS at  $150^\circ\text{C}$

- Next Generation  
Prototype Chemistries  
Segment Level  
Testing**

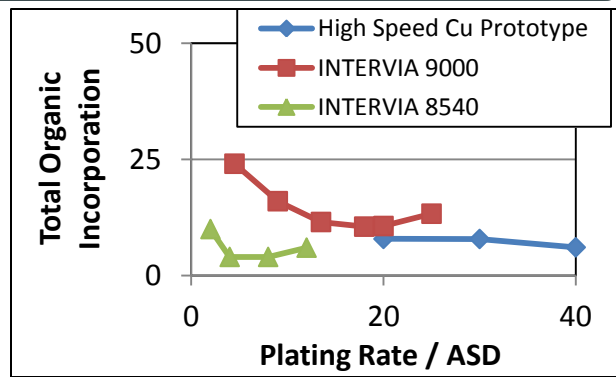
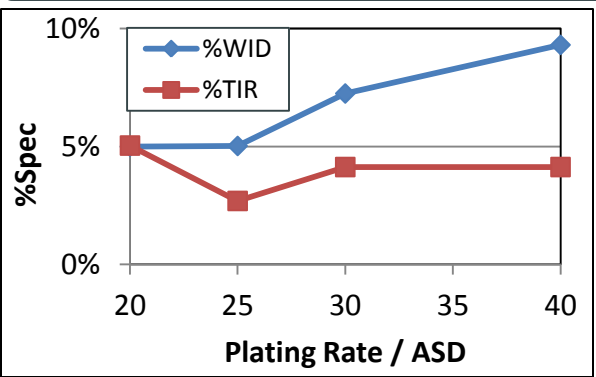
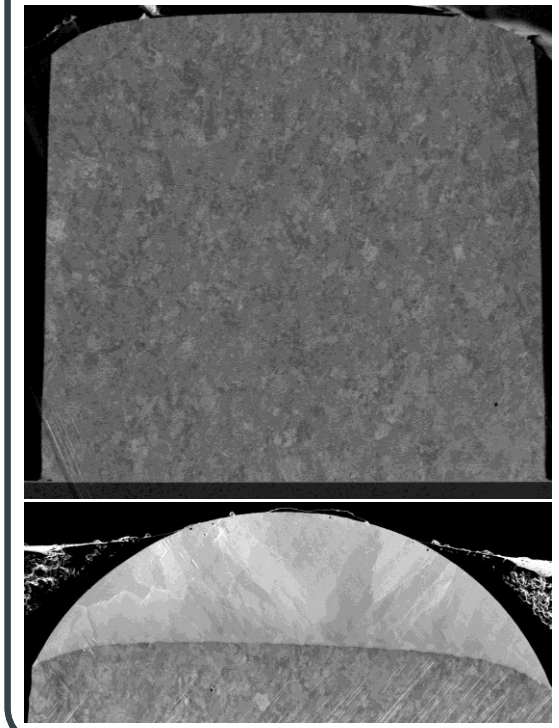


# 200 $\mu\text{m}$ Megapillar Prototype Chemistry 1

## Plating Rate / ASD



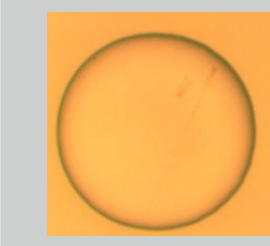
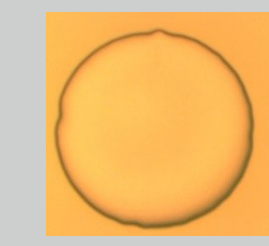
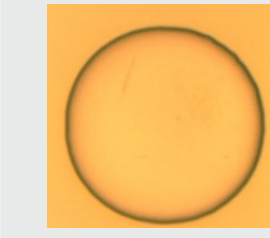
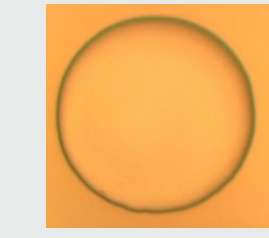
## 40 ASD



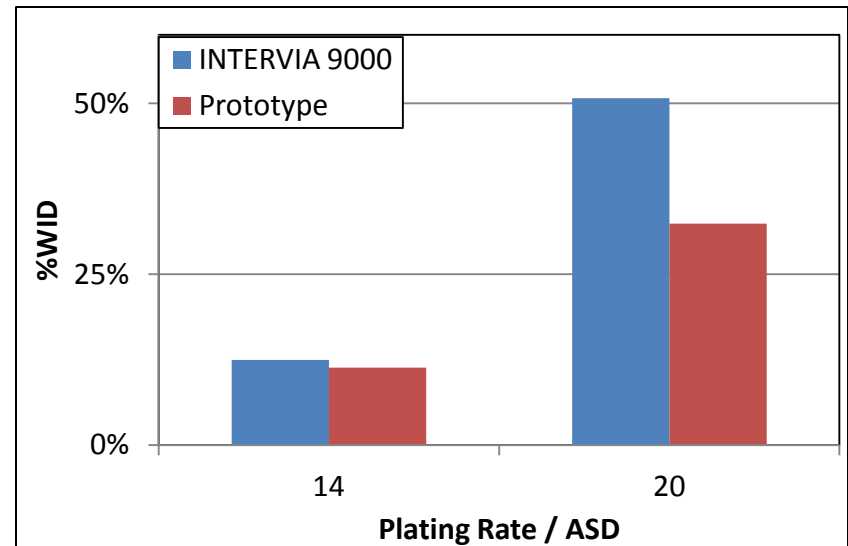
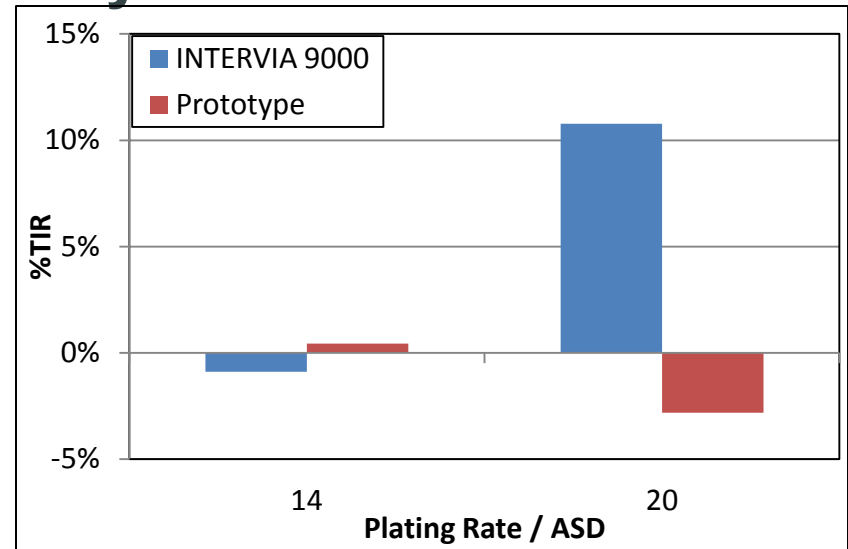
- High purity deposits with both INTERVIA 9000 Cu and new prototype chemistry at plating rates up to 40 ASD
- Uniform grain size without voiding up to 40 ASD

# 50 μm Pillar Prototype Chemistry 2

Optical Images

Plating Rate / ASD	INTERVIA 9000 Cu	Prototype Chemistry
14		
20		

- Similar TIR flat TIR performance in new prototype chemistry to INTERVIA™ 9000 Cu
- Significant improvement in WID at high plating rates with new prototype





**Thank  
You**

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