MACDERMID ENTHONE ADVANCED ELECTRONICS SOLUTIONS

A PLATFORM SPECIALTY PRODUCTS COMPANY

Eric Gongora, Device Packaging 2017

Agenda

- **Who is MacDermid Enthone?**
  - Part of Platform Specialty Products
  - Industry leader in Cu electroplating
  - Offer broad portfolio of wafer level Cu, Ni, Sn, and Au chemistries
- **Comparison between WLCSP and FO-WLP**
- **Advanced FO-WLP designs are introducing a new set of plating interactions and challenges**
  - Design
  - Chemistry
  - Tool
- **What is being done to meet these challenges?**

An introduction to…

PLATFORM SPECIALTY PRODUCTS

We are a global, diversified producer of high technology specialty chemical products and provider of technical services. Our business involves the formulation of a broad range of specialty chemicals created by blending raw materials through multi-step technological processes or formulating active ingredients into final products. These specialty chemicals are sold into multiple industries, including agricultural, electronics, graphic arts, metals and plastics plating, and offshore oil production. We refer to our products as “dynamic chemistries” due to their intricate chemical compositions. Our dynamic chemistries are used in a wide variety of attractive niche markets.

MacDermid Enthone – Advanced Electronic Solutions

MacDermid

- Founded in 1922
- Waterbury, CT

enthone

- Founded in 1930
- West Haven, CT

OMG OM Group

- Founded in 1964
- Cleveland, OH

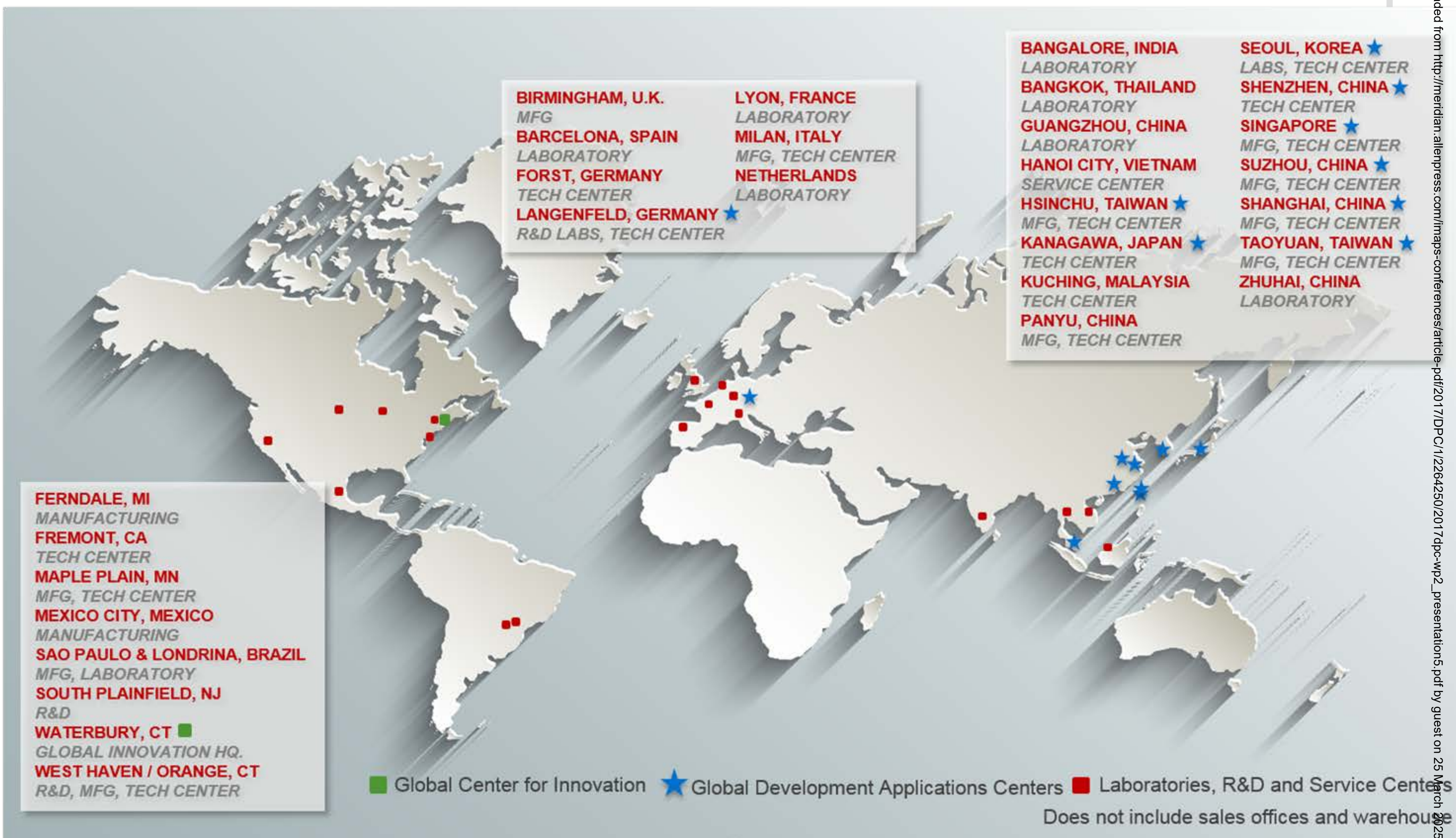
50 — Operations in more than 50 countries

14,000 — Over 14,000 customers served worldwide by direct sales/service

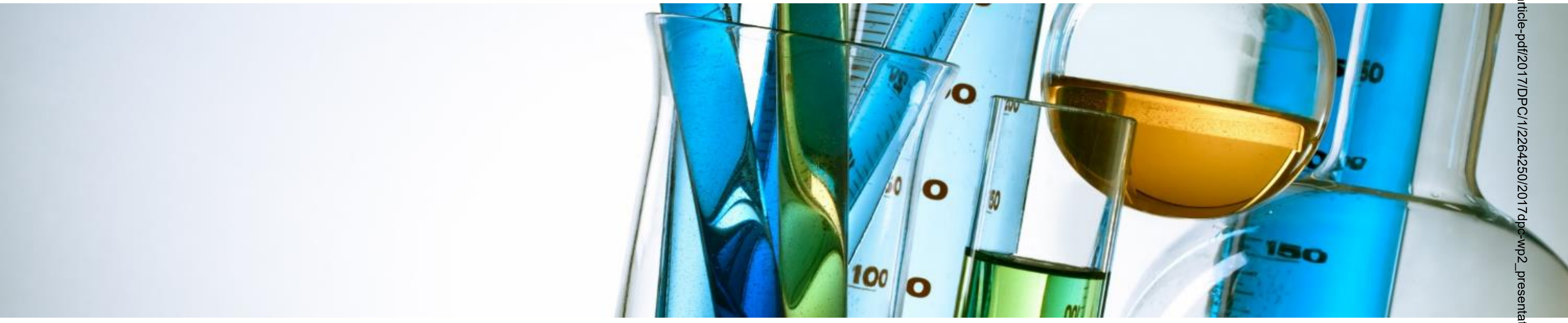
4,500 — Approximately 4,500 employees

A majority of employees in innovation and service roles

Our Global Presence – Innovation and Tech Centers



FO-WLP ELECTROPLATING CHALLENGES



A Platform Specialty Products Company.

Scope Of The Presentation

- **Wafer Level Packages were introduced in the late '90s**
  - Considered the next wave of packaging… all done at wafer level
  - Began with "Fan-In designs" supporting lower I/O densities
  - Transitioned to 2.5D and 3D-TSV configurations
  - Evolved to "Fan-Out designs"

- **Today, we are seeing the rapid adoption of Advanced (High Density) FO-WLP**
  - Advanced wafer nodes are being introduced
  - Applications are driving increased performance
  - Higher levels of integration is required
    - Multi-die and 3D capability
    - Finer feature sizes
    - Mixed Packaging Technologies, System in Package

- **This rapid adoption of Advanced FO-WLP has created an inherent set of design and electroplated feature challenges**

- **This presentation will focus on these growing challenges, how they impact us and what we are doing to address them.**

FO-WLP – Summary of Challenges

- Higher integration requirements driving finer plated features… pushing chemistry and tool capabilities
- Creates significant design variations for similar features across customer base
- As with WLCSP, customers are looking for a single chemistry to support features across all tool platforms
- A given chemistry may not perform equally across tool platforms; All tools are not created equal; there are ranges of capability
- Development cycle times for new chemistries < 6 months

Wafer Based Packaging – Quick Comparison

What are the electroplating differences between "Fan-In" and "Fan-Out"?

WLCSP

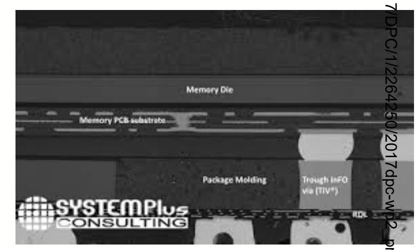
- **WLCSP (Fan-In)**
  - Package size ~7x7 and below (Die Size package)
  - Single Die with lower I/O counts…
  - Single RDL used to connect pads at die periphery to bump locations (directed internally)

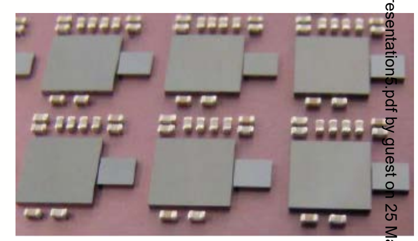
Single Die FO-WLP

Multi-Die FO-WLP

Images courtesy STATSChipPAC

- **FO-WLP (Fan-Out)**
  - Packages typically 7x7 and below, but now pushing to sizes ~ 15x15mm (InFO)
  - No longer a die size package
  - Can support multiple die with higher I/O counts
  - Multiple RDL to connect die to die, die to passives, die to bump pads
  - Utilize a variety of electroplated features (Cu Pillar, RDL, RDL + via fill, etc.)





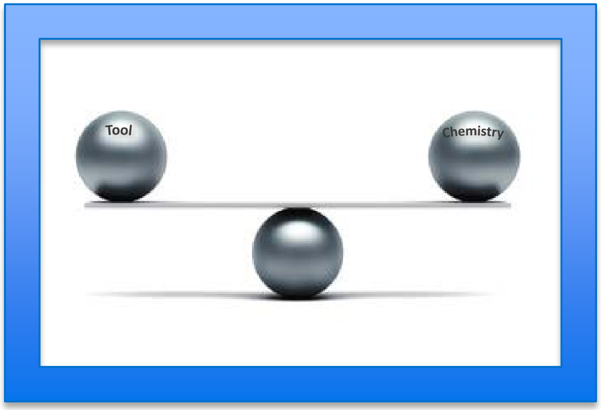
Images courtesy NANIUM

Wafer Based Packaging – A Closer Look

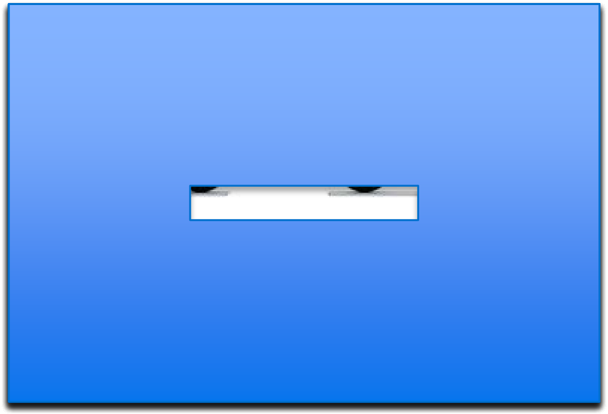
Attribute	WLCSP	FO-WLP	Electroplating Impact/Challenges
Die Size Package	Yes	No	NA
Package Size	7x7 and below	<20x20mm	NA
Package Types	One	eWLB, SWIFT, InFO, M-Series	Listed below
Pad Layout	JEDEC Standard	No Standard	NA
I/O Count	Low (<200)	High	Multiple RDL layers required?
I/O: ISO / Dense	No	Yes	Tighter process window required, bath chemistry to tool relationship is critical
# of Die	1	1 to ?	Multiple RDL layers required?
RDL	Typically single RDL	Up to 4	Dielectric to Cu adhesion challenges, Cu ductility, varying RDL widths
Die: First/Last	NA	Either	RDL Last – Yield is critical
Die: Face Up/Down	NA	Either	Through mold vias required?
Min. RDL Line Width	~10um	~2um	Tighter process window required, bath chemistry to tool relationship is critical
RDL Complexity	Low	High	Tighter process window required, bath chemistry to tool relationship is critical
Plated Features	RDL	RDL, Vias, Pillars	Tighter process window required, bath chemistry to tool relationship is critical; multiple chemistries may be required
Front-End Process	Wafer based equipment	Wafer equipment, moving to panel	Vertical plating required; bath chemistry to tool relationship critical
Higher Levels of Integration Possible	No	Yes	Tighter process window required, bath chemistry to tool relationship is critical

Wafer Based Packaging – Electroplating Comparison

WLCSP



FO-WLP



FO-WLP – Where are the Challenges

- **The FO-WLP electroplating challenges can be grouped into 3 main categories**
  - Design
  - Chemistry
  - Tool Capability

Design

- **Pillars ranging from 70x200um to 200x200um**
- **RDL Line/Space ranging from 2/2 to 10/10**
- **Coplanarity < 10um**
- **WIF <5um**
- **Dense or ISO-Dense**
- **Open area %**

Chemistry

- **Plating rate is never fast enough**
- **POR chemistry is pushed to the limits.. sometimes beyond**
- **Single chemistry used to plate a spectrum of feature sizes. Narrowing the process window**
- **KV free requirement**

Tool Capability

- **Some tools have more knobs to turn which can help widen the process window**
- **Tool mass transport capabilities are not all the same.. This limits current density and plating performance**
- **Tool anode designs are unique**
- **Each tool is not created equal**
- **Horizontal → Vertical plating**

FO-WLP – Closer look at the Design Challenges?

Feature	Cu %	L	A	S	CD	Temp	Agitation	Comments
70 x 200um Pillar	1				3	4	2	Mass transport key for higher CD
200 x 200um Pillar		4			2	3	1	Mass transport key for higher CD
Mixed Pillar Sizes	1				3	4	2	Mass transport; Coplanarity /Throughput tradeoffs
Dense / ISO	4	2			1		3	
Standard RDL	4	1		2	3			Low Cu %, Additives design is key
Advanced RDL	3	2		1	4			Additives design is key; wetting / surface tension
RDL + Via	3	1		4	2			
RDL + Via + Pillar	3	1		4	2			More difficult feature drives (RDL/Via)

Attribute	Cu %	L	A	S	CD	Temp	Agitation	Comments
Flat Bump Shape		1	2	3	4			
Domed Bump		1	2	3	4			
Coplanarity (WIW)	2	4				3	1	Current distribution across wafer and Cu%
WID	2	3			1		4	WIW and WID
KV Free		1			2		3	Mainly driven by Leveler and CD

- Features are primarily a function of the chemistry, the tool, or both
- Advanced pillars are closely tied to tool capability
- Advanced RDL features are closely tied to chemistry capability
- Aggressive attributes are a function of tool and chemistry

FO-WLP – RDL + Via Design Variations

2 in 1	Item	RDL + Via Pad features					
		A	B	C	D	E	F
Generic	Wafer Opening	50%	65%	20-40%	35%	10 - 20%	
Via Pad	PR Thickness	10	7.6	10	7	8 - 10	5
	PI Thickness	5	7	5	8 - 20	5 - 12	7
	PR Opening	TBD	42	TBD	10 - 20	20	55
	PI Opening (Top)	20	22	12	10 - 20	13	50
	PI Opening (Bottom)	15	10	10	10 - 20	10	25
RDL	L/S	NA	2/4	2/2	3/3/ - 15/15	5/5	TBD
	RDL Thickness	NA	3.4	8	7	3 – 7	TBD
Seed Layer	Thickness	TBD	TBD	0.2	0.2 - 0.5	0.3 - 0.5	TBD
	Metal Type	Cu	Cu	Cu	Cu	Ti/Cu	TBD
	Conformal Coverage	Y	Y	Y	Y	TBD	TBD

- RDL + Via designs are not consistent between applications, package design, etc.
- The Open area percentage varies from 10 – 65%
- A single chemistry may not support all of the designs above.
- In addition to the these attributes there are integration challenges… ductility

FO-WLP – Summary of Challenges

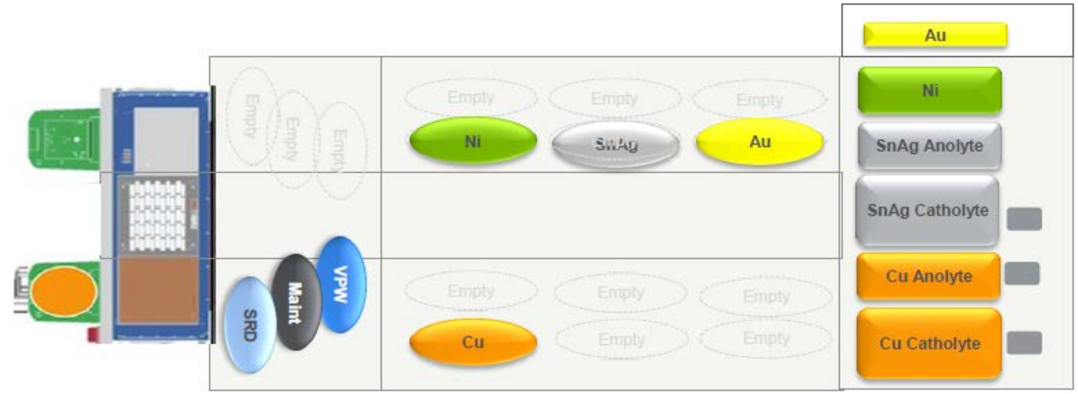
- Higher integration requirements driving finer plated features… pushing chemistry and tool capabilities
- Significant design variations for similar features across customer base
- Customers looking for a single chemistry to support features across all tool platforms
- A given chemistry may not perform equally across tool platforms; All tools are not created equal; there are ranges of capability
- Development cycle times for new chemistries < 6 months

FO-WLP – Overcoming Challenges

- **Standardization of design rules being driven by OEMs**
- **Necessitating collaboration between customer, tool vendor and chemistry supplier**
- **Provide a complete solution (chemistry stacks)**
- **Reduce cycle time to POR solution**
  - **Innovation Labs**
  - **Comprehensive Additive Library**
  - **Minimize iterations**

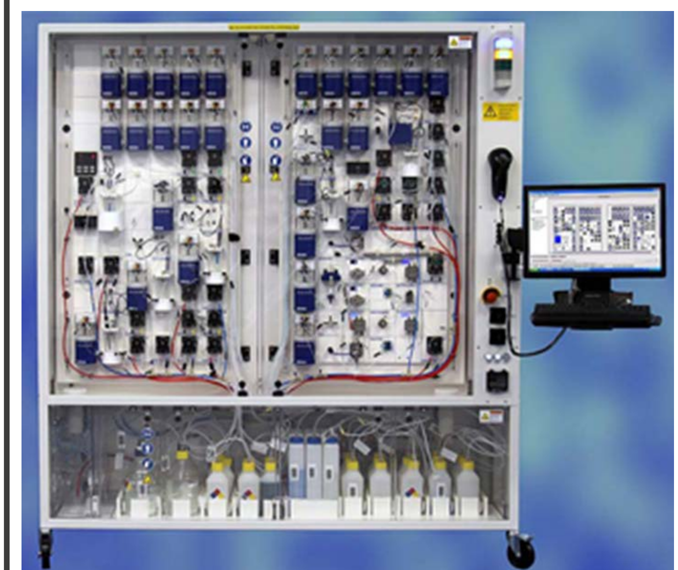
AES Taiwan Innovation Lab (ITRI)

- **Develop products and processes with customers in a customer environment**
  - Leading Edge 300mm process equipment
  - Clean-room environment
  - Advanced in-line Metrology and Process Control
- **Rapid product and process development**
  - Located near Hsinchu Science Park – ITRI
    - Access to ITRI characterization and process equipment
  - Direct Customer access to AES labs and equipment
  - Wet chemistry lab for sample preparation and characterization
  - Commercial and Technical Support Team located within Labs



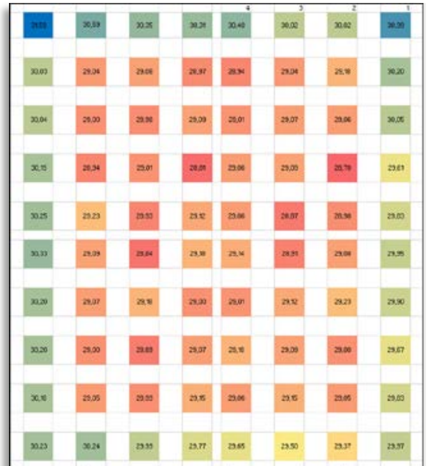
AMAT NOKOTA Plating Tool

SEMI Gear Geneva STP300



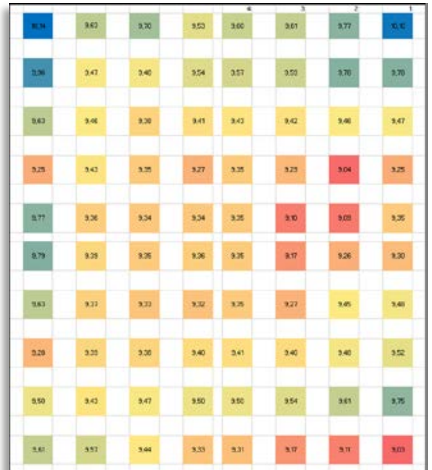
Ancosys Ancolyzer

Panel Plating Feasibility Study



max / µm	min / µm	avg / µm	range/2*avg (%)	1Sigma (%)
31.59	27.78	29.47	4.8	2.0

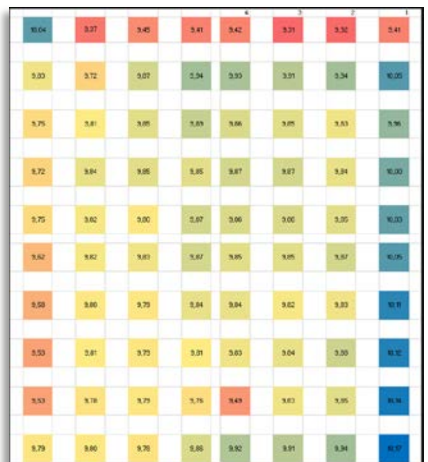
30um Pillar



max / µm	min / µm	avg / µm	range/2*avg (%)	1Sigma (%)
10.14	9.04	9.45	5.9	2.2

10um Pillar

SEMSYSCO



max / µm	min / µm	avg / µm	range/2*avg (%)	1Sigma (%)
10.17	9.31	9.81	4.4	1.8

10um RDL