O.C. Chapter of the IPC Designers Council, Inc.

presents:

"Eliminating the WAG in Final Finish Selection"

Kathleen S. Palumbo, CEO & Founder

Member Of:

Types of Final Finishes

Types of Final Finishes

- HASL
- Silver Immersion (directly over Copper)
- Gold Immersion (over Electroless Nickel)
- Tin Immersion
- OSP (Organic Solderability)
- Bare Copper
- PPT (Precision Pad Technology or SIPAD)

Final Finishes Overview

HASL Surface Finish Overview

- HASL=HOT AIR SOLDER LEVEL(directly over Copper)
  - ✓ Fabrication Design Note
    - ❖ Copper Lands/Pads Are to Be Coated With a Solder Composition of Sn60, or Sn63 of ANSI/J-STD-004 & ANSI/J-STD-006. PCB Must Pass ANSI/J-STD-003 Solderability Test C Category 2 by an Independent Lab. Certificate of Conformance and Passing Lab Report Shall Be Provided Prior to Lot Acceptance.

Silver Immersion Surface Finish Overview

- Silver Immersion (directly over Copper)
  - ✓ Fabrication Design Note
    - ❖ Copper Lands/Pads Are to Be Over-plated With 4 to 10 Micro Inches of Silver Using the Alpha Level Process or MacDermid Sterling Silver Process

Gold Immersion Surface Finish Overview

- Gold Immersion (over Electroless Nickel)
  - ✓ Fabrication Design Note
    - ❖ Copper Lands/Pads Are to Be Overplated With a Minimum of 150 Micro Inches of Low Stress Nickel Followed With 5 to 7 Micro Inches of Flash Gold

Tin Immersion Surface Finish Overview

- Tin Immersion (directly over Copper)
  - Fabrication Design Note
    - Copper Lands/Pads Are to Be Over-plated With .7 to 1 Micrometers (Microns) of Immersion Tin.

OSP Surface Finish Overview

- OSP=Organic Solderability Preservative (directly over Copper)
  - Fabrication Design Note
    - Copper Lands/Pads Are to Be Over-coated With a Uniform Coating of OSP.

Bare Copper Surface Finish Overview

- Bare Copper
  - ✓ Cleaned Prior to Packaging and Shipment
  - ✓ Cost Effective
  - ✓ Solderability Is Good for at Least 3 Days
    - ❖ More If Proper Environmental and Handling Controls Are in Place
  - ✓ Limited Thermal Cycles
  - ✓ Excellent Solderability
  - ✓ Fabrication Design Note
    - ❖ Copper Lands/pads Are to Be Clean Bare Copper.

PPT Surface Finish Overview

- PPT (Precision Pad Technology or SIPAD)
  - ✓ Patented Solid Solder Deposit Process
  - ✓ Coating Over HASL, Immersion Gold, Immersion Silver, Immersion Tin, OSP, or Just Plain Copper
  - ✓ Surface Is Flat With a "*Mesh*" Impression
  - ✓ CCA Does Gross Print With Tacky Flux
  - ✓ Capable of Handling Multiple Thermal Cycles

PPT Surface Finish Overview

- PPT (Precision Pad Technology or SIPAD)
  - ✓ Fabrication Design Note
    - ❖ Copper Lands/pads Are to Be Coated With a Solder Composition of Sn63 Using the Patented Precision Pad Technology or SIPAD Process. Solder Quantity Shall Allow for the Formation of Acceptable Solder Fillets Per IPC-A-610 CCA Requirements.

Final Finishes
From A CCA Point of View

THINGS TO CONSIDER – CCA View
Internal Needs

- **Internal Needs**
  - ✓ Must Maintain Pristine Signal Integrity
    - ❖ Especially True When Dealing With Assemblies That Run at Very High Frequencies…mostly Above 3 GHz
      - Despite the Mass of the Trace Lines, the Electrical Signals Run Along the Outer Perimeter of the Traces
      - This Phenomenon Is Referred to As the "Skin Effect”

THINGS TO CONSIDER – CCA View Internal Needs Continued

- Finishes That Rely on Electroless Nickel (ENIG, Ni-PD-AU) Do Not Perform Well on Boards That Run Speeds in Excess of 5 Ghz
  - Due to Nickel Plate Remaining on Copper Traces
  - Due to the “Skin Effect”
  - Slows the Signal Because Copper Is a Much Better Conductor

THINGS TO CONSIDER – CCA View Internal Needs Continued

- ✓ High Joint Strength
- ✓ Assist in Controlling Electromagnetic Interference
- ✓ Low Contact Resistance for Life of Product (Some Systems)
  - ❖ Touch Pads (Such As Keyboards)
  - ❖ Plated Edge Rails (Make Electrical Contact With the System's Chassis)
- ✓ Wire Bonding May Also Be a Requirement

THINGS TO CONSIDER – CCA View External Needs

- **External Needs**
  - #1 Need Is Wetting & Solderability
    - Wettability Is an Indication of the Solderability
      - Solderability Must Result in High Joint Strength
    - Cost, Cost, Cost!
      - Not Just Economical, but Reliable As Well
      - Remember the Hidden Cost of Yield Loss

THINGS TO CONSIDER – CCA View External Needs Continued

- Inspectable & Testable
- Prevents Bridging and Misprints
- Shelf Life
  - Short Shelf Life Leads to Reduced Solderability and an Increase in Replacement Costs
- Reworkable (Saves Expensive Re-makes)
- Maintains All of Its Properties for the Life of the Product

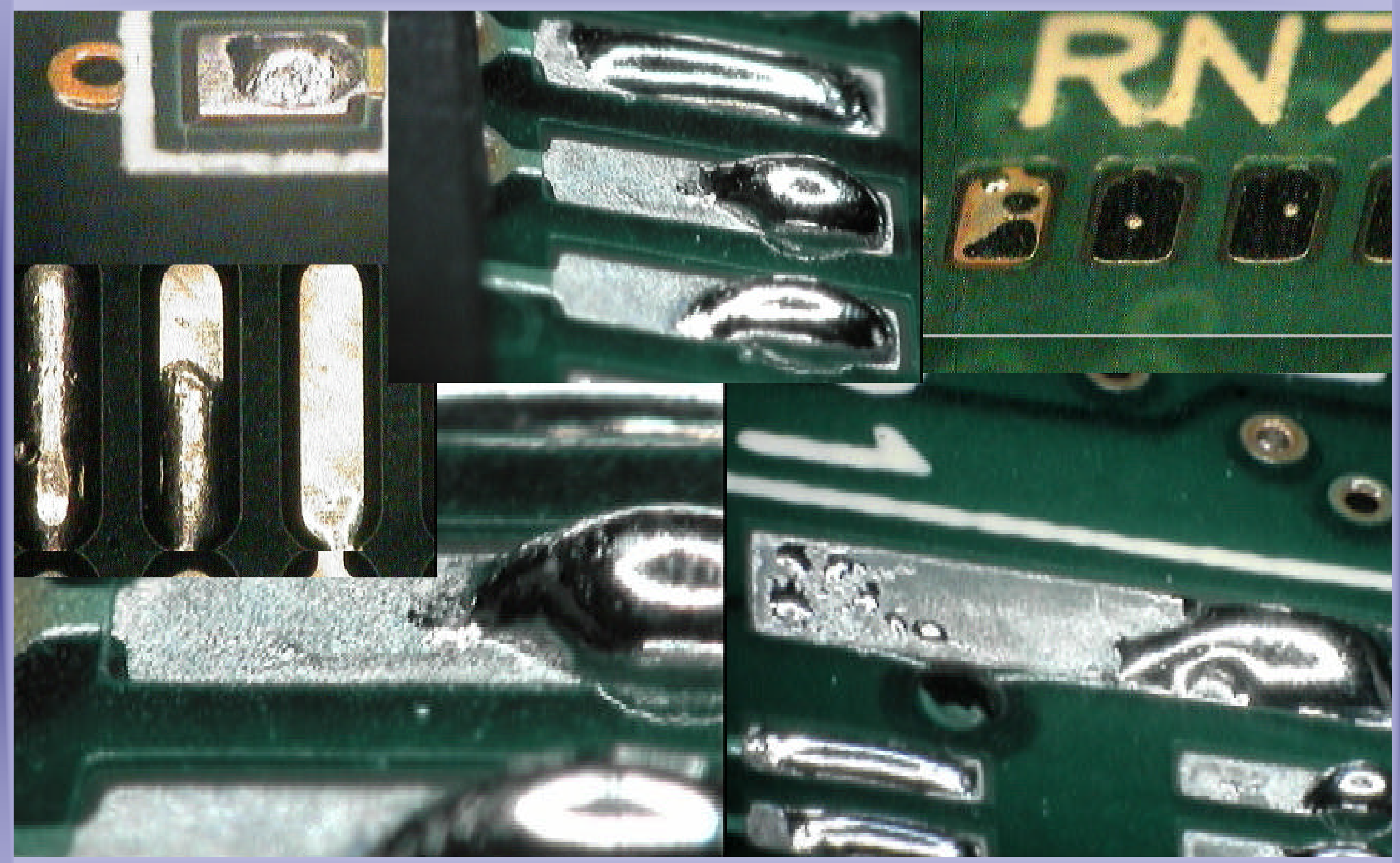
THINGS TO CONSIDER – CCA View External Needs Continued

- ✓ **The Big Question…**
  - ❖ **Is There One Surface Finish That Can Fulfill All of My Needs?**
    - The Closest Is ***Silver Immersion***
    - Not Well Suited for Back Panel Applications

HASL Surface Finish – CCA View

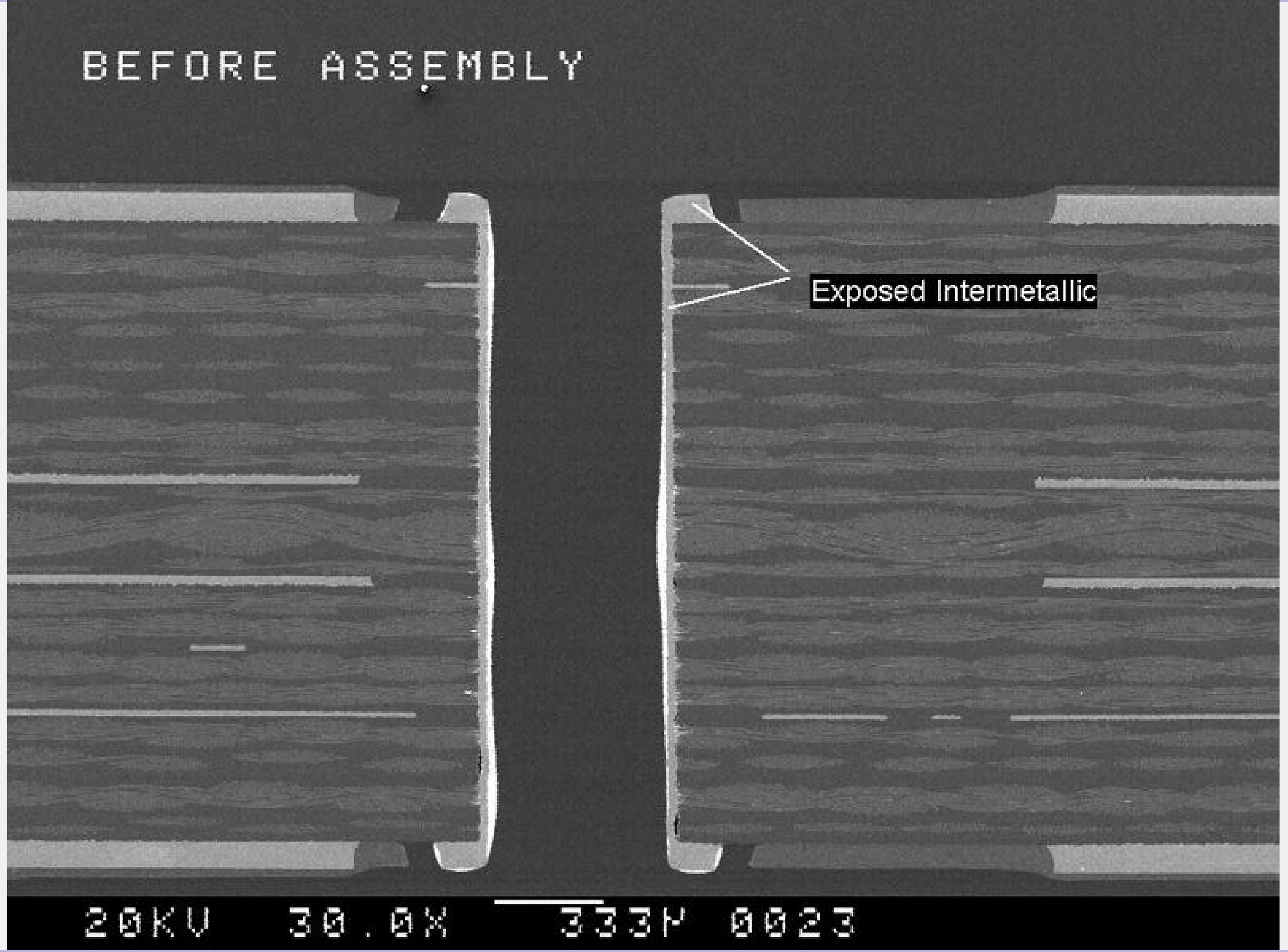
- HASL
  - ✓ Many Board Houses Sub-out Their HASL Process
  - ✓ Many HASL Shops Lack Process Controls
    - ❖ If It Didn't Solder the First Time (Probably Due to Dirty Copper) They Send It Back Through
    - ❖ Each Thermal Excursion Affects PCB MTBF Rate
    - ❖ HASL Shops Do Not Properly Maintain Solder Bath
      - ▪ Copper Level Is Too High, Which Causes Dewetting
      - ▪ Dewetting? No Turning Back…it Can't Be Fixed!
  - ✓ HASL Hides "*Real*" Issues
    - ❖ Solderability Testing Absolute Must!
  - ✓ Lead Free – Maybe…if HASL Solder Bath Is Lead Free

Reasons For…



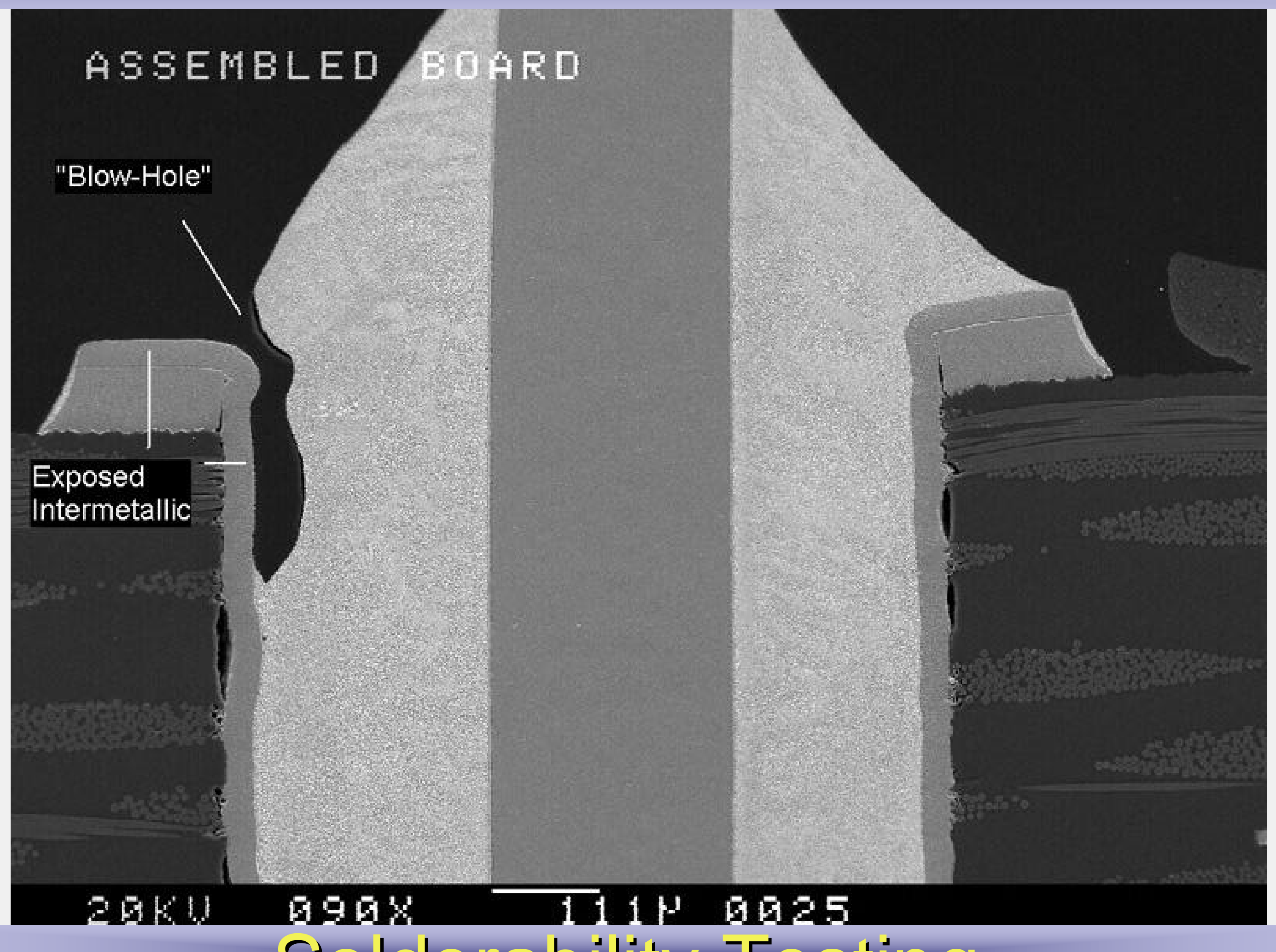
Solderability Testing

Reasons For…



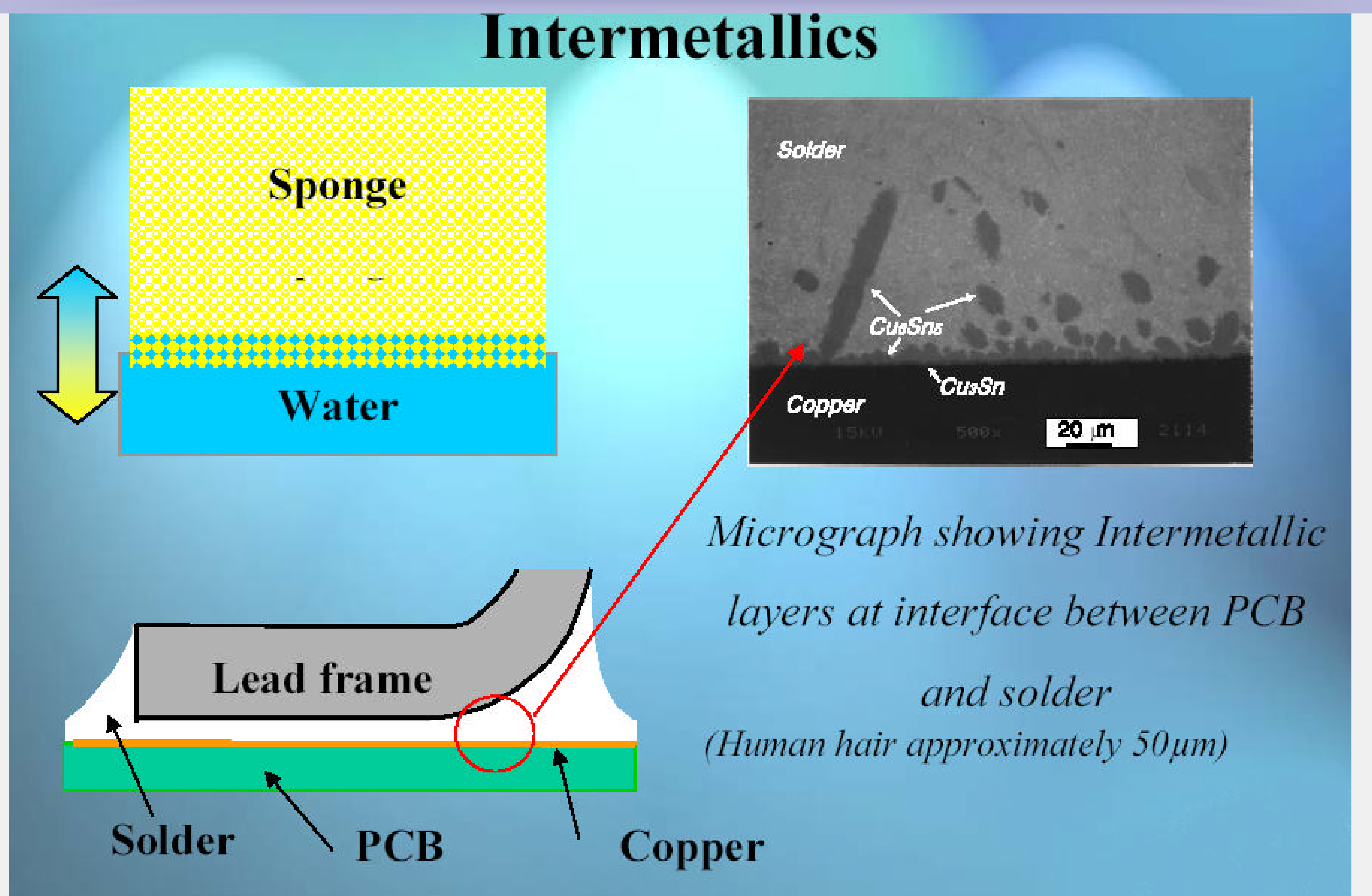
Solderability Testing

Reasons For…



Solderability Testing

Reasons For…



Solderability Testing

Intermetallic Impact on Solder Joint Reliability

- Intermetallics are present in SnPb joints.
- Intermetallics continually grow at ambient temperatures and rapidly at higher temp.
- Initial Intermetallic thickness is directly linked to soldering temperatures.
- Lead-Free processes will operate higher soldering temperatures.
- Hence thicker Intermetallic layer with lead-free soldering.

Silver Surface Finish – CCA View

- Silver Immersion
  - ✓ Silver Molecular Structure Related to Solder
  - ✓ Silver Amalgamates Into the Solder
  - ✓ Surface Is FLAT, FLAT, FLAT!
  - ✓ Great Shelf Life
  - ✓ Neutral PH Bath at Low Temperatures
  - ✓ Silver Migration…no!
    - ❖ Never Proven - Silver Is Too Thin of Coating
  - ✓ Silver Won't Stick to Dirty Copper
  - ✓ Great Contrast…allows Naked Eye Detection
  - ✓ Silver Finish Is Actually REWORKABLE
    - ❖ Silver Can Be Removed, Copper Cleaned, and Recoated
  - ✓ Lead Free - YES

Silver Surface Finish – CCA View

- Silver Won't Stick to Dirty Copper
  - ✓ Great Contrast Allows Naked Eye Detection
- Silver Finish Is Actually REWORKABLE
  - ✓ Silver Can Be Removed, Copper Cleaned, and Recoated

Silver Surface Finish – CCA View

- **WHAT EVERYONE SHOULD KNOW ABOUT SILVER IMMERSION…**
  - ✓ Millions in the Field & No Reported Defects
  - ✓ Co-deposition of an Organic Compound Reduces Electromigration and Tarnishing
  - ✓ Most Tested Surface Finish on the Market Today
  - ✓ Minor Tarnishing From Improper Drying or Storage Will Not Degrade Functionality of the Deposit (Signal Integrity and EMI Leakage)
  - ✓ Inexpensive
  - ✓ Safe

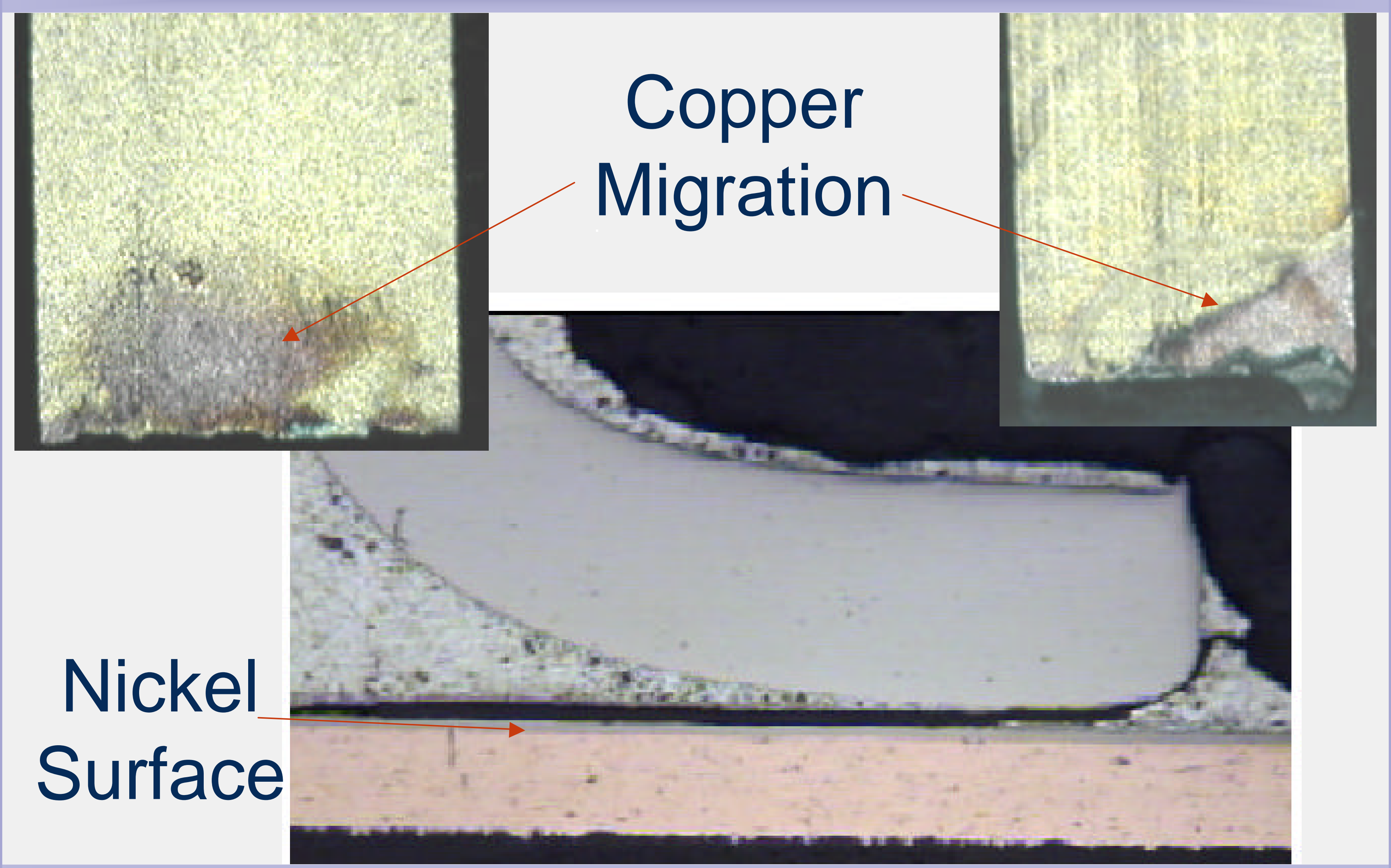
Silver Surface Finish – CCA View

- ✓ Co-planar
- ✓ Best for High Speed Signals and RF Boards
- ✓ Easy to Process
- ✓ Less Polluting
- ✓ Has a Long Shelf Life
- ✓ Can Be Stripped and Re-applied
- ✓ Doesn't Affect the Final Hole Size
- ✓ Incurs No Added Thermal Excursions to the PCB
- ✓ Is a Drop-in Process for the Assemblers
- ✓ Can Be Reworked Multiple Times by Fabricator and Assembler
- ✓ Excessive Tarnish Is Easily Detected

Gold Surface Finish – CCA View

- Immersion Gold over Electroless-Nickel
  - ✓ Can't Get Silver…then It Will Have to Do
  - ✓ Gold Is Porous and Does Not Seal Nickel Well
    - ❖ Nickel Will Oxidize Over Time
    - ❖ Becomes Impervious to Solder
    - ❖ Typical Max Shelf Life = 3 Months
  - ✓ Sensitive to Handling
  - ✓ Nickel Plating Bath Is High Ph/high Temp…
    - ❖ Another Thermal Cycle…affects MTBF of PCB
    - ❖ Major Issues With Black Pad
  - ✓ Requires a HOTTER Oven Profile During CCA Reflow Process
  - ✓ Lead Free - YES

Gold Surface Finish

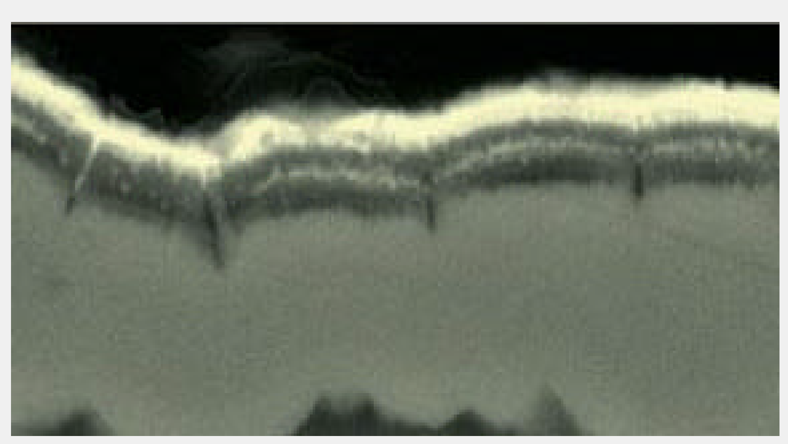


The Type of Failures to Expect

Gold Surface Finish

- Early 1990s ENIG Was Almost Qualified As a Universal Finish
- Rise of "Black Pad" Dashed Those Hopes
- Defect Has Not Been Solved

Examples of Black Pad

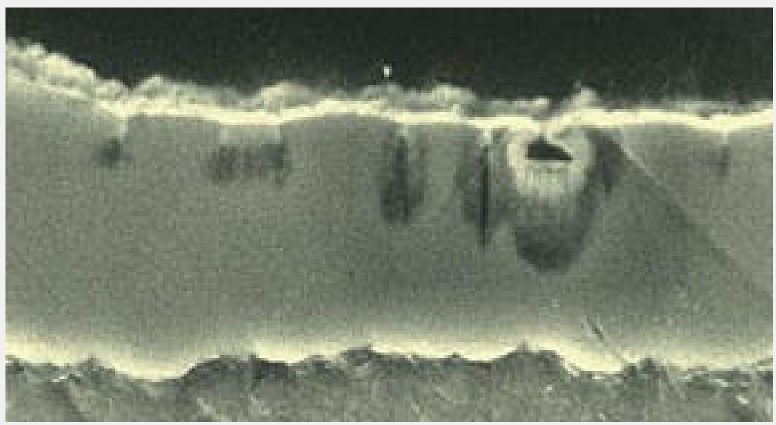


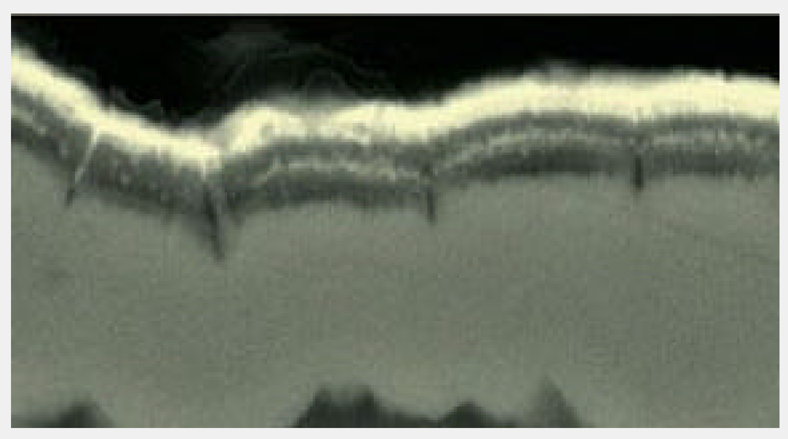
The Type of Failures to Expect

Gold Surface Finish

- Every ENIG Process on the Market Is Prone to This Defect
- Tight Process Controls & Proper Service From Vendor Can Limit Its Formation

Examples of Black Pad



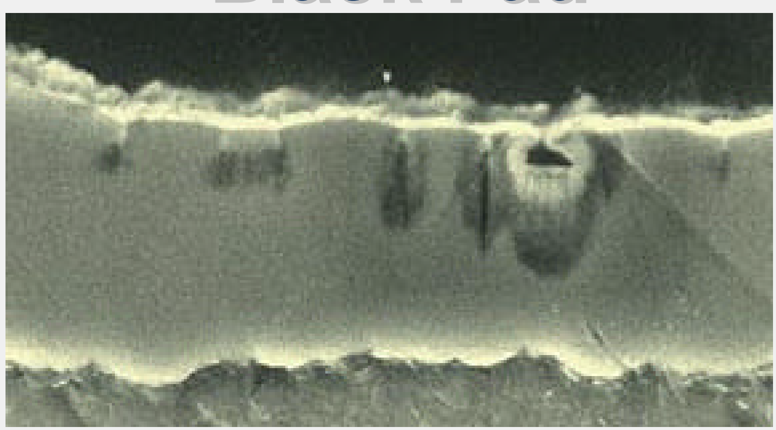


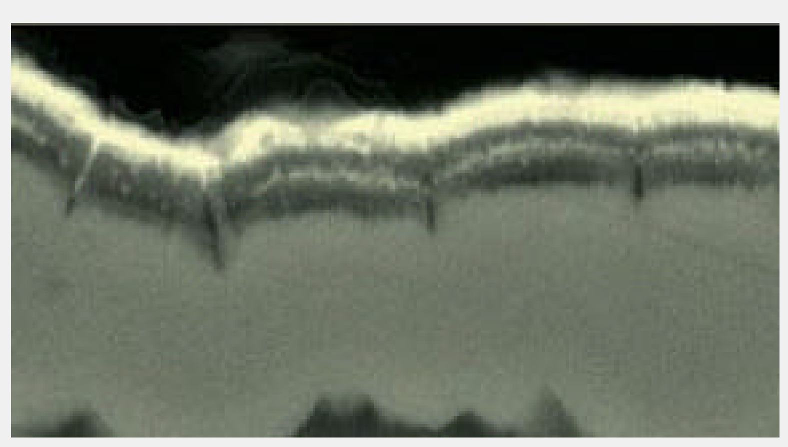
The Type of Failures to Expect

Gold Surface Finish

- Fine Pitch Boards More Prone to Black Pad
  - ✓ Reduced Spacing Cause PCB Feature to Exhibit a "Galvanic" Effect
  - ✓ Essential for Formation of a Hyper-corrosive Nickel Species, AKA: Black Pad

Examples of Black Pad



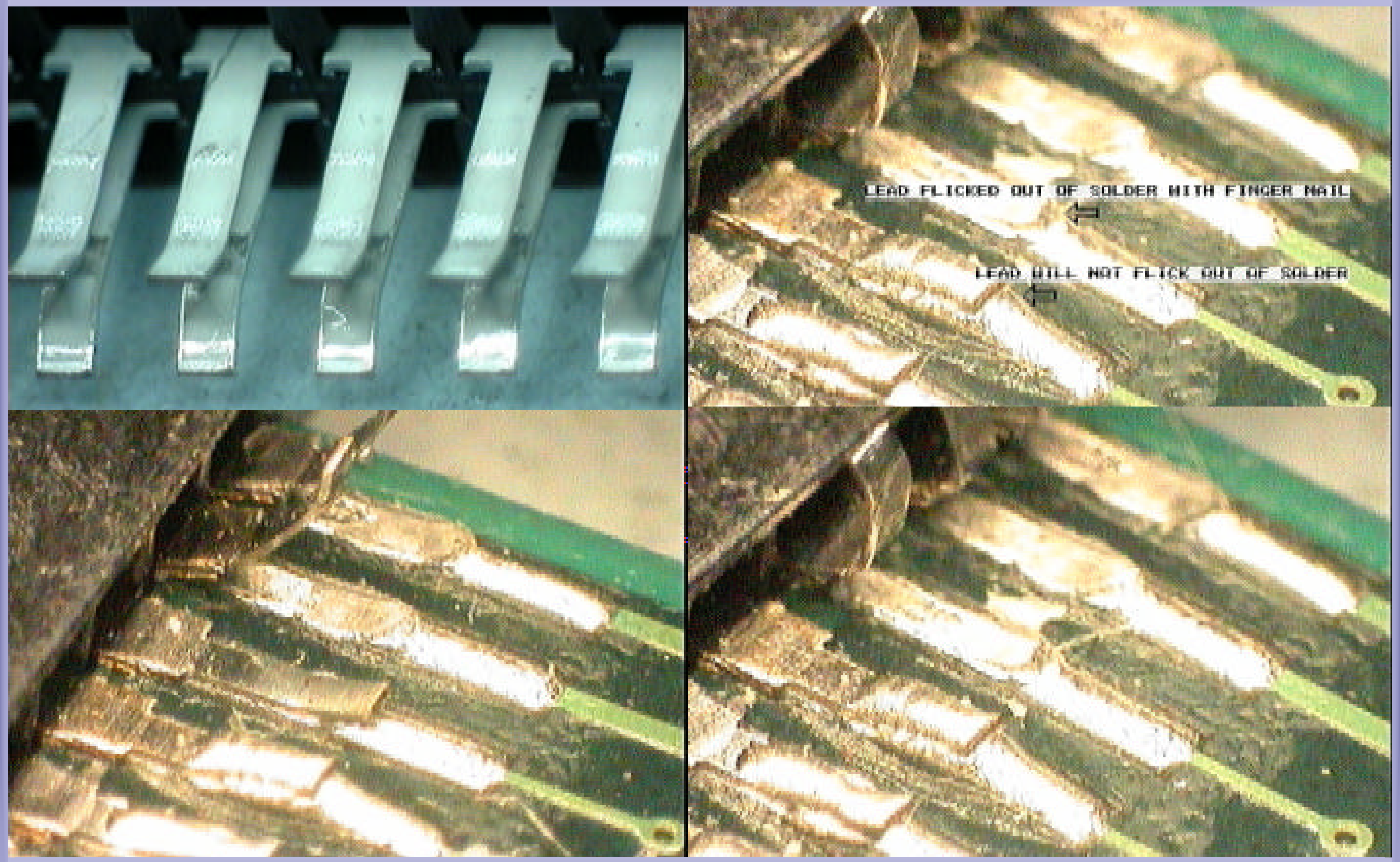


The Type of Failures to Expect

Tin Surface Finish – CCA View

- Tin immersion
  - Soldering issues are more prevalent
  - Multiple handling issues
  - Poor shelf life
  - Oxidizes easily
  - Soldering process requires two things
    - Lots and lots of highly active flux
      - Typical activator is fluoride or chloride
        - Both are extremely corrosive
    - Lots and lots of heat
  - Hazardous waste generated by bath is costly
  - Lead free - yes

Reasons Most CCA's Tend To Avoid



Tin Surface Finish

Reasons Most CCA's Tend To Avoid

Whisker Growth Examples

Sn plating (on nickel) chip resister (0805)

Zero cyc. No whiskers

100 cyc. 10.2 µm

500 cyc. 13.5 µm

1000 cyc 8.2 µm

1. Whisker growth was confirmed with both SnPb & Sn after TCY –55 / +125 °C*
2. No whiskers were confirmed after high temp high humidity test 60 °C @85%RH

* 70 minutes @ 55 °C - 30 minutes @ '125 °C

Tin Surface Finish

OSP Surface Finish – CCA View

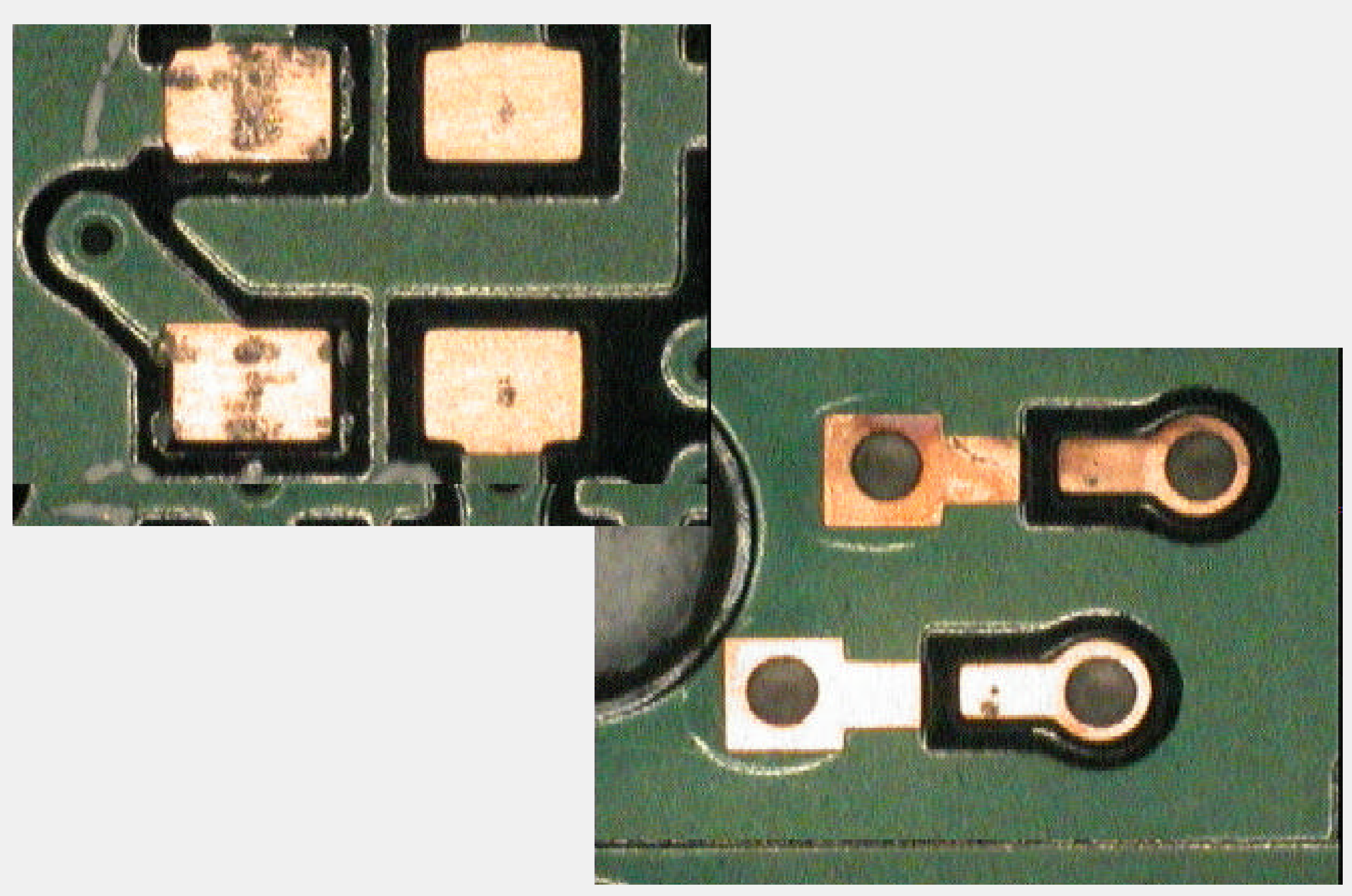
- OSP
  - Proper Thickness…no Problem…otherwise Forget It…
    - Be Prepared for Soldering Issues
  - Major Handling Issues
    - No Finger Cots or Gloves…then OSP Is Not for You
  - Major Storage Issues

OSP Surface Finish – CCA View

- No Environmental Controls…then OSP Is Not for You
  - Storage of Raw Materials Is by the Back Door With the Wind Blowing Through
- Typical Shelf Life With Good Controls Is 3 Months or Less

✓ Lead Free – Yes, the Coating Is; However Evidence Has Shown That OSP's Can Not Withstand the Elevated Temperatures Needed for Lead Free Soldering…so, NO…

OSP Surface Finish – CCA View



Bare Copper Surface Finish – CCA View

- Copper - Just Bare Copper
  - ✓ A Clean Copper Surface Can Remain Solderable for up to 3 Days
    - ❖ Copper Will Only Oxidize So Far, and Then It Will Stop
  - ✓ Great Approach to Consider for Proto-type Builds

PPT Surface Finish – CCA View

- PPT or SIPAD
  - ✓ Extremely Flat Solder Coating With “*Mesh*” Impression
  - ✓ CCA Does Gross Print With Tacky Flux
    - ❖ Phenomenally Better End Results
    - ❖ 100% Yields Every Single Time
    - ❖ PPT Passed HALT & HASS Testing
      - Pad & Laminate Tore While Solder Joint Remained in Tact
- Ideal For:
  - ❖ Parts With a Pitch of .015” (.381mm) or Less

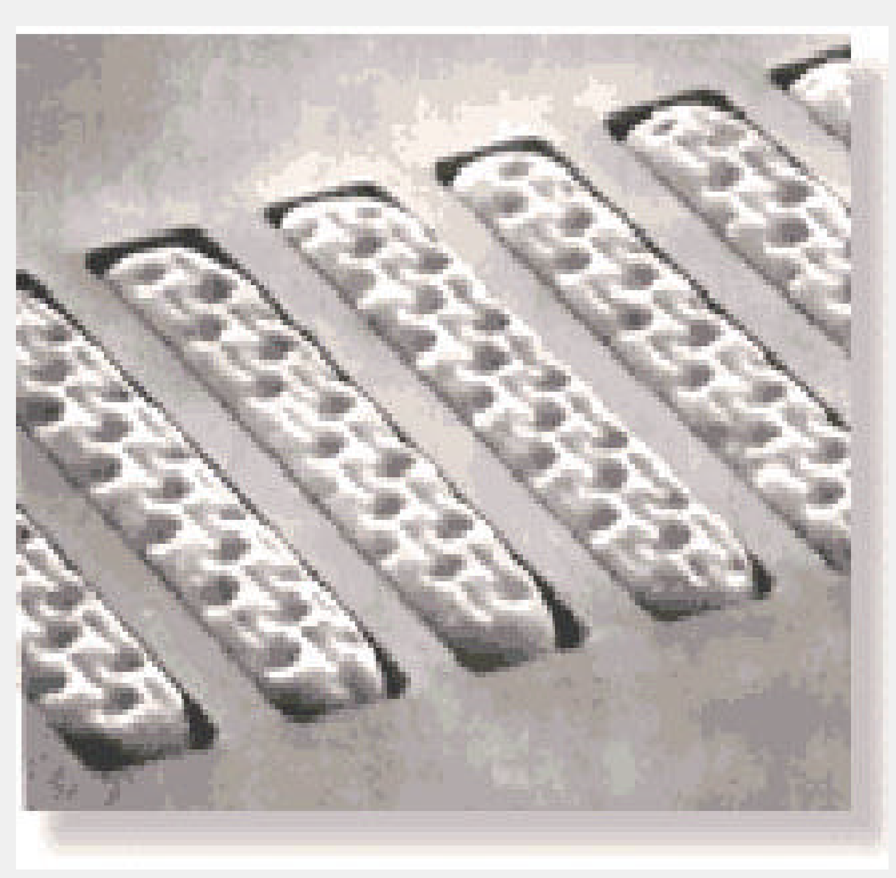
PPT Surface Finish – CCA View

- ❖ uBGA's With Solder Spheres .015" (.381mm) or Less
- ❖ 0201 Devices

✓ Cost:

- ❖ 5-cents/sq. Inch for Single-sided PCB
- ❖ 10-cents/sq. Inch for Double-sided PCB
- ❖ Potential Cost Center for a PCB House
  - Typical Charge for HASL = 1 Cent/sq. Inch
  - Catch 22 - If You Don't Ask, They Don't Offer! So Ask!

PPT Surface Finish – CCA View



FINAL FINISH PRO'S & CON'S GUIDE

Category	SnPb	Ag	Au	Sn	OSP	Cu	PPT
Applied Directly Over Bare Copper	Y	Y	N	Y	Y	N/A	Y
Good Application Controls	N	Y	N	Y	N	N/A	Y
Low Maintenance / User Friendly	N	Y	N	Y	N	N/A	Y
Either Vertical or Horizontal	Y	Y	Y	Y	Y	N/A	N/A
No Additional Thermal Stresses	N	Y	N	Y	Y	N/A	Y

FINAL FINISH PRO'S & CON'S GUIDE

Category	SnPb	Ag	Au	Sn	OSP	Cu	PPT
Coating Thickness Controllable	N	Y	Y	Y	N	N/A	Y
Stable Chemistry	N	Y	N	Y	N	N/A	N/A
Finish is Reworkable	N	Y	N	Y	N	Y	Y
Same or Less Cost (vs. HASL)	N/A	Y	Y	Y	Y	Y	N
Readily Available	Y	Y	Y	Y	Y	Y	N

FINAL FINISH PRO'S & CON'S GUIDE

Category	SnPb	Ag	Au	Sn	OSP	Cu	PPT
Flat/ Planar Surface	N	Y	Y	Y	Y	Y	Y
Storage Life (G=Good, F=Fair, P=Poor)	F	G	F	P	P	P	G
No Finger Cots Required	Y	Y	Y	N	N	N	Y
Multiple Reflow Compatible	Y	Y	Y	N	N	Y	Y

FINAL FINISH PRO'S & CON'S GUIDE

Category	Sn Pb	Ag	Au	Sn	OSP	Cu	PPT
LF Compatible	N	Y	Y	Y	N	Y	Y
Wire Bond Capable	N	Y	Y	N	N	N	N
Touch Pad Functionality	N	Y	Y	N	N	N	N

PCB Fab House & Final Finish Technology Guide

Category	Level I	Level II	Level III	Level IV
Board Thickness	=.054	=.034	=.025	=.020
Part Pin Pitch	=.050	=.025	=.025	=.025
Surface Finish	HASL LF = Ag/Au	HASL LF = Ag/Au	LF = Ag/Au	LF = Ag/Au /LF PPT
Line Width	=.010	=.008	=.004	=.003
Line Spacing	=.010	.008	.004	=.004

PCB Fab House & Final Finish Technology Guide

Category	Level I	Level II	Level III	Level IV
Impedance	None	= 50O	= 28O	= 28O
Smallest Hole Size	=.030	=.010	=.010	=.010
Layer to Layer Precision	=.005	.004	.003	.002
Solder Mask Material	LPI	LPI	LPI	LPI
Buried Via's	NO	NO	NO	Yes

PCB Fab House & Final Finish Technology Guide

Category	Level I	Level II	Level III	Level IV
Blind Via's	NO	NO	NO	Yes
Via any Layer	NO	NO	NO	Yes
Copper Weight (oz.)	1	1	1/2	=3/8
Minimum Core Thickness	.008	.006	.0025	=.0025

PCB Fab House & Final Finish Technology Guide

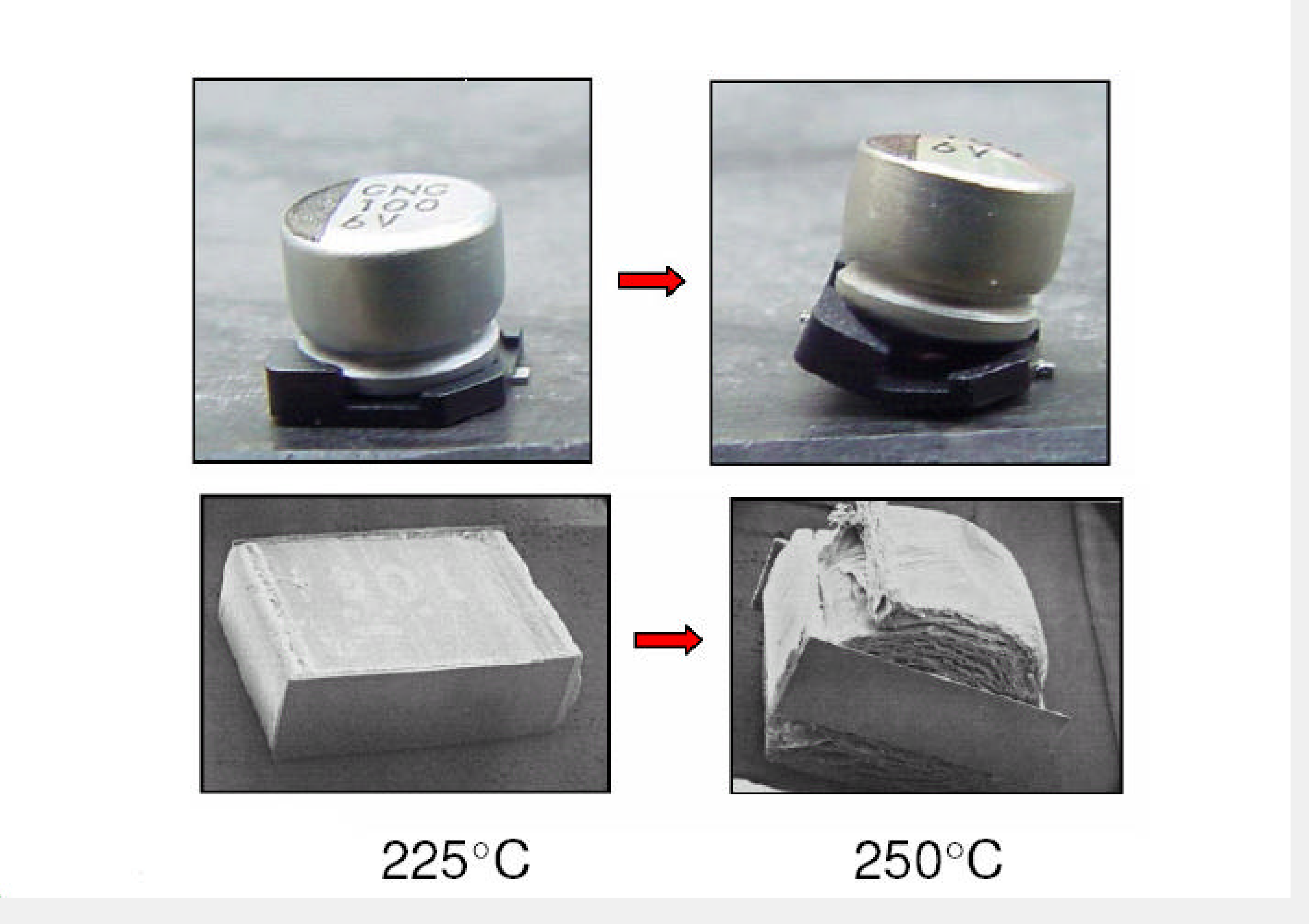
Category	Level I	Level II	Level III	Level IV
Edge Contact Plating	Sn	Au/Tin	Au	TBD
Plating Technique	Panel	Panel	Pattern	Pattern
Imbedded Resistors	No	No	No	Yes
Imbedded Capacitors	No	No	No	Yes
HDI (Micro-Via's)	No	No	No	Yes

PCB Fab House & Final Finish Technology Guide

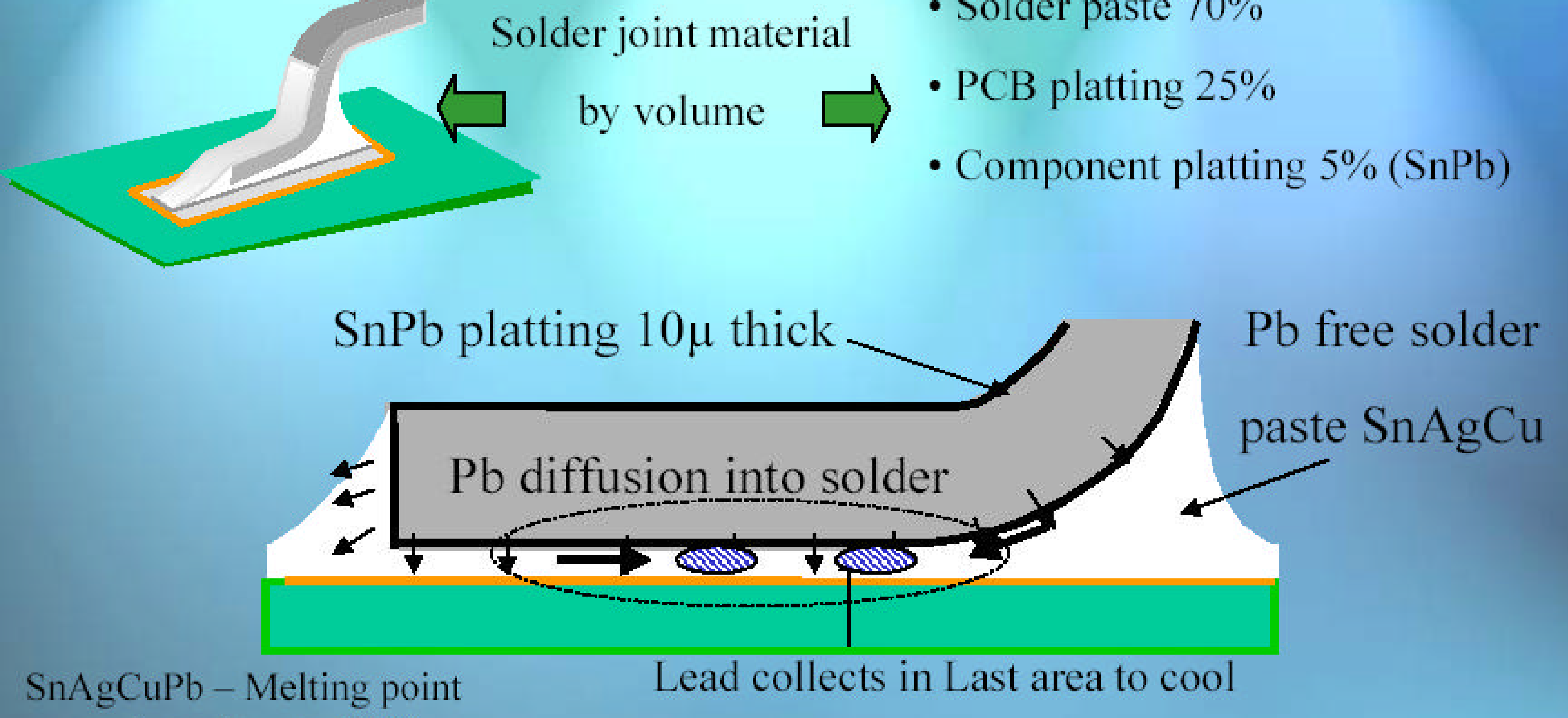
Category	Level I	Level II	Level III	Level IV
Material Type	IPC-4101/21	IPC-4101/24	IPC-4101/24	TBD
IPC-2221 Class	1	1,2	1,2	1,2,3
IPC-2222 Type	1,2,3	1,2,3	1,2,3	1,2,3,4,5,6

LEAD FREE
&
WHAT YOU SHOULD KNOW

Effects of High Temp Soldering Process On Non-lead Free Devices



Lead-free Solder Joint Failure via Lead Contamination.



Lead-free Technology – Barrel Electroplating (Sn passives)

Paste	Peak (℃)	Termination Finish	
		Sn/Pb	Sn
Sn-37Pb	200		
Sn-3.0Ag-0.5Cu	230		

Note: Lead-free joints may look slightly duller and uneven

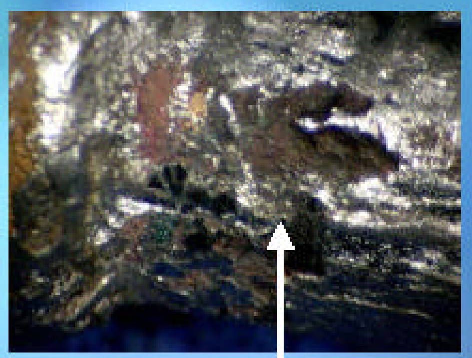
Not recommended because of lead contamination issue

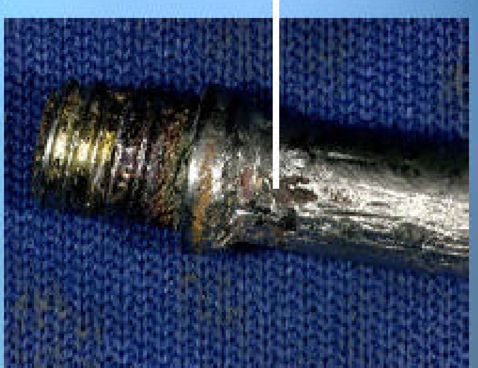
Lead-free component Implementation Summary

- Lead-free components can be reliably mixed with leaded components in a SnPb assembly process with NO adjustment to the current process parameters.
- Lead-free component plating gives solder joint strengths equivalent or superior to current SnPb plating in a leaded solder process. *(Improved thermal cycling)*
- Wetting times of lead-free components in a leaded solder process are comparable with current soldering systems.

  - Component wetting is slower in a totally lead-free process.
  - Increase solder temperature / Nitrogen gas.

Solder Machine Erosion with Lead-Free Solders





- Solder bath and impellor shaft erosion
- New problem within lead-free trials.
- Iron erosion of metal parts & contamination of expensive lead-free solder.
- High Sn(Tin) content solders will erode metal bath.

Manufacturing survey and investigation by TWI, DTI and NPL

Two views of a 6mm diameter, 316 stainless steel shaft after rotating at 1,500rpm in tin/silver/copper solder at 400°C for only 30 hours