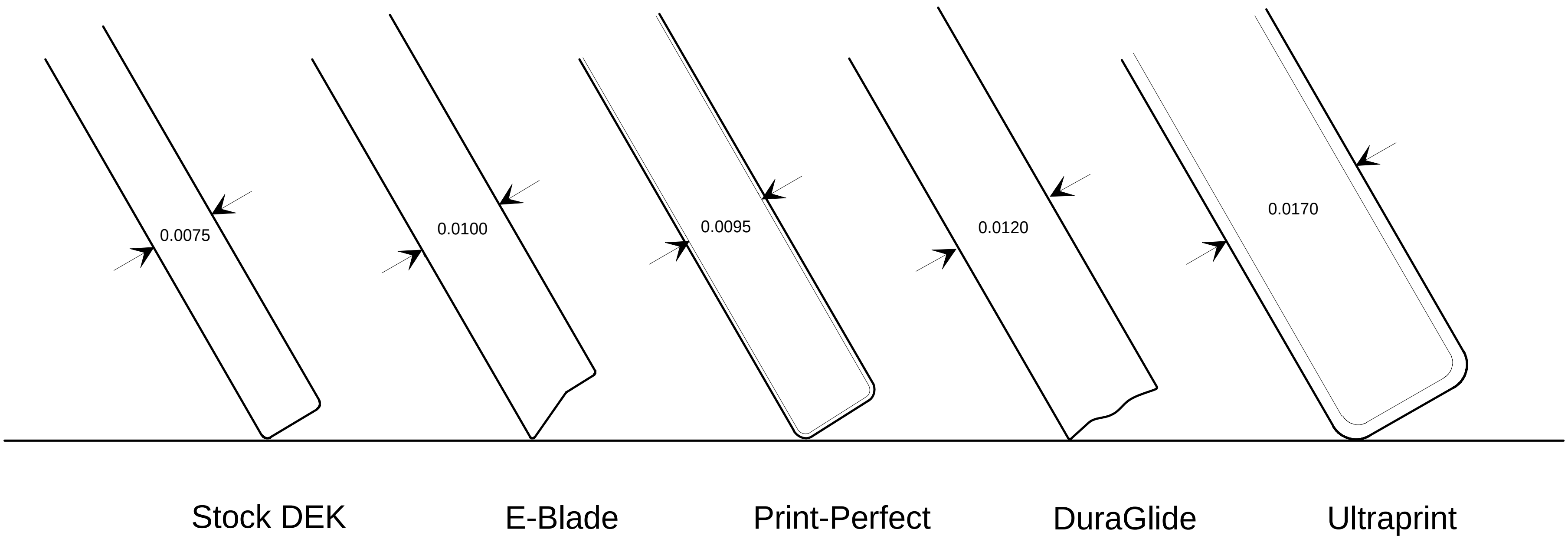
Heraeus

Troubleshooting SMT Solder Paste Problems

Printing Basics

- **Print speed and Squeegee pressure are inter-related**
  - **Factors effecting speed**
    - Temperature
      - **Cold = slow as pastes are very temperature sensitive**
    - Squeegee Material
      - **Polymer is faster than metal**
        - **Poly is simply a better squeegee (windshield wipers)**
        - **Poly wears very quickly, not common today**
      - **Sharpness**
        - **Not all metal squeegees are equal**
        - **Plating of Transition Automation is round and dull**
      - **Angle**
        - **60 degree is faster than 45 degree**
        - **Watch out for MPM; long blades = low angles with high pressures**

Various Metal Squeegee Blades



Various Metal Blade Characteristics

	Stock DEK	E-Blade	Print-Perfect	DuraGlide	Ultraprint
Supplier	DEK	AMTX (PhotoStencil)	Transition Automation	Photo Stencil	Alpha Metals
Material	Spring Stainless	Nickel	Spring Steel	Spring Steel	Spring Steel
Forming Method	Machined	Electroplated	Machined	Etched	Machined
Coating	None	None	“Permalex” Teflon/nickel	Titanium Nitride	Nickel plate
Body Thickness	7.5 mils	10 mils	9.5 mils	12 mils	17 mils
Tip Thickness (bottom 0.1”)	7.5 mils	10 mils	10 mils	11.5 mils	17 mils
Relative Sharpness**	6	8	4	7	4

F365 Print Speed Benchmarks With Various Squeegees

45 Degree Squeegee

	Stock DEK	E-Blade	Print-Perfect	DuraGlide	Ultraprint
Maximum speed at 3lb/in	2.00 IPS	1.25 IPS	1.50 IPS	3.75 IPS	1.60 IPS
Maximum speed at 2lb/in	1.25 IPS	1.00 IPS	1.25 IPS	1.75 IPS	1.00 IPS
Minimum pressure at 6IPS	N/O	N/O	N/O	5.5 lb/in	N/O

60 Degree Squeegee

	Stock DEK	E-Blade	Print-Perfect	DuraGlide	Ultraprint
Maximum speed at 3lb/in	4.25 IPS	3.75 IPS	3.25 IPS	**6.00 IPS**	2.75 IPS
Maximum speed at 2lb/in	3.25 IPS	3.25 IPS	1.30 IPS	4.25 IPS	1.80 IPS
Minimum pressure at 6IPS	N/O	N/O	N/O	**2.7 lb/in**	**4.3 lb/in**

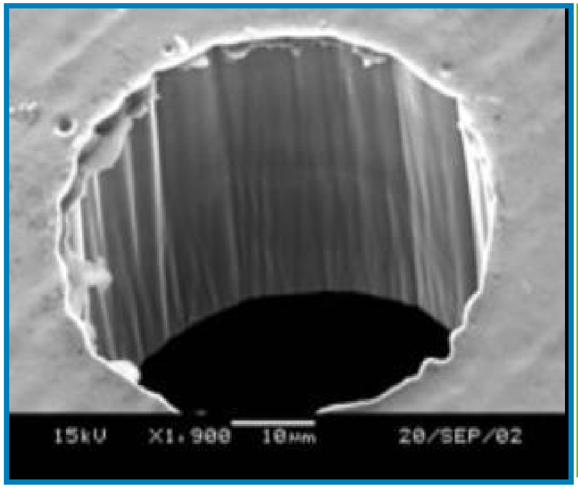
Printing Basics (continued)

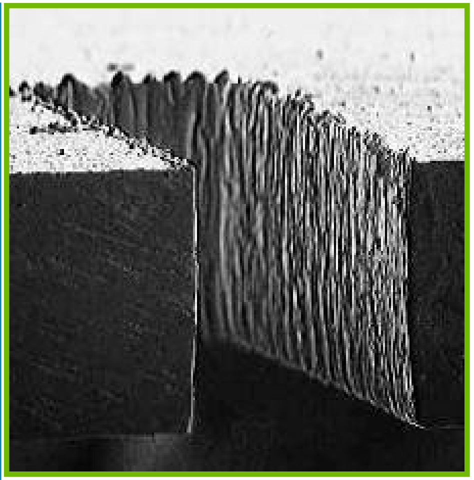
- **Stencil Roughness**
  - Rougher better for roll
  - Rougher requires more pressure for clean wipe
  - Etched or lasered foil is more rougher than EFAB
- **Paste factors**
  - Higher viscosity usually equates to slower print speed and higher pressure.
  - Higher tackiness usually equates to slower print speed and higher pressure.
- **Squeegee pressure take away message**
  - "Apply minimum pressure to get a clean wipe, (no solder powder) around the apertures"
  - This is independent of all of the other variables effecting squeegee pressure

Printing Basics (continued)

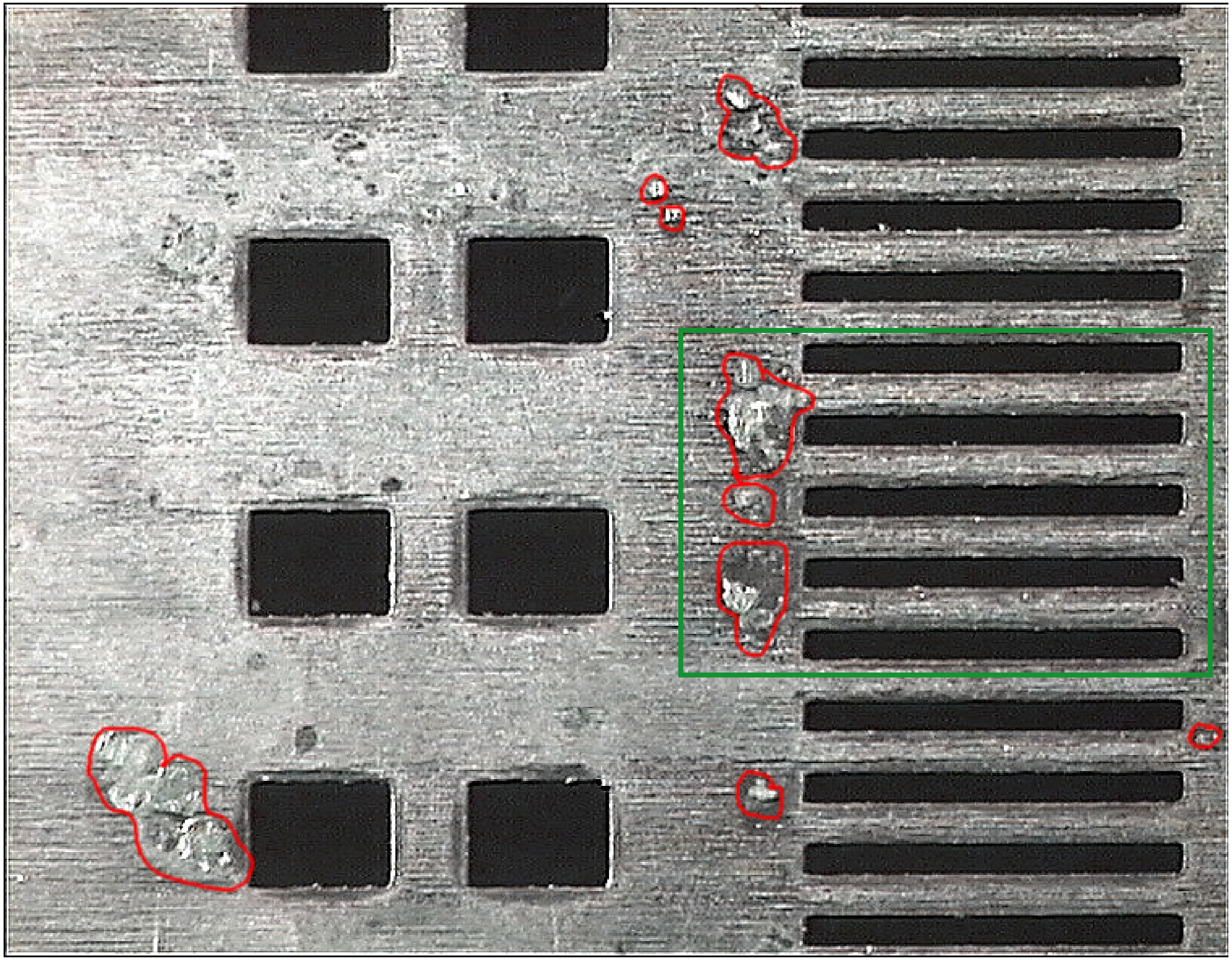
Stencil Issues

- **Not all stencils release equally well**
  - EFAB is best
  - Laser is OK, with electro polish or nickel plate is better
  - Chemical etch is worst
- **Stencil wiping not totally effective**
  - Automated better than manual
  - Coined solder can remain and cause more needed wiping






Coined solder on bottom of stencil



Printing Basics (continued)

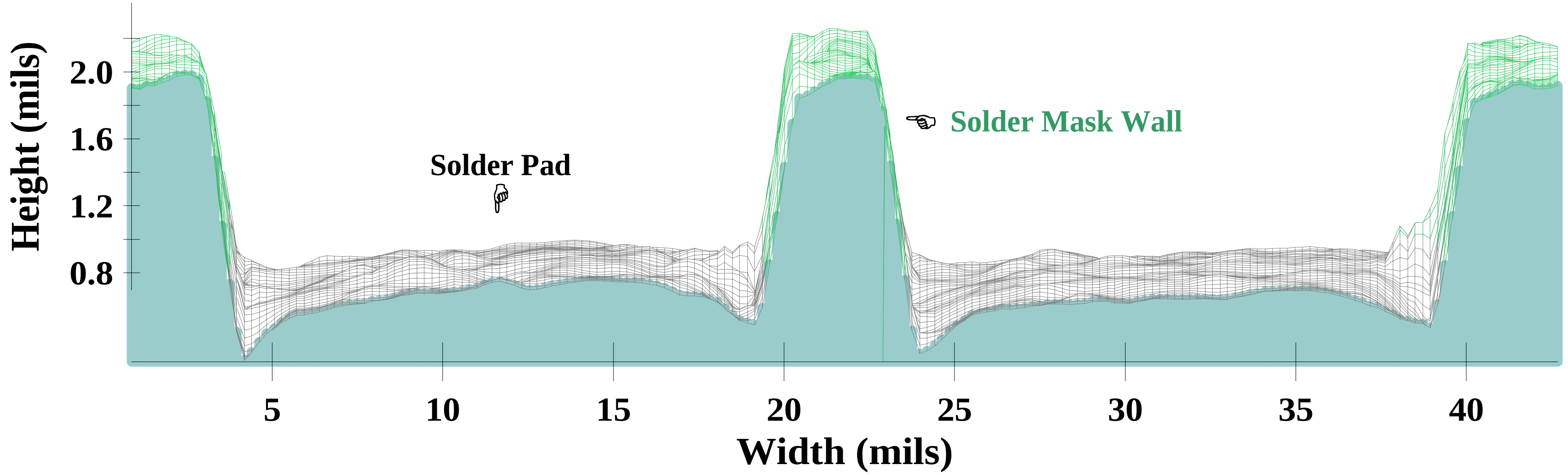
Sticking to squeegee

- **Paste viscosity too high**
  - Solids too high
  - Paste got hot in storage or shipment
- **Insufficient paste on the stencil**
  - Start with 15gr/cm of squeegee length
- **Squeegee lift incorrect**
  - Too high after stroke
    - **0.5” to 0.75” is OK**
  - Too slow
    - **Fast (>10mm/s) helps shear paste and leave on stencil**
- **Pause between prints too long**
  - Paste rheology goes back to rest viscosity
  - Short stroke
  - AOI too slow

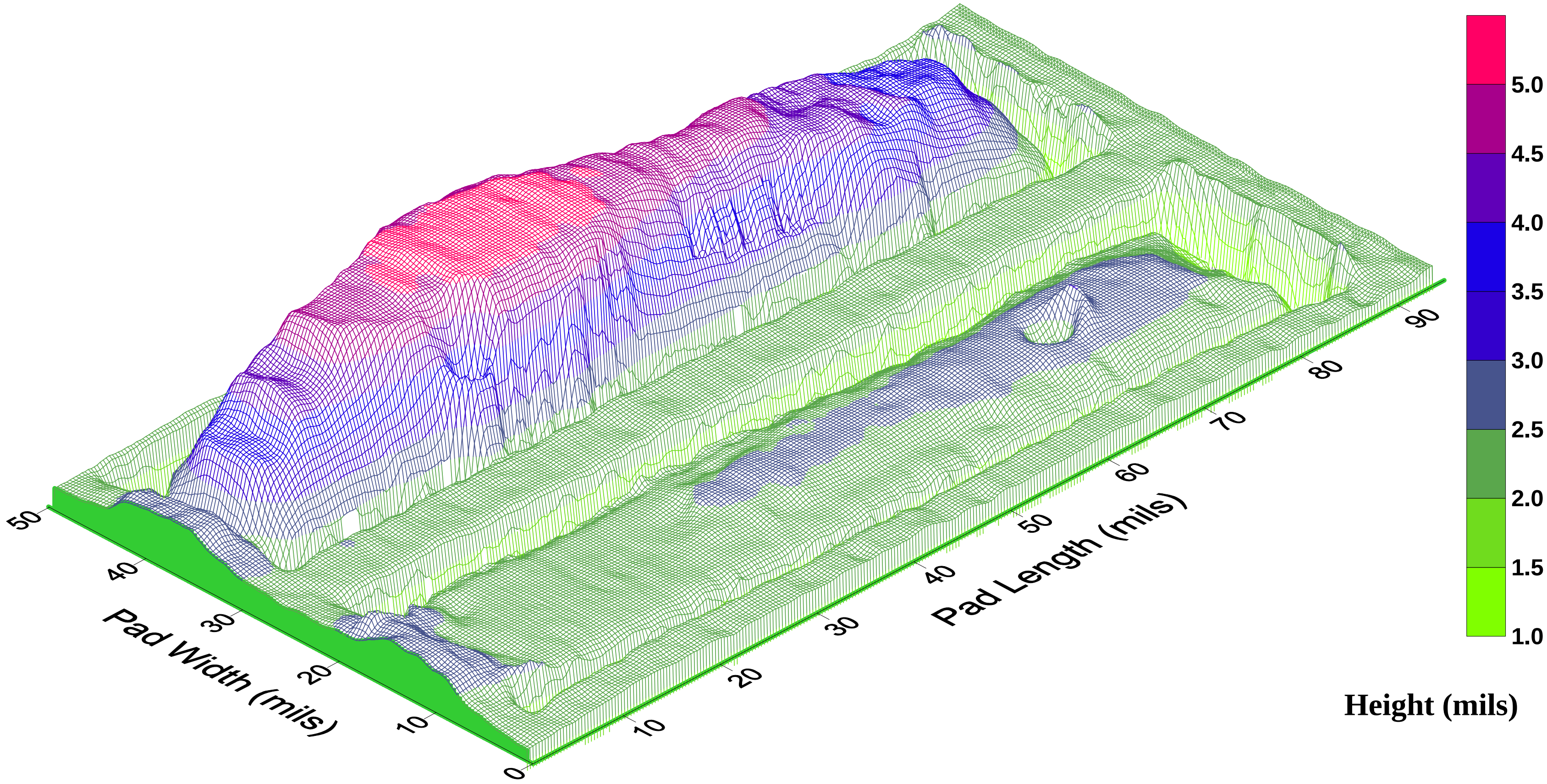
Printing Basics (continued)

Gasketing is critical for good paste release

- **Aperture must be smaller than pad in both length and width**
  - Critical for fine pitch, small components
- **Legend near fine pitch is NG**
- **Bar code or other labels near fine pitch is NG**
- **Mask should be < pad height except over traces**
- **HASL can be a hassle**

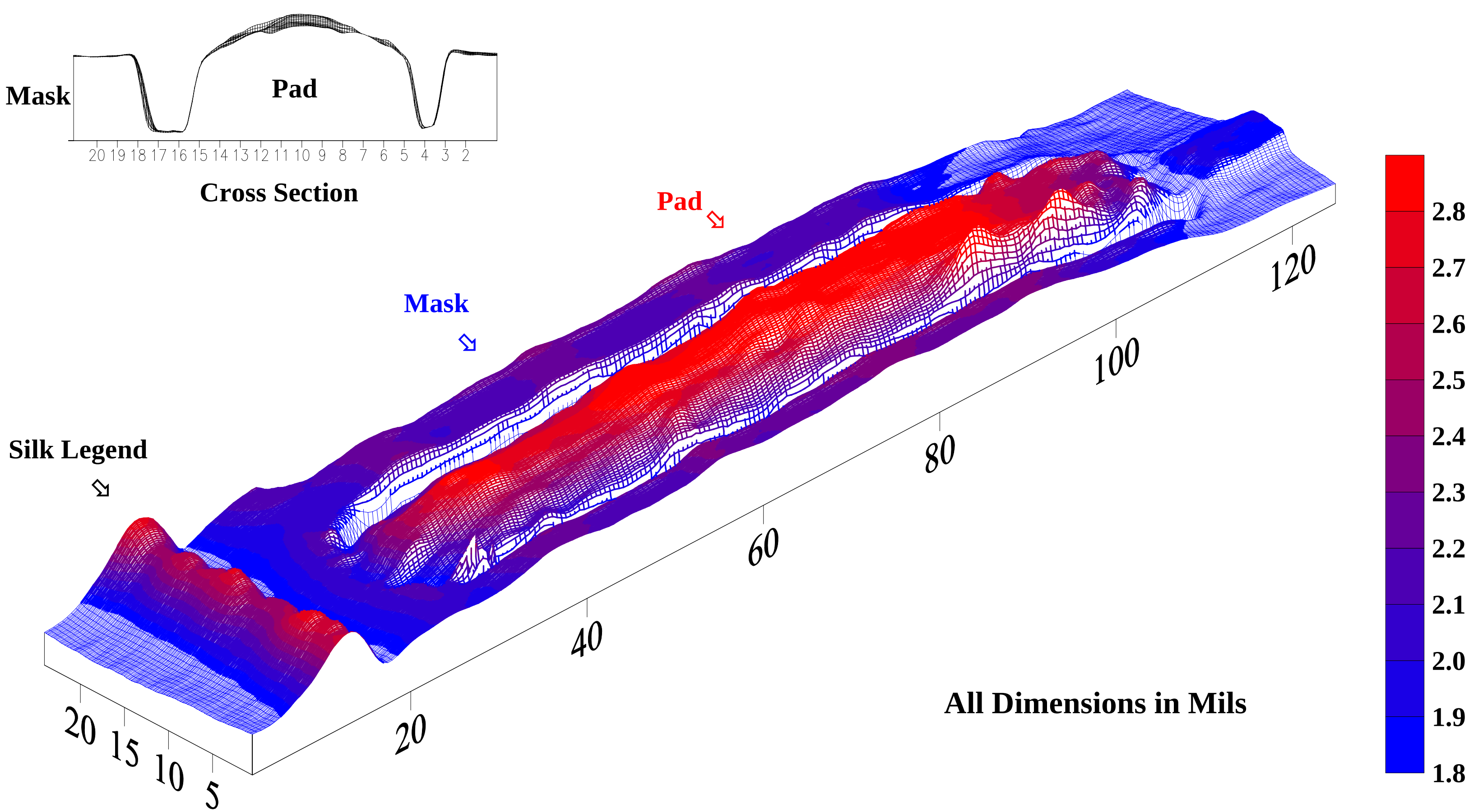


Single Pad HASL Anomaly



Fine Pitch Solder Pad

82C593 Pin 181



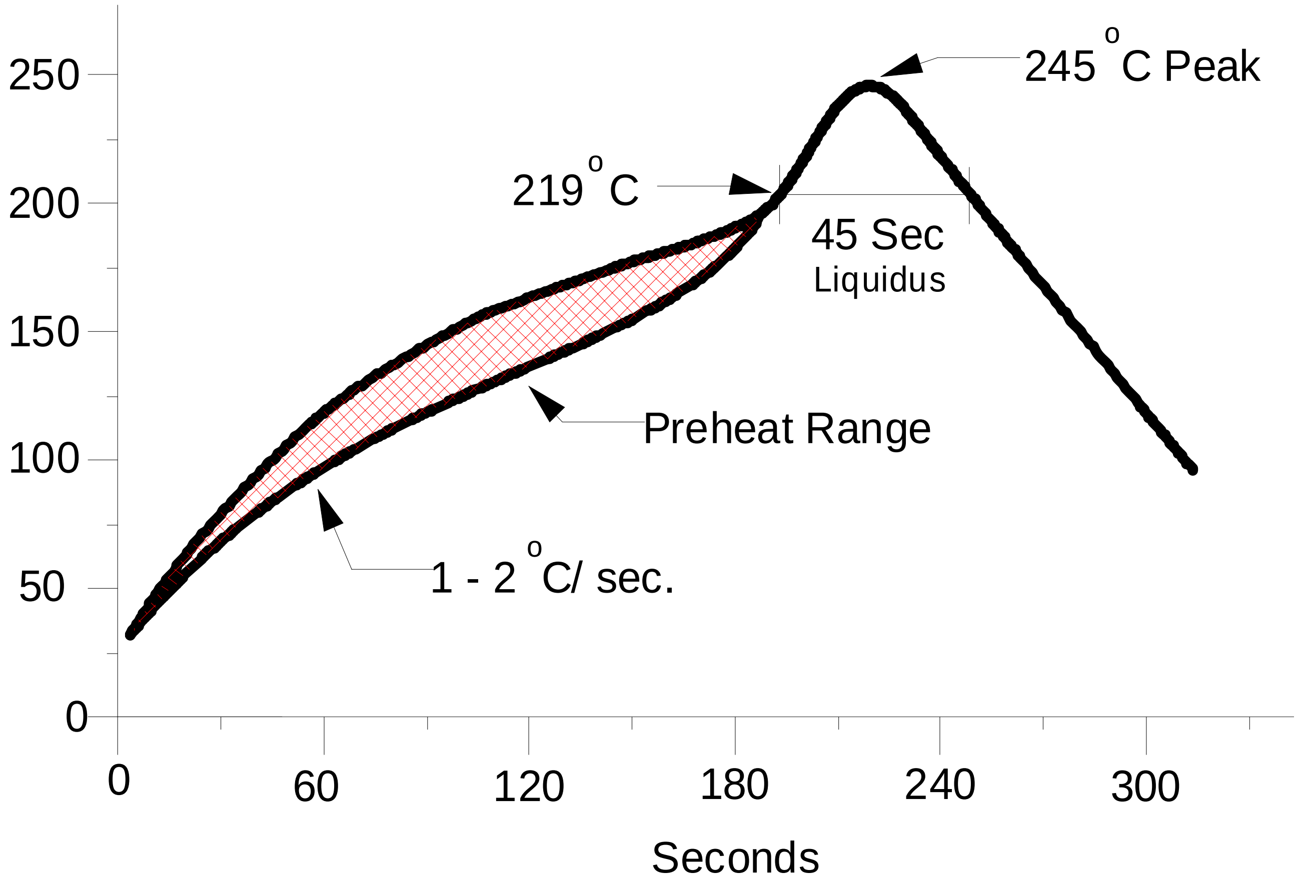
Printing Basics (continued)

Compaction (happens only with solder paste)

- **ProFlow is DEK**
  - Compaction in corners and upper head
- **Rheopump is MPM**
  - Compaction is in center (print area)
- **Compaction is “pressured separation”**
  - Flux squeezed out, solids rise, flow inhibited
- **Remedies**
  - Thixatrope level
  - Solids
  - Powder source
  - Cannot be fixed in the process!
- **Temporary solution**
  - Clean out head and replace with fresh material
- **Show ProFlow Head**

Reflow Basics

Generic Profile



Reflow Basics (continued)

Profiling

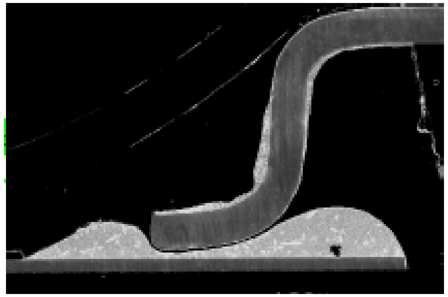
- **Fast response thermocouples (thin gauge)**
- **Tip must be welded not twisted to be accurate**
- **Thermocouple, connectors and lead wires must all be the same type (J,K)**
- **Type “K” most common, “J” also works**
- **Tip must be fixed to surface to be measured**
  - Aluminum tape or high temp solder are best
  - Too much Kapton tape (yellow) can “tent” thermocouple and give lower reading
  - Not fixed to surface can give too hot a reading
- **Best is high temp solder to component leads**
- **For BGA, bury the thermocouple tip into a center ball (coldest)**
- **Basic needs for Applications Support**
  - Peak temp
  - Time above liquidus (TAL)
  - Time from entrance to peak
  - Shape of preheat

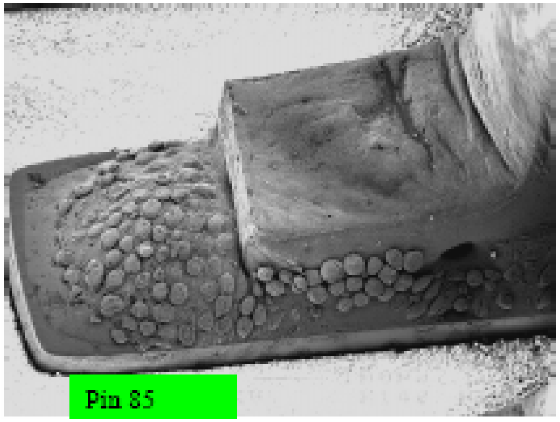
Reflow Basics (continued)

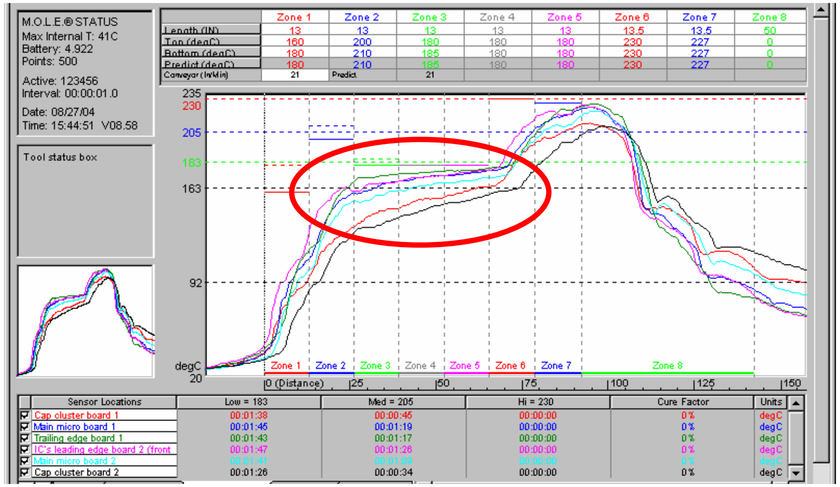
Preheat Shape

- **Soak or Ramp?**
  - Soak is less preferred but necessary with certain applications
    - **Very thick board (back panels, etc.)**
    - **Laminated metal backing or heat spreader**
    - **Assemblies in any type of tray, fixture or jig**
    - **Excessive soak time (>60s) or temp (>150C) can weaken paste activation**
      - **“Cold” looking solder joints**

Customers Profile



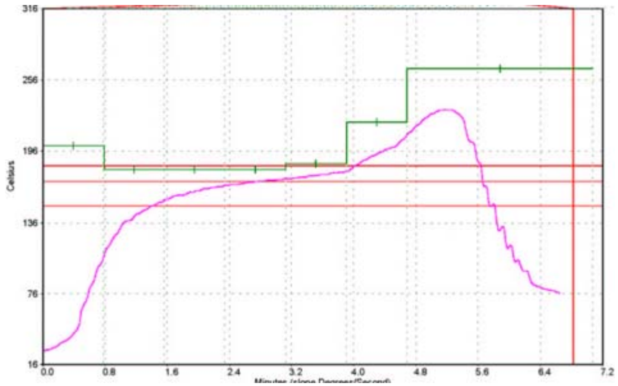


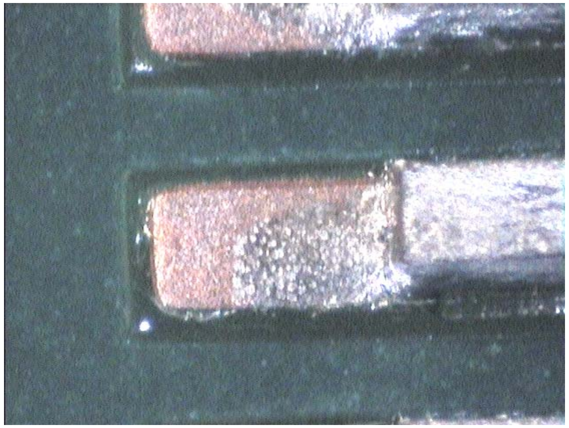


Reflow Basics (continued)

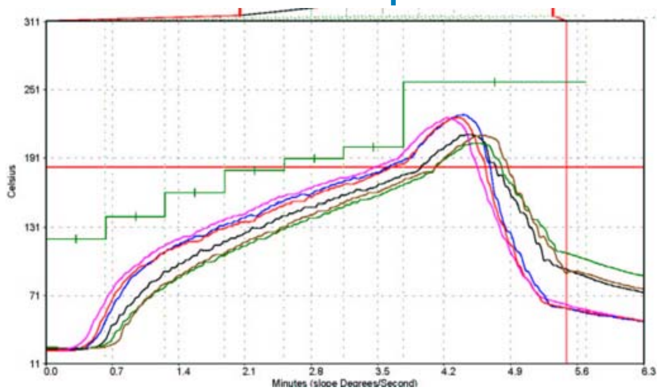
- Ramp is preferred preheat shape in ALL applications where possible and ALL formulations

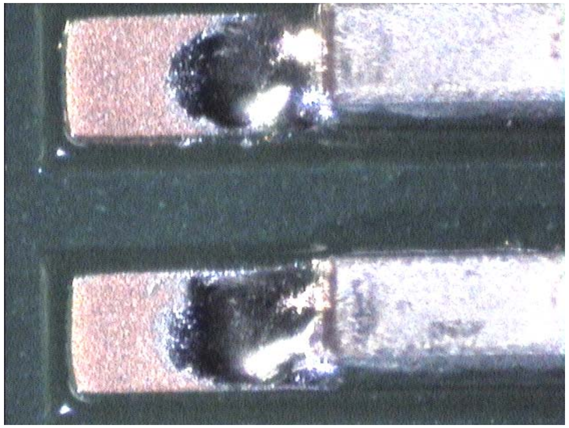
Soak





Ramp





Reflow Basics (continued)

- **N_2 versus O_2 reflow Environment**
  - **N_2 Benefits**
    - Wetting
      - **Lead free components**
      - **Lead free alloys**
      - **Old components**
      - **Oxidized surface finishes (Sn)**
    - Flux appearance
      - **More residue spread, appears like less residue**
      - **Lighter color**
      - **Better cleaning (for water cleans)**
    - Less solder balls
    - Helps OSP survive more reflow excursions

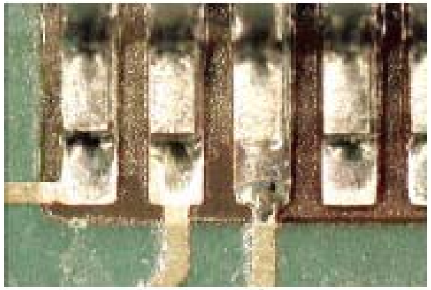
Reflow Basics (continued)

- **N_2 Disadvantages**
  - Cost
  - Not all ovens or facilities are capable
  - Some defects are aggravated
    - **Tombstones**
    - **Solder beads**
  - Flux mobility
    - **Flux will move farther from solder joint due to lower surface tension**
      - **Can get down a via to the backside of the assembly**
      - **Can contaminate wire bond finger or connection pad surface**

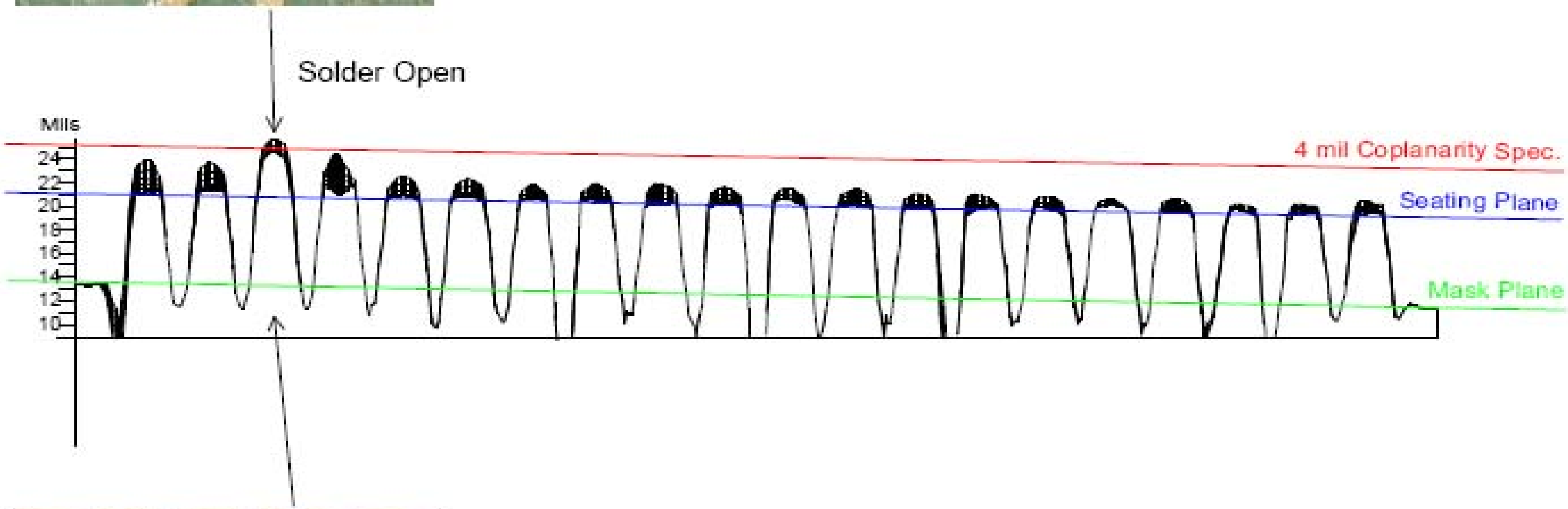
Reflow Basics (continued)

Wetting Issues

- **Component solderability**
  - Lead free components in a Sn63 process
    - **Extend liquidus time, peak temp or both**
  - MUST test shows slow wetting time but strong wetting forces
    - **Extend liquidus time, peak temp or both**
  - MUST test shows slow wetting time and weak wetting forces
    - **Add solder volume**
    - **Replace with stronger activation paste**
    - **Use nitrogen reflow**
    - **Have customer seek replacement from component supplier or distributor**
- **Component Coplanarity**
  - Add solder height
  - Add placement depth
  - Replace with stronger activation paste
  - Use nitrogen reflow



Board #1 (Bright IC Leads) Solder Defects Vs Lead Coplanarity



QFP Coplanarity Example

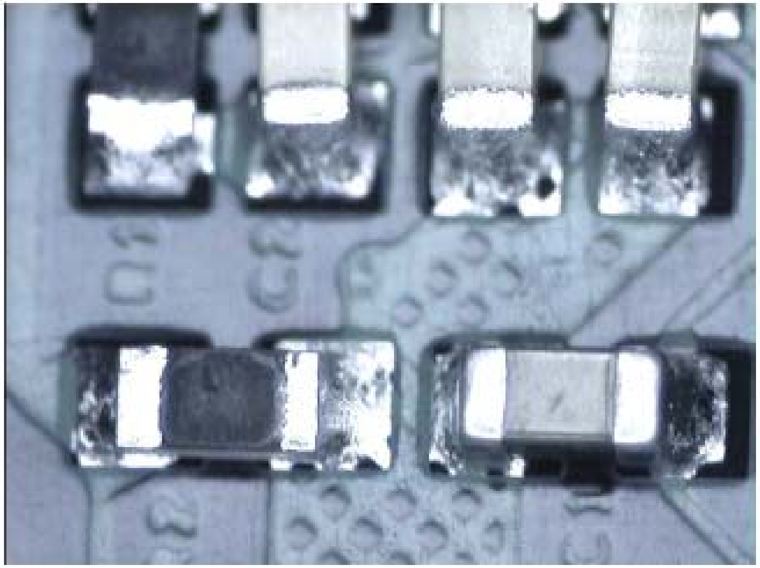
Foot-in-mud, Ball-in-socket, Head-in-pillow defect formation theory

At placement, a component with some (>0) coplanarity is placed on top of the solder deposit. The high lead, in these defects, is not touching the solder paste or barely touching the solder paste. During the preheat portion of the reflow profile the solder paste goes from a firm paste consistency to a hard deposit. There is a slight shrinkage due to the loss of solvents and other volatiles but the printed pads of solder paste hold their shape rigidly. So at this point in the reflow process there is still an air gap between the bottom of the lead and the top of the solder paste. If there was just barely contact at placement then there most likely is now an air gap going into the reflow portion of the profile. Without a physical bond of the lead foot bottom surface and the top of the solder paste there is no or an inadequate thermal link between the surfaces to be soldered (lead, solder & PCB pad). This thermal link is a basic requirement for the formation of a solder joint that includes the lead of the component. Very shortly into the reflow portion the solder paste deposit under the bent lead, without the thermal burden of the lead, will reach liquidus and collapse abruptly soldering only to the pad. Shortly after that event the rest of the leads will reflow and the component will collapse towards the board at a rate which is directly proportional to its solderability. Very solderable parts combined with pads designs wide enough to accommodate the generation of side fillets will collapse more vigorously. At the moment of this collapse the bent or high lead which was originally deprived of flux at placement and through pre-heat will push into the molten solder beneath it and solidify unsoldered as the reflow process ends. These leads may actually have a layer of flux residue under them but this brief thermal link came too late in the reflow process to initiate the soldering process to the lead foot.

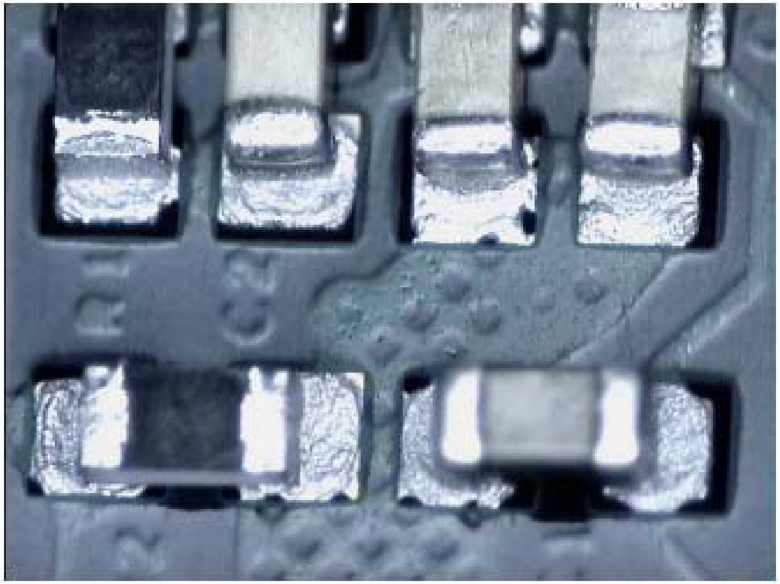
From a solder paste standpoint the firmer the deposit the worse, this can be aggravated by higher solids that also presents less wetness to the solder deposit which is critical to form that early thermal bond that is critical. Increased placement depth and reduced component coplanarity are the most powerful elements for elimination of this defect type. With most of the lead finishes moving to lead free (Sn) these days, solderability will be compromised. A higher peak temp and/or a longer liquidus (~90s) can help solderability with pure tin plated leads.

Reflow Basics (continued)

- **Gold Plating too thick**
  - Bulk solder looks “cold”
  - Solder joints have massive voiding
  - Solder joint is extremely brittle
    - **> 3-5% gold in bulk solder**

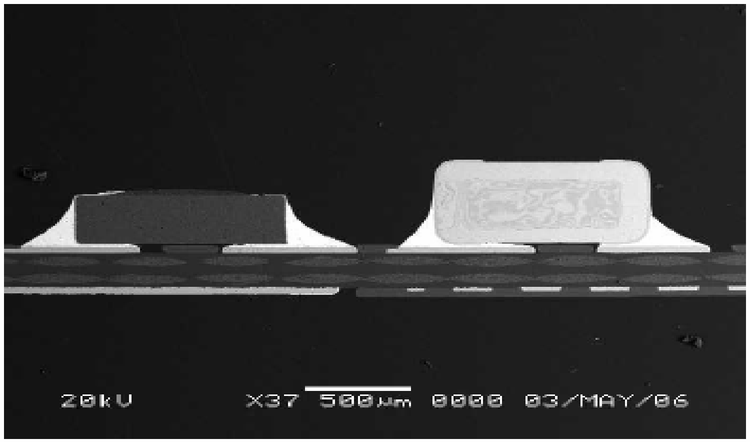


Known good (smooth joints)

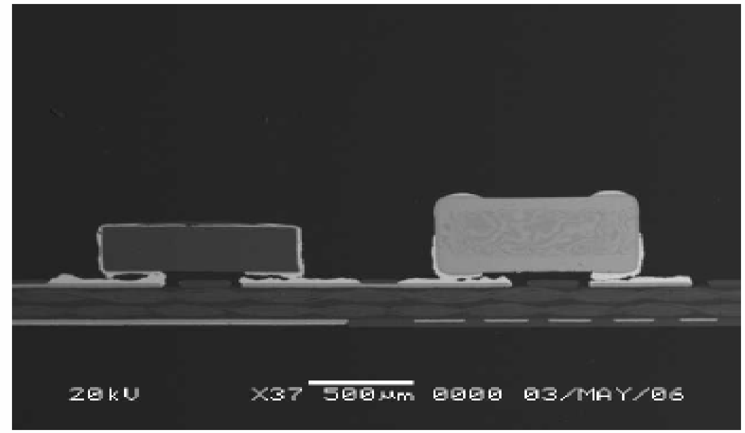


Known bad (grainy, dull, brittle)

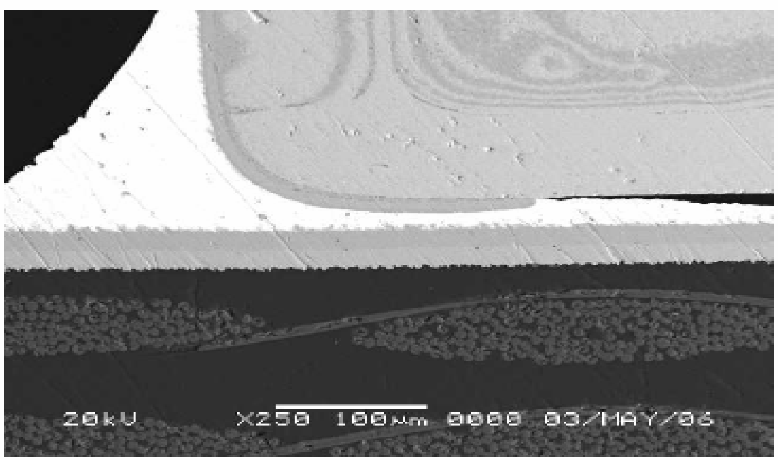
Reflow Basics (continued)



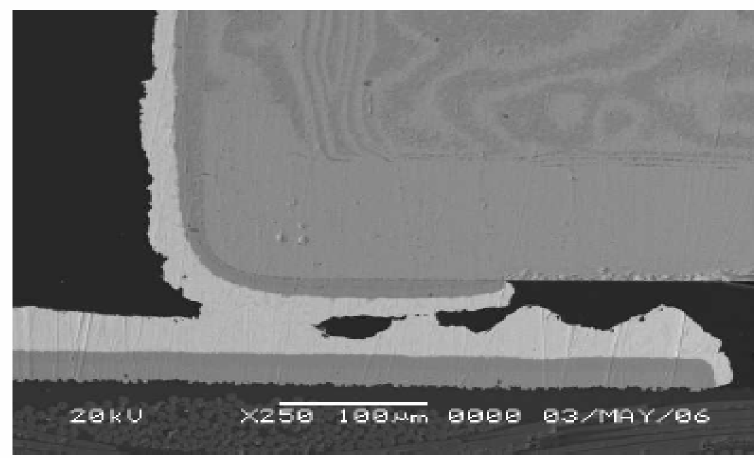
Known good chips



Known bad chips

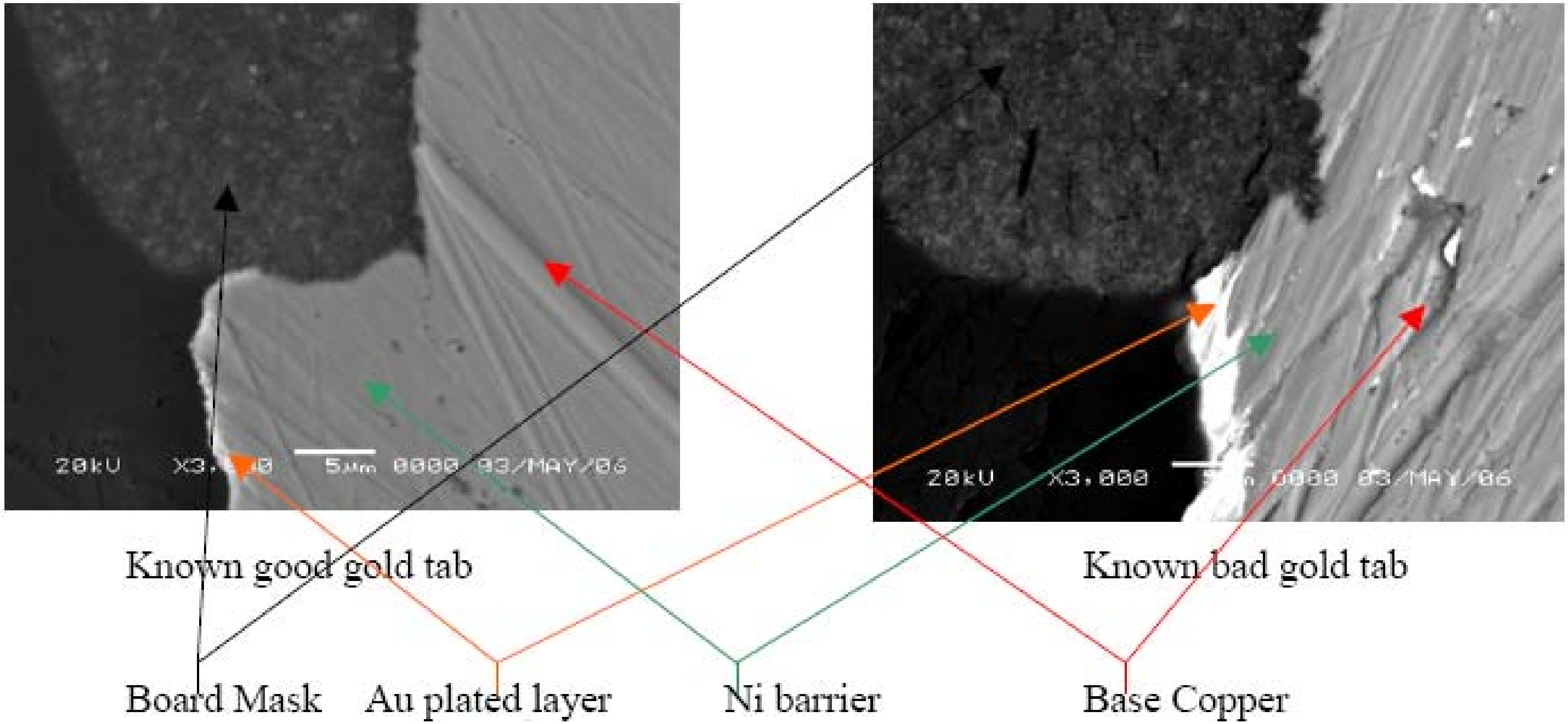


Known good



Known bad

Reflow Basics (continued)



Gold: 0.5µ - 1.0µ

Gold: 3.0µ

Customer Spec: 0.4µ - 0.9µ

Reflow Basics (continued)

Surface finish effects

- **ENIG is simply best**
  - Wetting
  - Voiding
  - Defects
  - IPC-4552 covers this finish specifications
    - **Electroless Nickel: 120 -240μin (3-6 microns)**
    - **Immersion Gold: 3-5μin (0.075-0.125 microns)**
- **Immersion silver is second best**
  - If thickness is too thick, Champaign voiding is inevitable
- **OSP and Immersion tin are third**
  - OSP = limited reflow excursions
  - Concern of shelf life and variability with Immersion tin

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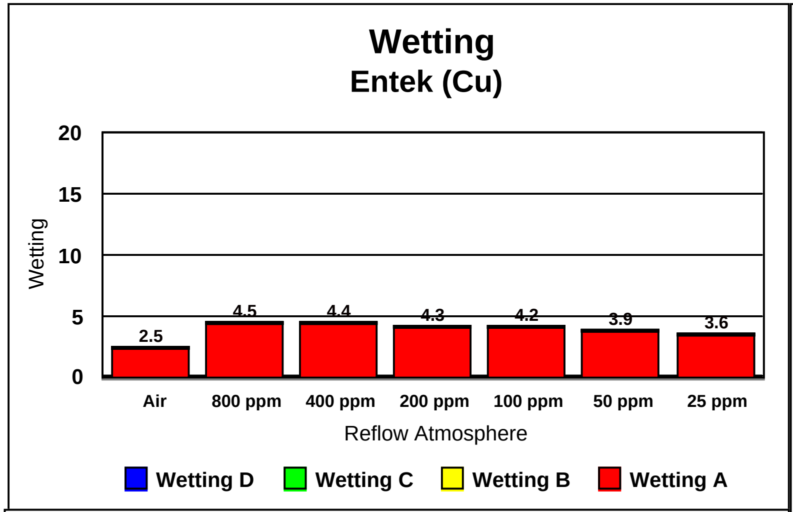
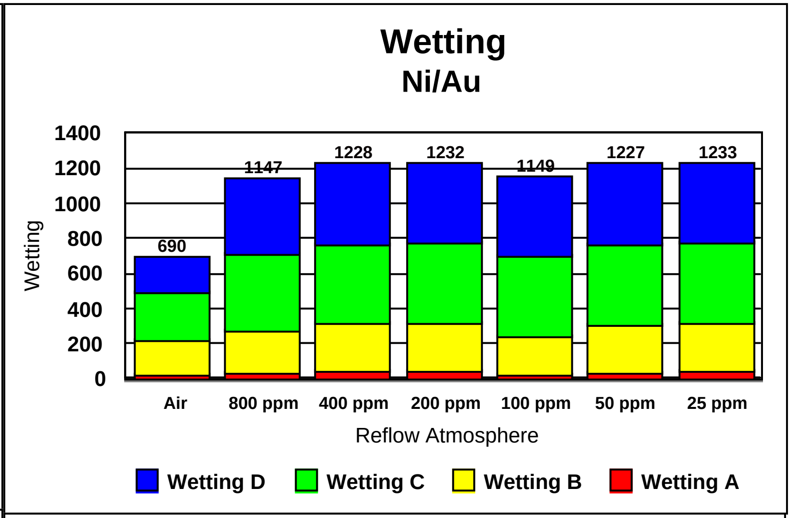
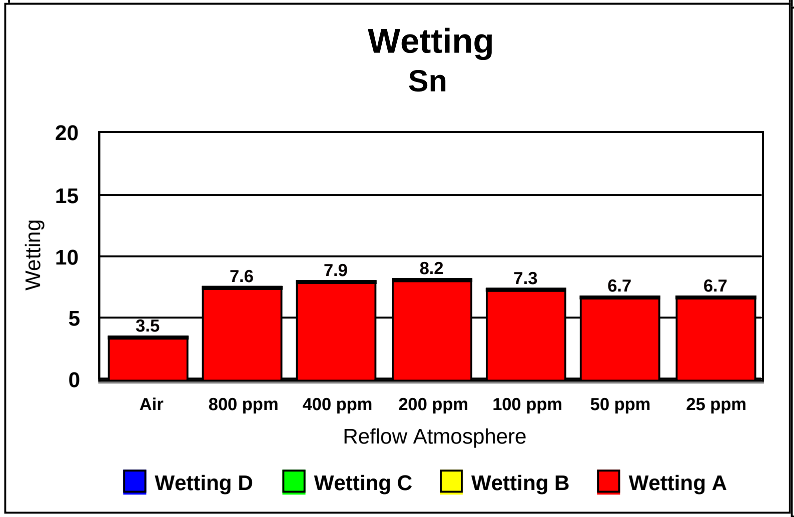
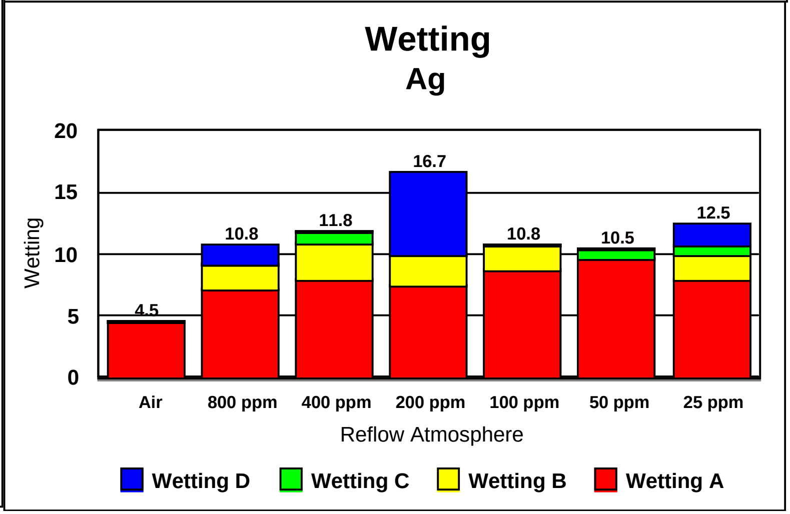
Reflow Basics (continued)

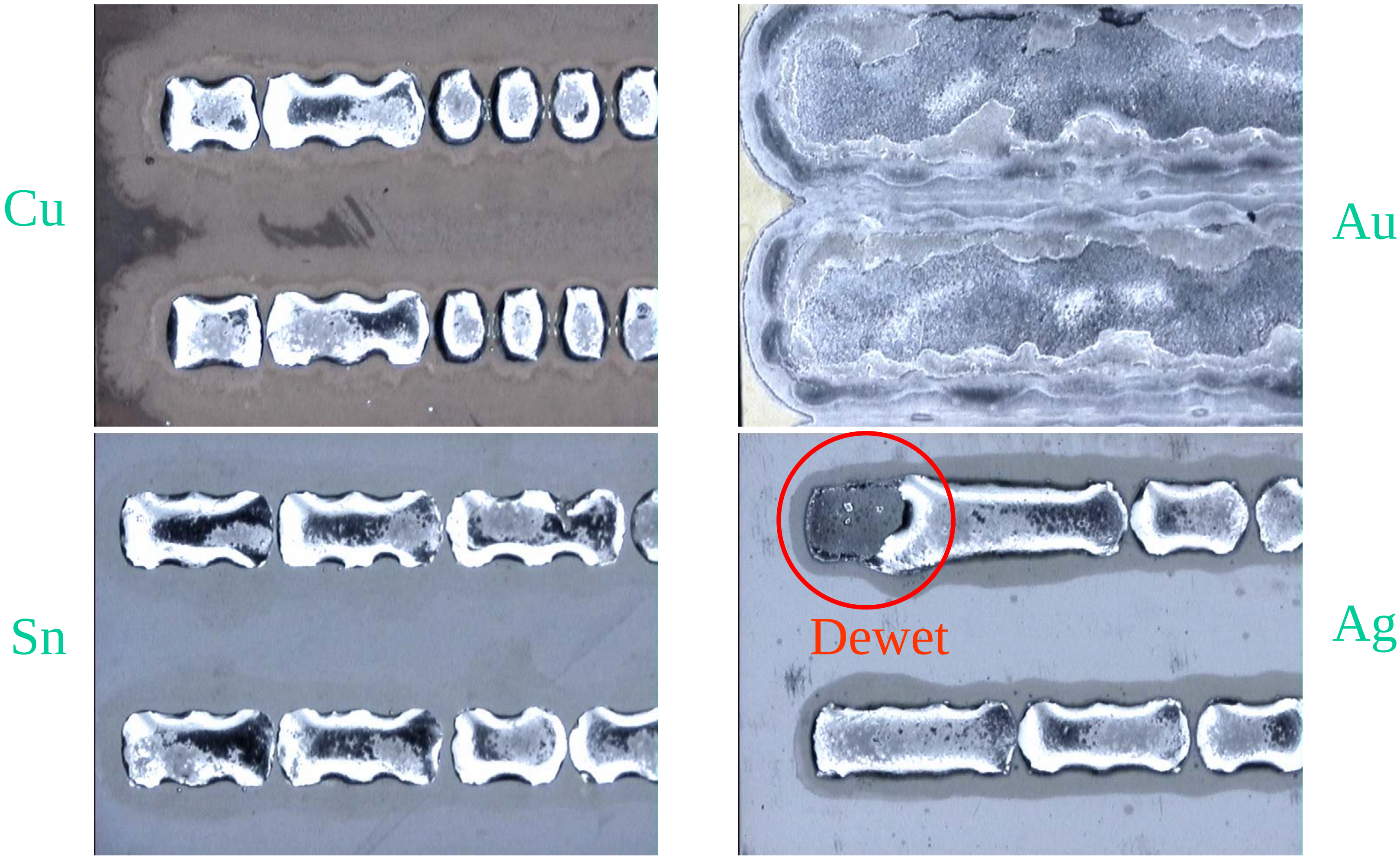




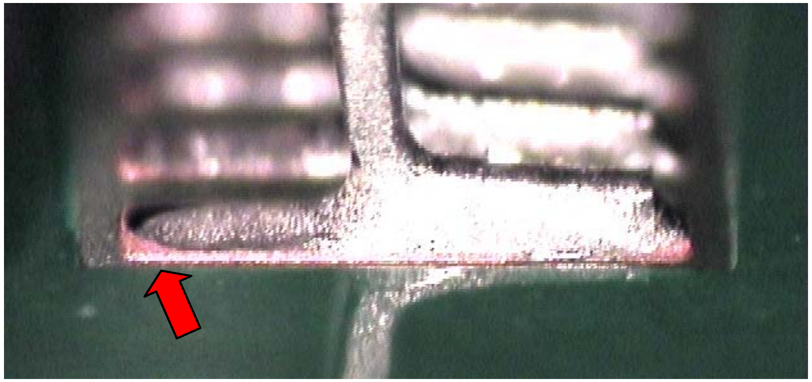




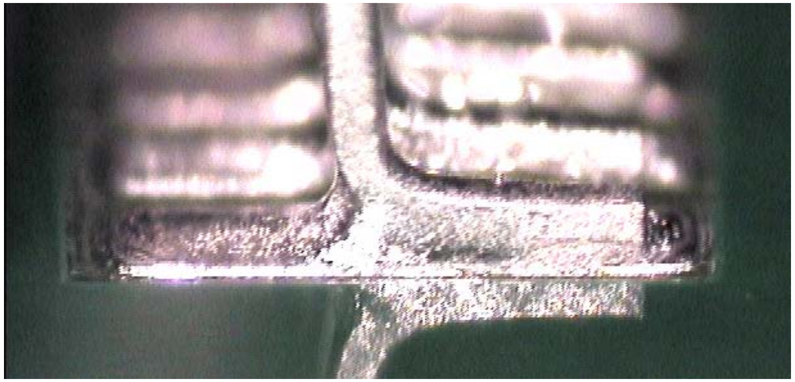
Reflow Basics (continued)



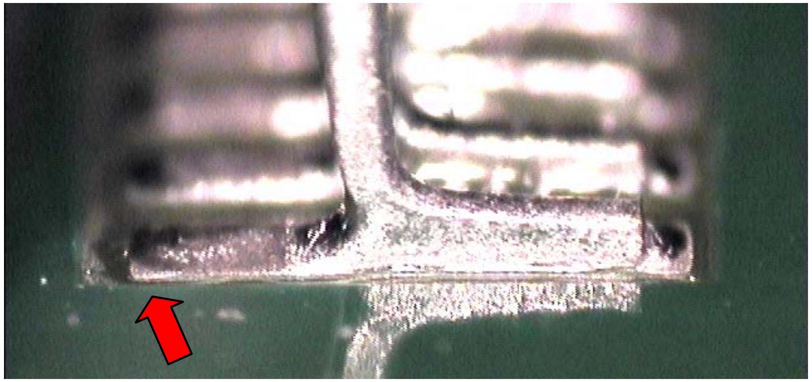
Reflow Basics (continued)



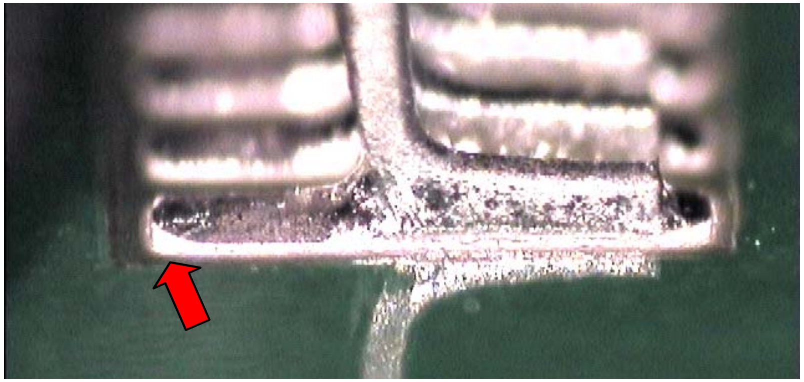
Cu



Au

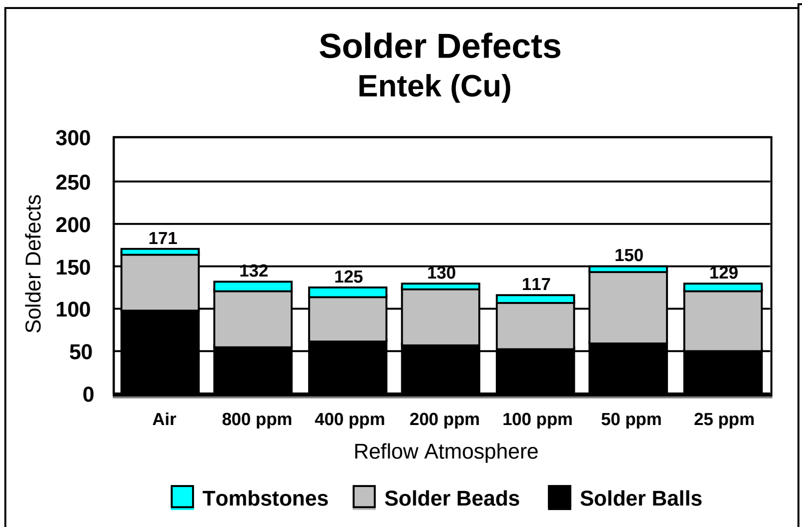


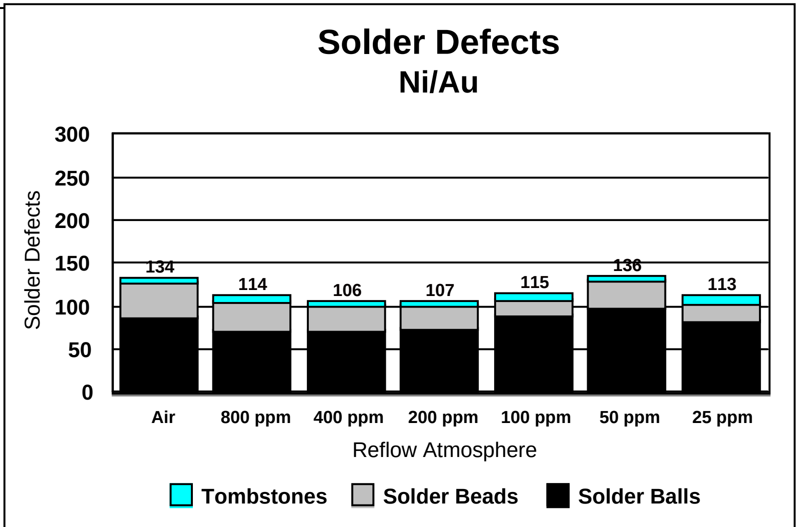
Sn

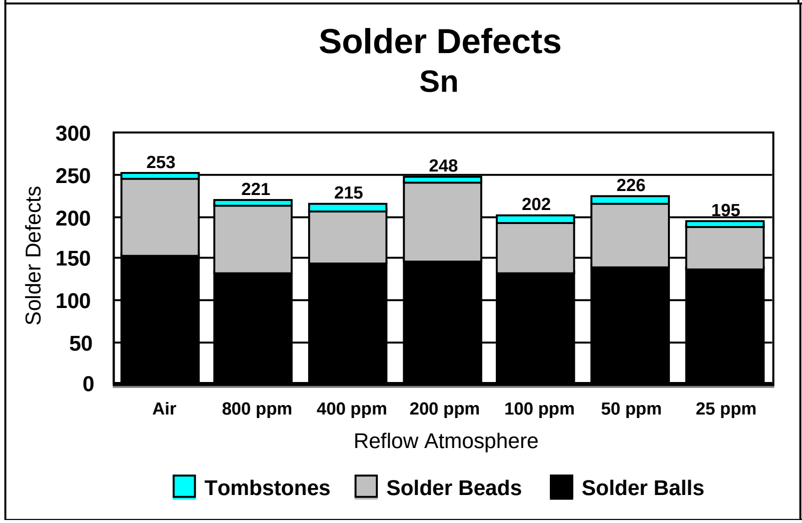


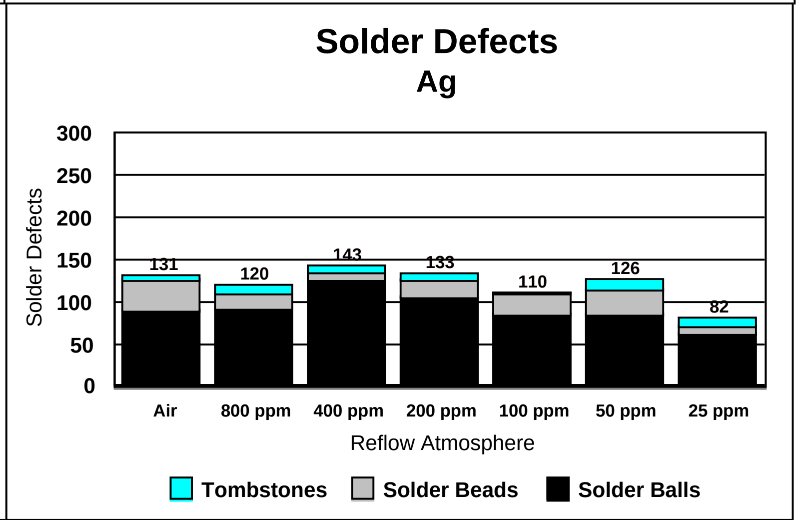
Ag

Reflow Basics (continued)

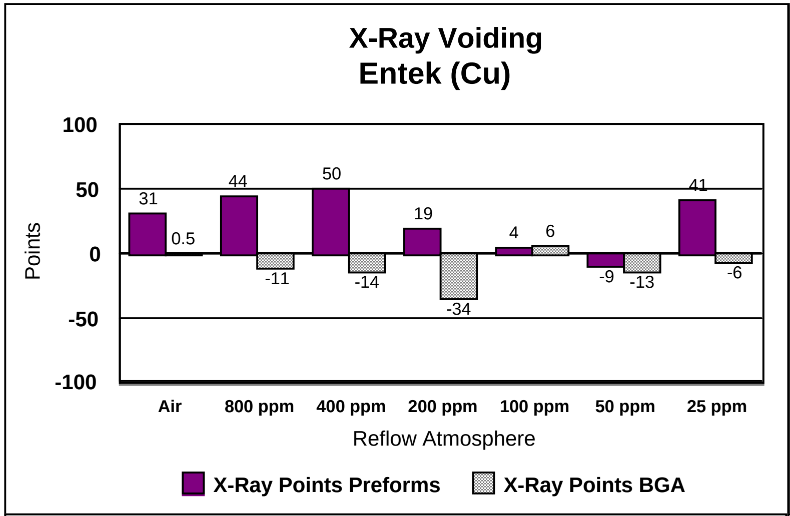


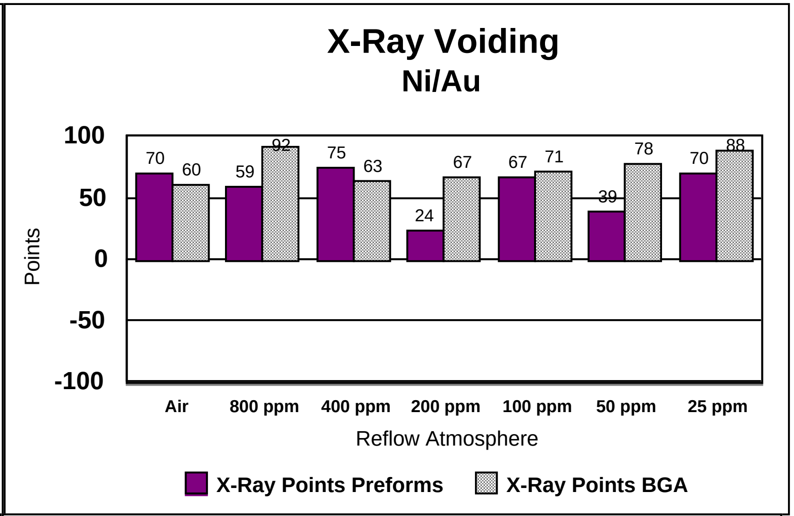


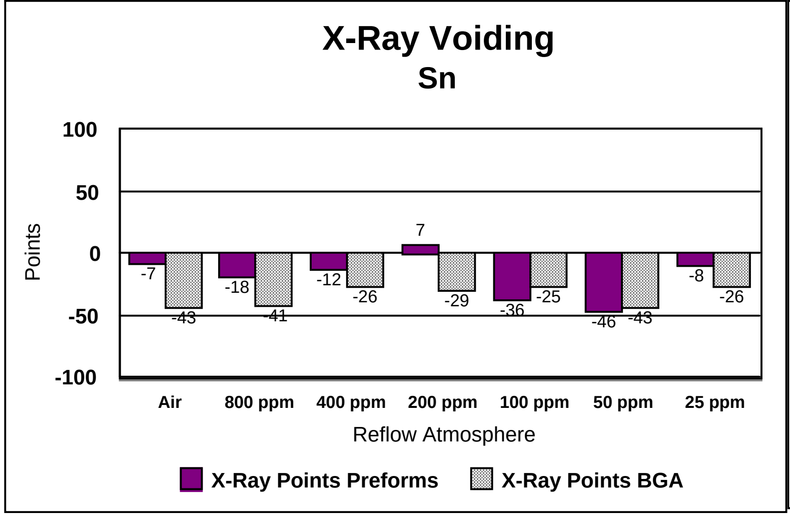


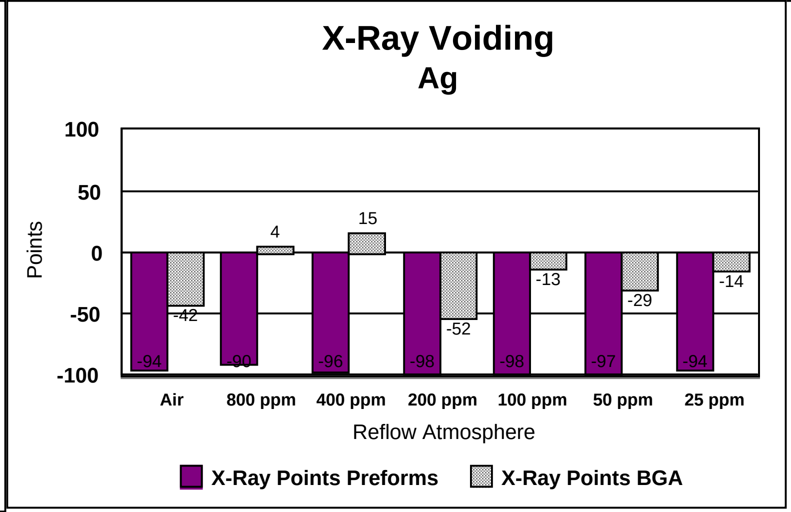


Reflow Basics (continued)

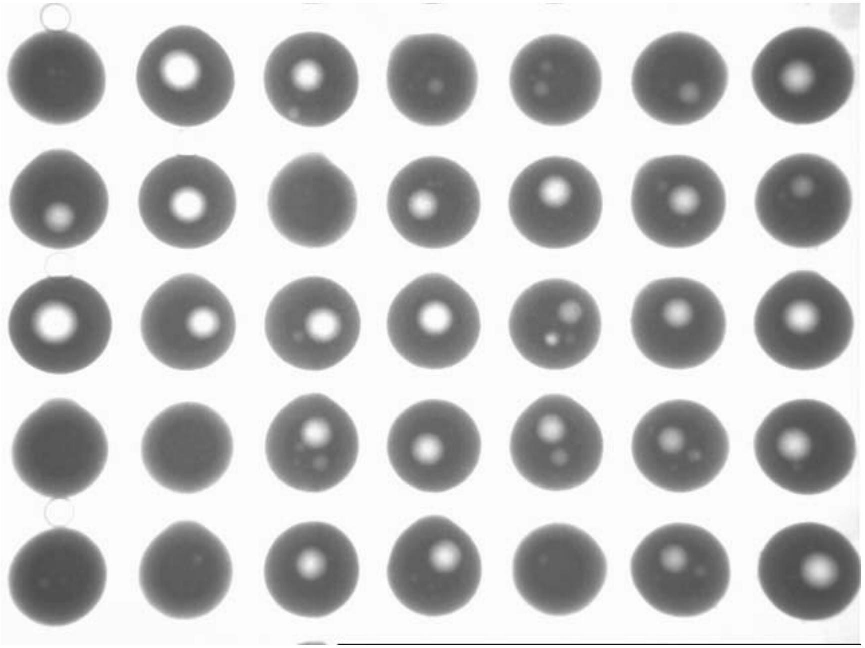




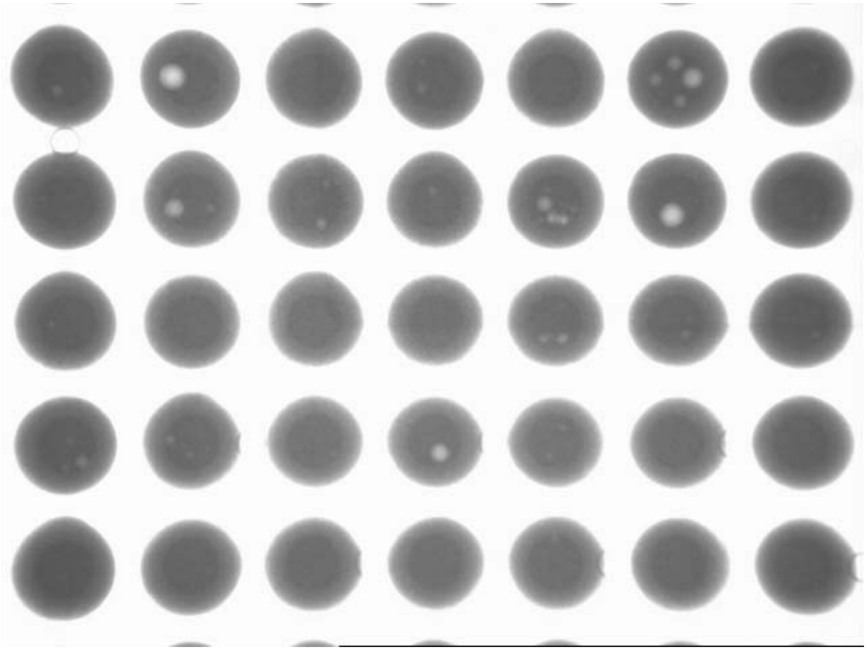




Reflow Basics (continued)

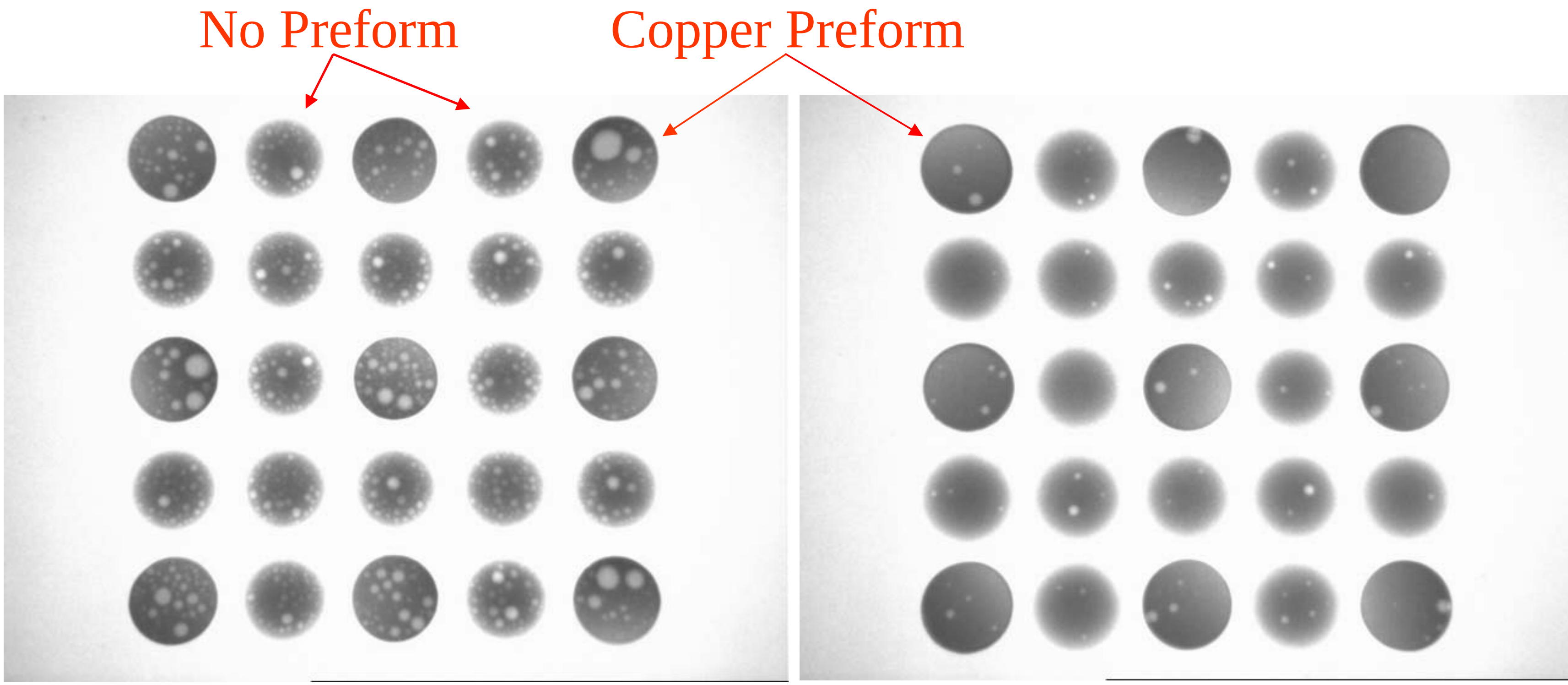


Immersion Tin



Immersion Gold

Reflow Basics (continued)

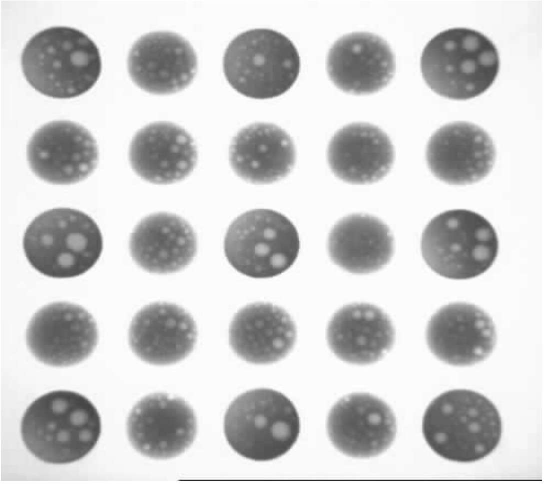


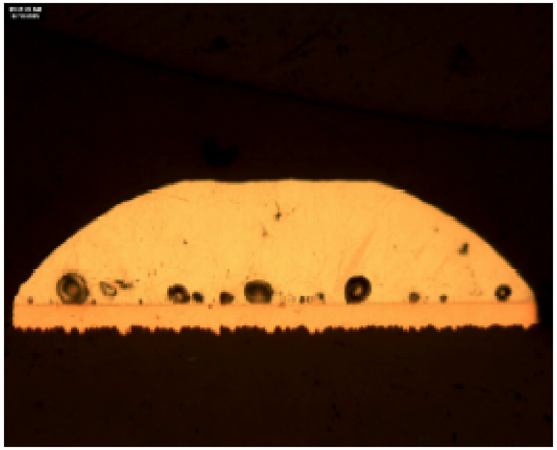
Immersion Silver

Immersion Gold

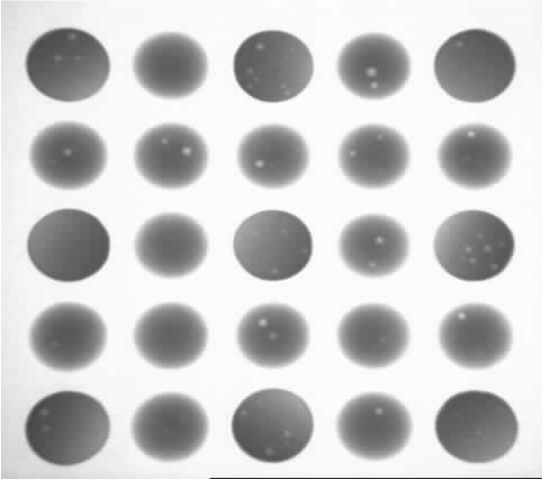
Reflow Basics (continued)

Old Board Lot





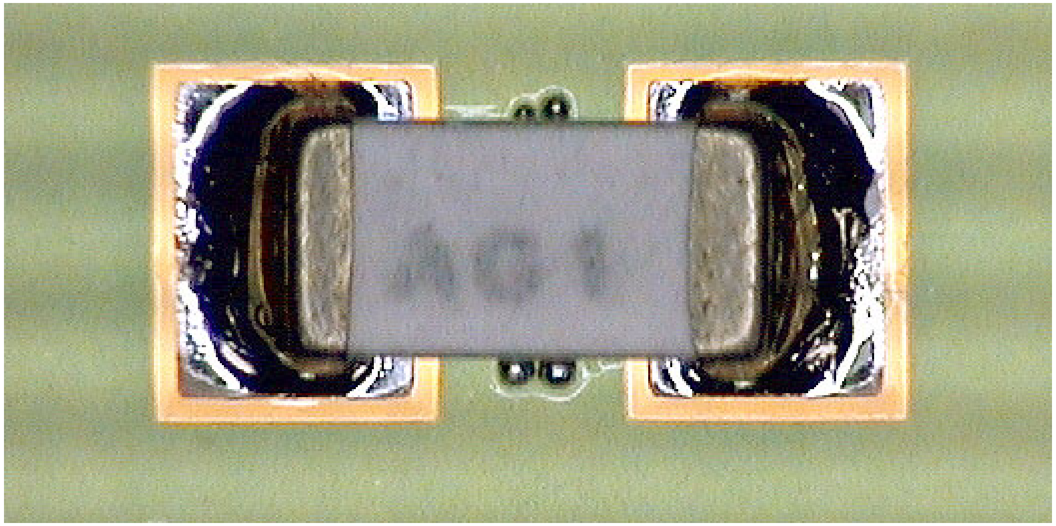
New Board Lot



Reflow Basics (continued)

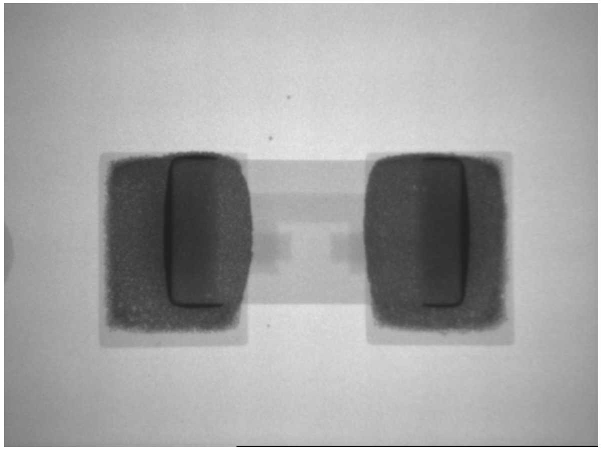
Common Reflow Defects

- **Solder Beads**
  - Higher solids paste can help
  - Paste with low or no hot slump can help
  - Air reflow (if nitrogen) can help
  - Home plate aperture design (effective)
  - Crown aperture design (most effective)

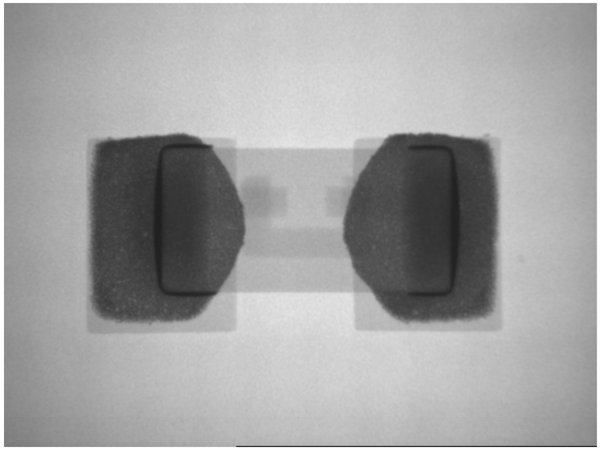


Reflow Basics (continued)

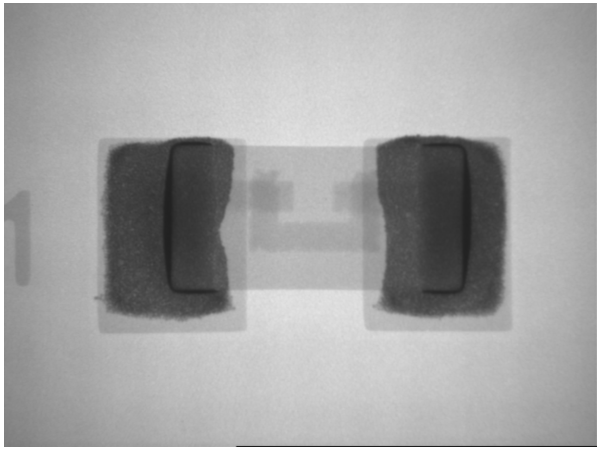
X-Rays after placement but before reflow



10% Inside Reduction

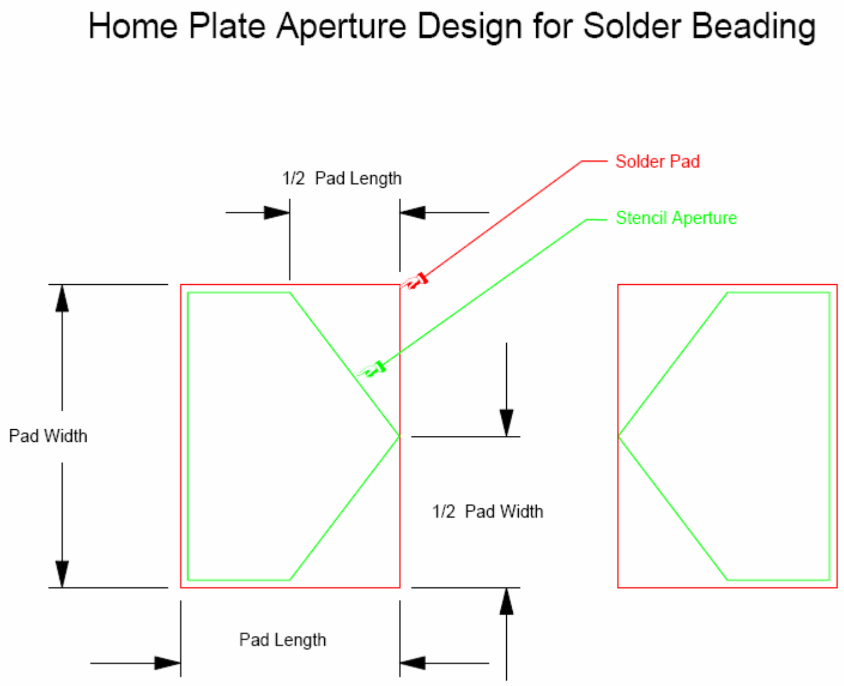


Home Plate



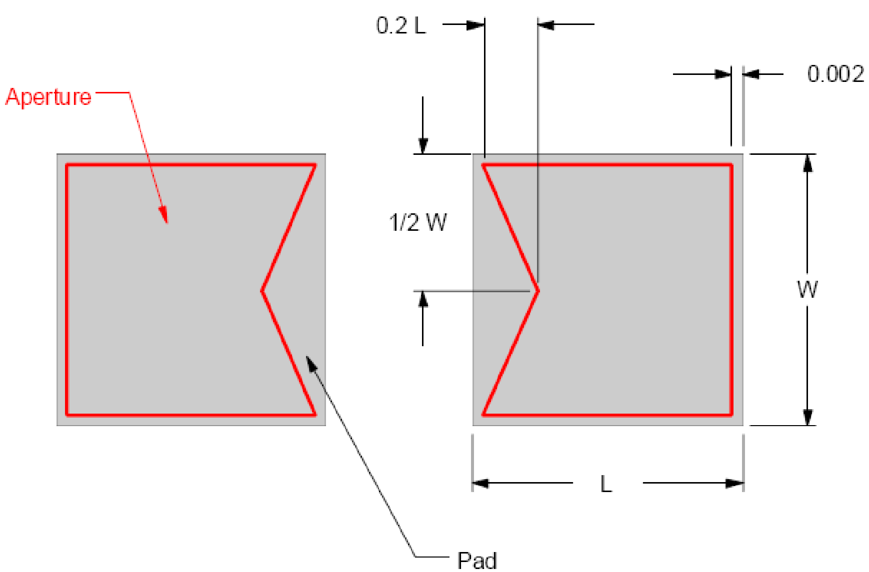
Crown

Reflow Basics (continued)



Crown Aperture Design Guideline

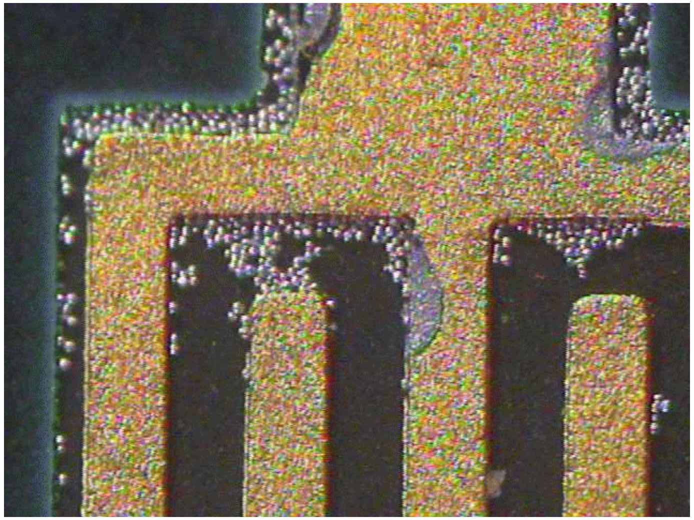
(Solder Bead Reduction)

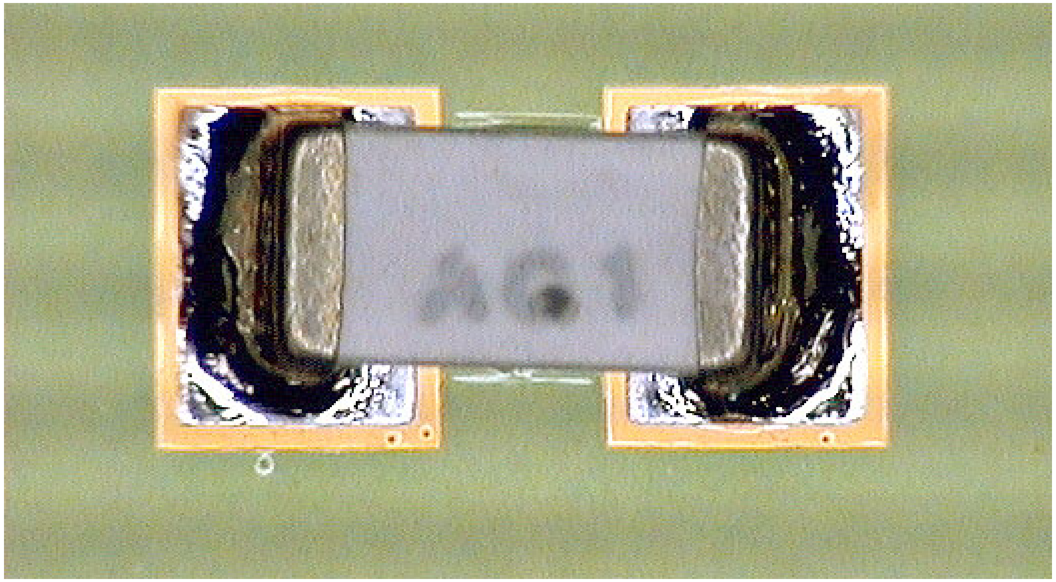


Preferred Solution

Reflow Basics (continued)

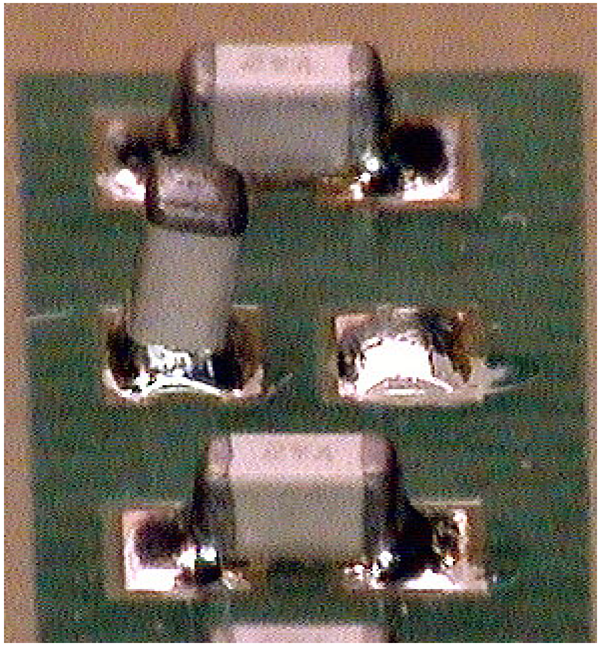
- **Solder Balls**
  - Nitrogen reflow can minimize
  - Poor miss-print board cleaning?
    - **Look for solder balls in the vias**
  - Water clean
    - **Pre cleaning process solder balls are normal**
  - Poor stencil to pad gasketing?
  - Profile not optimal
    - **Ramp-to-spike preferred**





Reflow Basics (continued)

- **Tombstones**
  - Paste not registered pads properly
  - Component not centered on pads
  - Inter-pad gap too big (common in European designs)
    - **Shrink gap**
  - One pad tied to thermal drain such as a via
  - Variable component end term solderability
  - Air reflow (assumes nitrogen reflow)
  - Anti-tombstone alloy
    - **Blurs reflow event to help form both solder joints together**
    - **Post reflow alloy is the same**



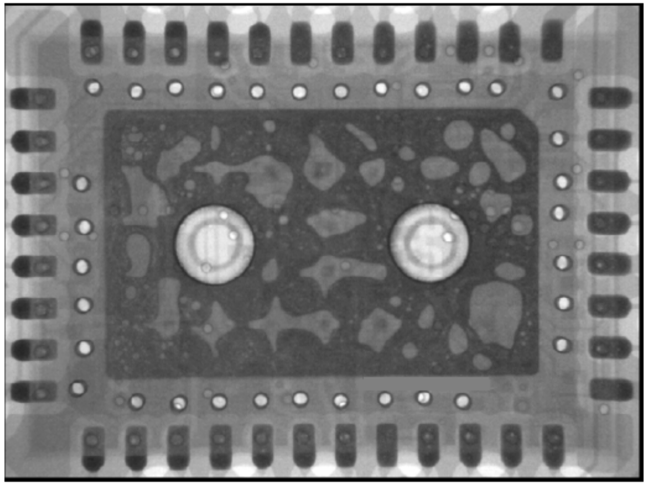
The Tombstone effect

by

CMD-PDF-TS

Reflow Basics (continued)

- **Voiding**
  - Voiding is mainly due to expanding gas during reflow (liquidus)
    - **Water vapor**
    - **Solvents**
    - **Gaseous reaction byproducts**
  - Main source is paste formulation
    - **Generally more active formulations = more voiding**
    - **Generally Sn63 is better than Lead Free alloys**
  - Secondary source is surface finish
    - **ENIG is best, OSP is worst**
  - Tertiary source is component type
    - **BGA's give central large void**
    - **Leadless and SOT devices have large parallel surfaces to trap voids**
  - Last (and least powerful) is profile
    - **Ramp is better than soak in preheat**



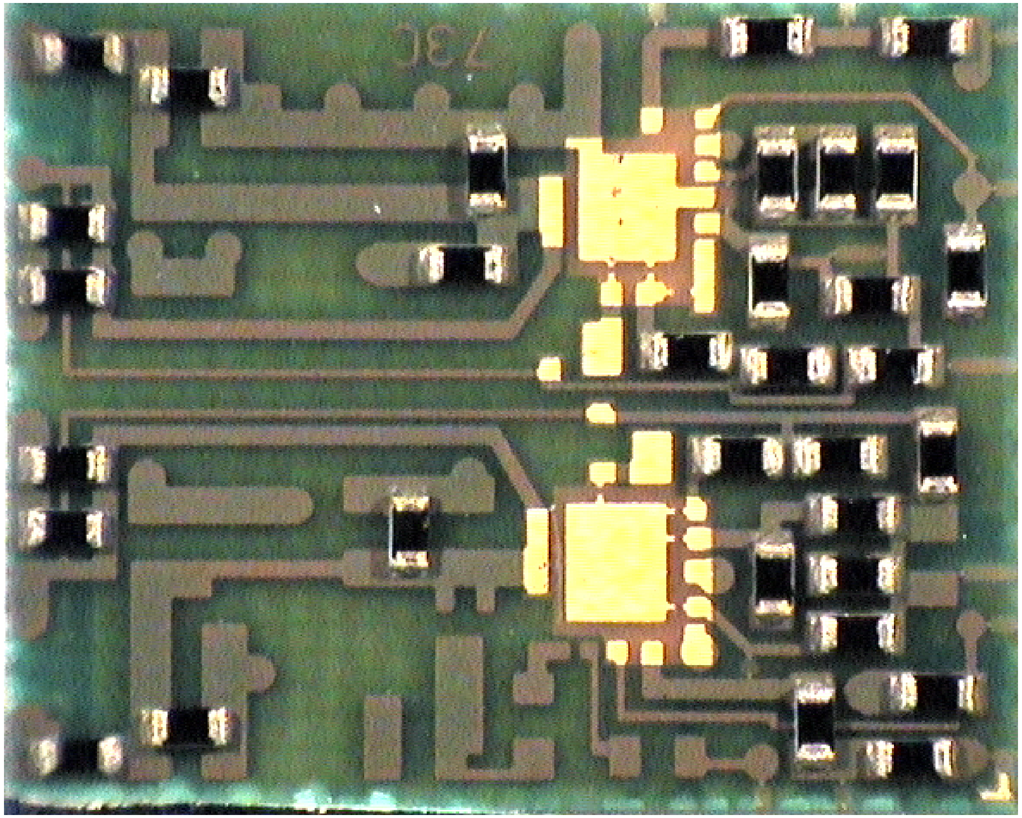

9:12:37 PM

Cleaning Basics

- **Most no cleans are "Not Cleans"**
- **Water Clean basics**
  - **Water should be de-ionized (DI)**
  - **Water should be heated (120-160F)**
  - **Impinging spray is best**
    - Gets under components
    - Adds mechanical cleaning energy
  - **Drying is last step in cleaning process**
  - **Certain high surface area dark solder masks will retain "flux stains"**
    - Cosmetic and very difficult to remove
    - Nitrogen reflow helps
    - Cleaning right after reflow helps
    - Lowering peak reflow temp helps
  - **Clean after every reflow !**

Cleaning Basics (continued)

Case Study: SiP Module "White Ring"



Light Microscope

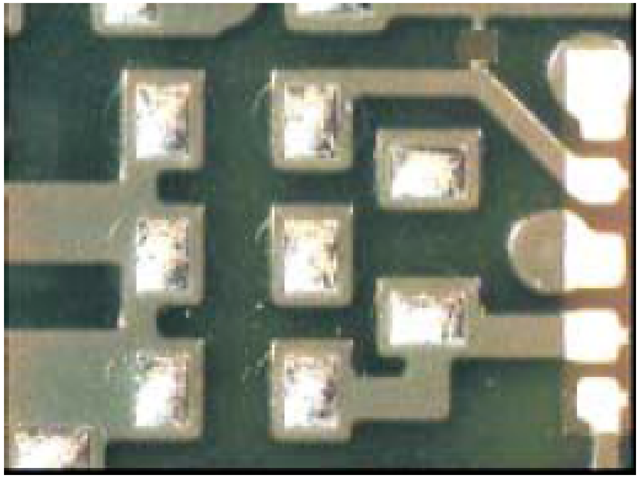


Figure 4 F540Ag35 Reflow in Air

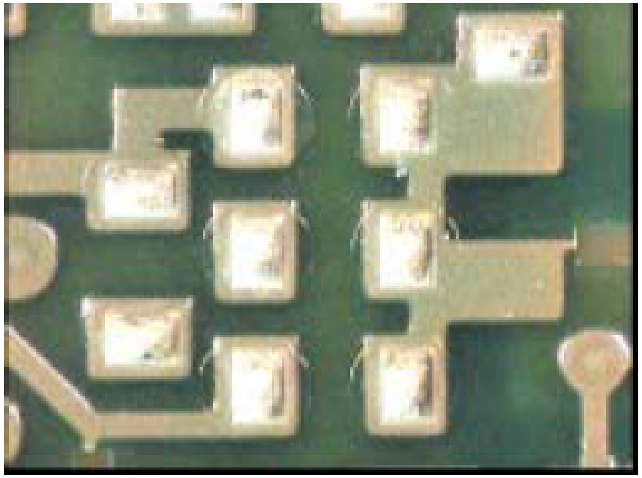


Figure 5 F540Sb5 Reflow in Air

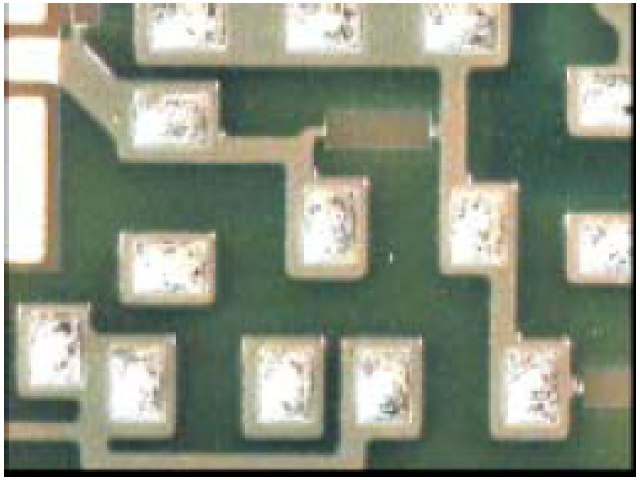


Figure 6 F540Ag35 Reflow in Nitrogen

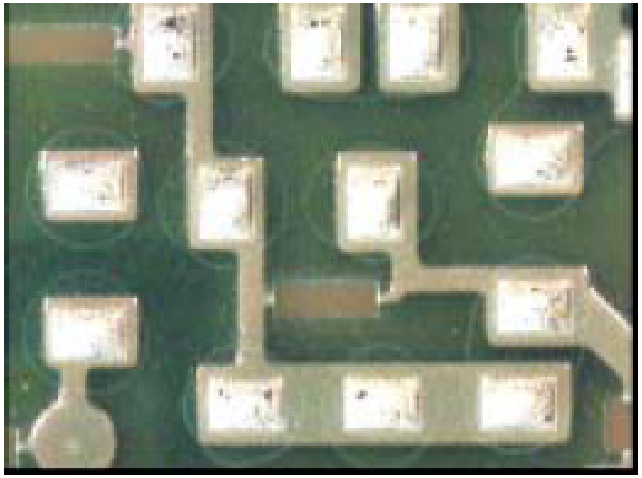


Figure 7 F540Sb5 Reflow in Nitrogen

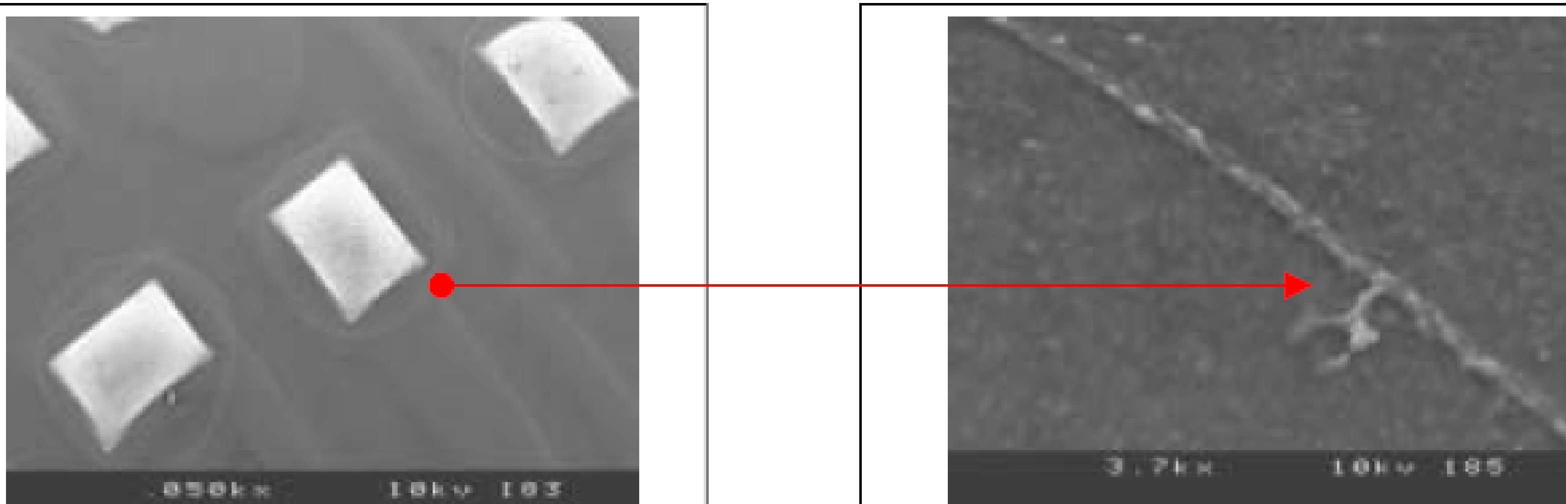


Figure 12 F540Ag35 in Air

Figure 13 SnO2 White Ring @ 3,700X

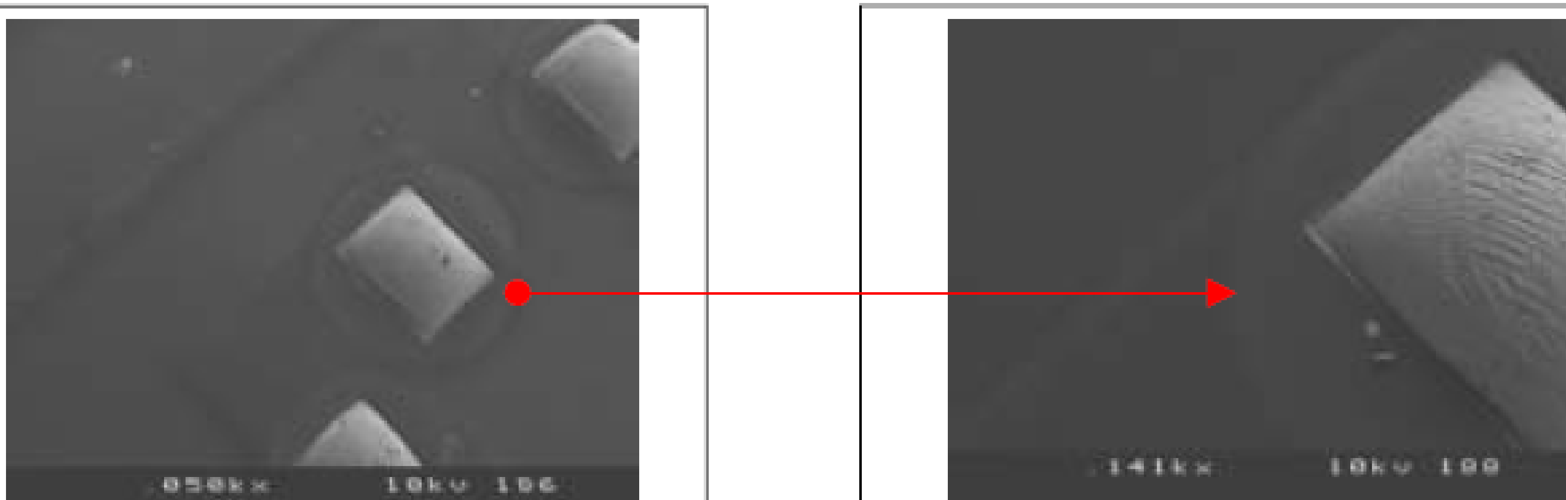


Figure 14 F540Ag35 in Nitrogen

Figure 15 F540Ag35 in nitrogen

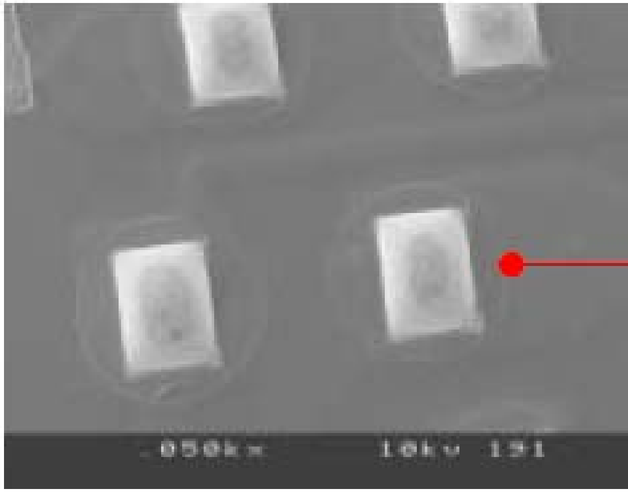


Figure 16 F540Sb5 in Air

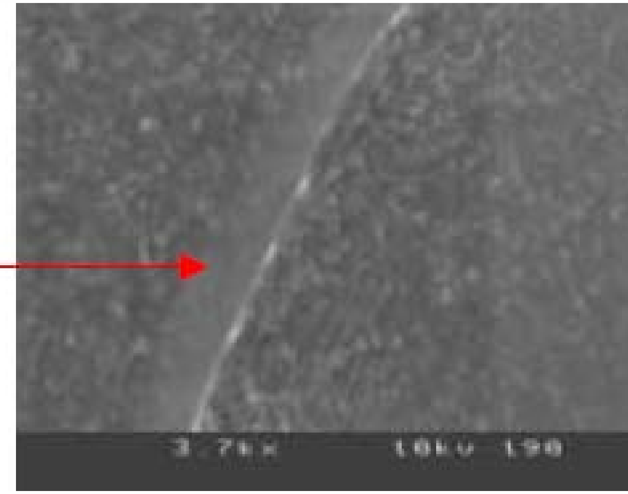


Figure 17 Sn02 Residue Ring @ 3,700X

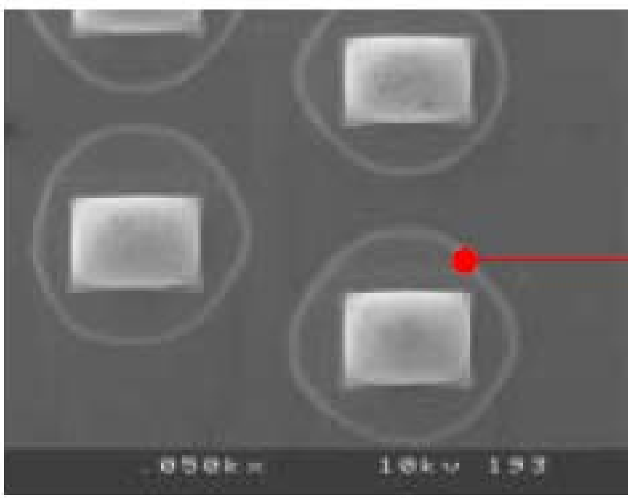


Figure 18 F540Sb5 in Nitrogen

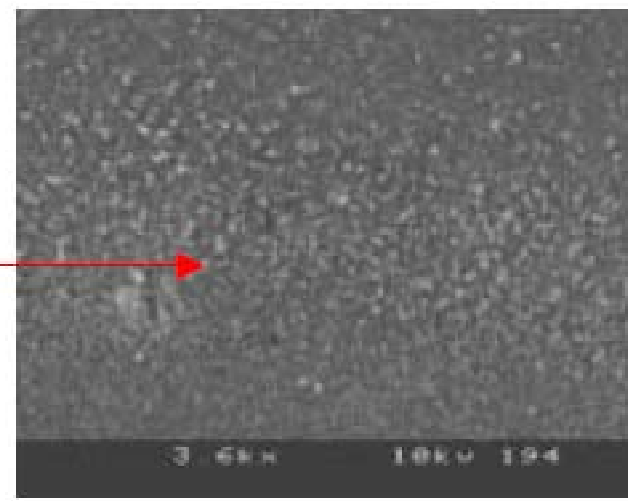


Figure 19 SnO2 Residue Ring @ 3,600X

Ion	F540Sb5 90H3 Nitrogen Reflow Maximum Wash	F540Sb5 90H3 Air Reflow Maximum Wash	F540Sb5 90H3 Air Reflow Minimum Wash	F540Ag35 90M3 Nitrogen Reflow Maximum Wash
	S1	S2	S3	S4
Fluoride	ND	ND	ND	ND
Chloride	ND	ND	ND	ND
Nitrite	ND	ND	ND	ND
Bromide	ND	ND	ND	ND
Nitrate	ND	ND	ND	ND
Sulfate	ND	ND	ND	0.29
Phosphate	ND	ND	ND	ND
Acetate	0.14	0.15	0.28	0.29
Formate	ND	0.15	0.28	0.29
MSA	ND	ND	ND	ND
Adipic	ND	ND	ND	ND
Succinic	ND	ND	ND	ND
Lithium	ND	ND	ND	ND
Sodium	ND	0.15	0.43	0.29
Ammonium	0.14	ND	0.14	0.15
Potassium	ND	ND	ND	ND
Magnesium	ND	ND	ND	ND
Calcium	1.00	ND	ND	1.17
Chloride (Cl)	ND	ND	ND	ND
Bromide (Br)	ND	ND	ND	ND
Sodium + Potassium	ND	0.15	0.43	0.29
Total	1.14	0.15	0.57	1.90

Ion	F540Ag35 90M3 Air Reflow Minimum Wash	F540Ag35 90M3 Air Reflow Maximum Wash	Blank Board
	S5	S6	S7
Fluoride	ND	ND	ND
Chloride	0.14	0.14	ND
Nitrite	ND	ND	ND
Bromide	ND	ND	ND
Nitrate	ND	ND	ND
Sulfate	0.14	0.14	0.45
Phosphate	ND	ND	ND
Acetate	0.28	0.29	0.45
Formate	0.28	0.57	1.21
MSA	ND	ND	ND
Adipic	ND	ND	ND
Succinic	ND	ND	ND
Lithium	0.00	0.00	ND
Sodium	0.28	0.43	1.21
Ammonium	0.14	0.14	0.15
Potassium	0.00	0.00	ND
Magnesium	0.00	0.00	0.15
Calcium	1.25	1.43	4.55
Chloride (Cl)	0.14	0.14	ND
Bromide (Br)	ND	ND	ND
Sodium + Potassium	0.28	0.43	1.21
Total Inorganic	1.94	2.29	6.52

Heraeus

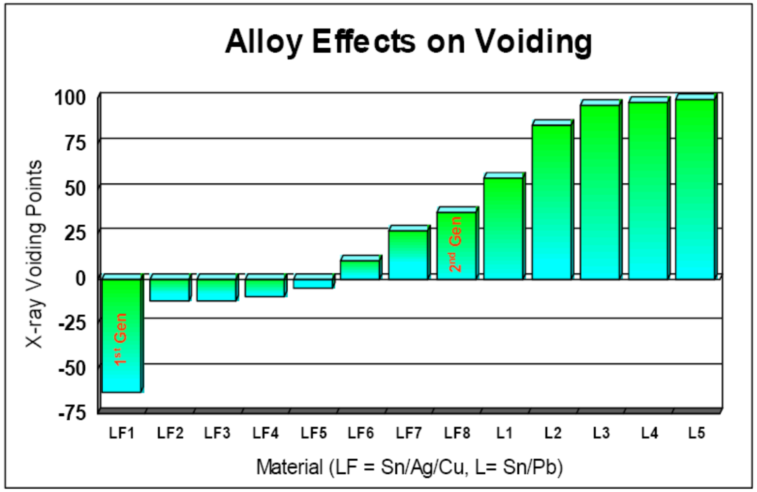
Cleaning Basics (continued)

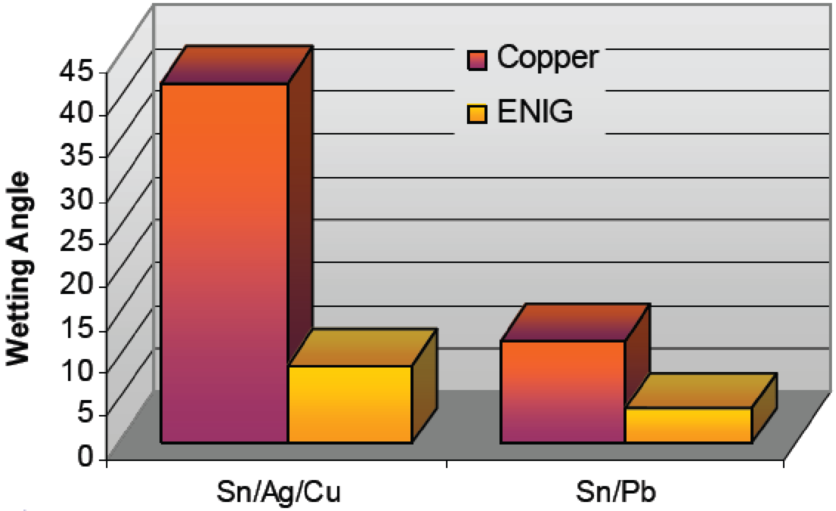
- **SiP reflow/clean experiment conclusions**
  - White ring visible with both light microscope and electron microscope
  - White ring is tin oxide
  - Nitrogen minimizes ring
  - All test coupons pass ion chromatography
  - Blank boards failed for calcium ion
  - White ring is cosmetic

Lead Free Basics

– Common issues

- **Printing is equal to or better than tin/lead**
- **Hot slump is typically more than tin/lead**
- **Wetting can be less than tin/lead**
  - Nitrogen reflow is helpful
  - Surface finish of board very powerful
- **Voiding can be more than tin/lead**





Lead Free Basics (continued)

- **RoHS Challenges**
  - “We cannot defend our position as RoHS compliant from a customers solder joint”
    - **Amount of material is too small for a quantitative assay**
    - **Solder in solder joint is a blend of board finish, paste and component finish**
    - **Ownership of the assembly process is the customers.**
  - “Last word” testing is an ICP assay of bulk metal
    - **Requires 5-10grams reflowed in clean crucible**
  - Hand held XRF is useful and accurate for paste samples
    - **Borderline readings must be refereed by ICP**
  - SEM EDS is only qualitative