Improving Yields and Quality: Two Case Studies: Graping and the Head-on-Pillow defect

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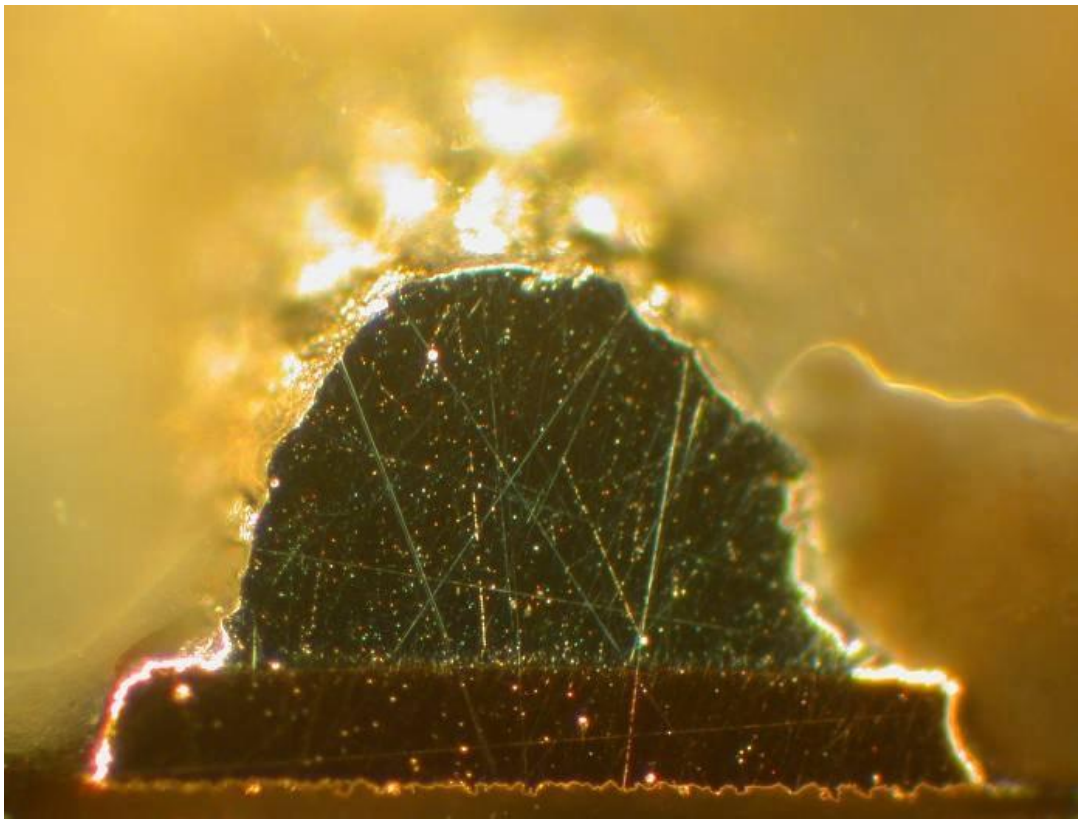
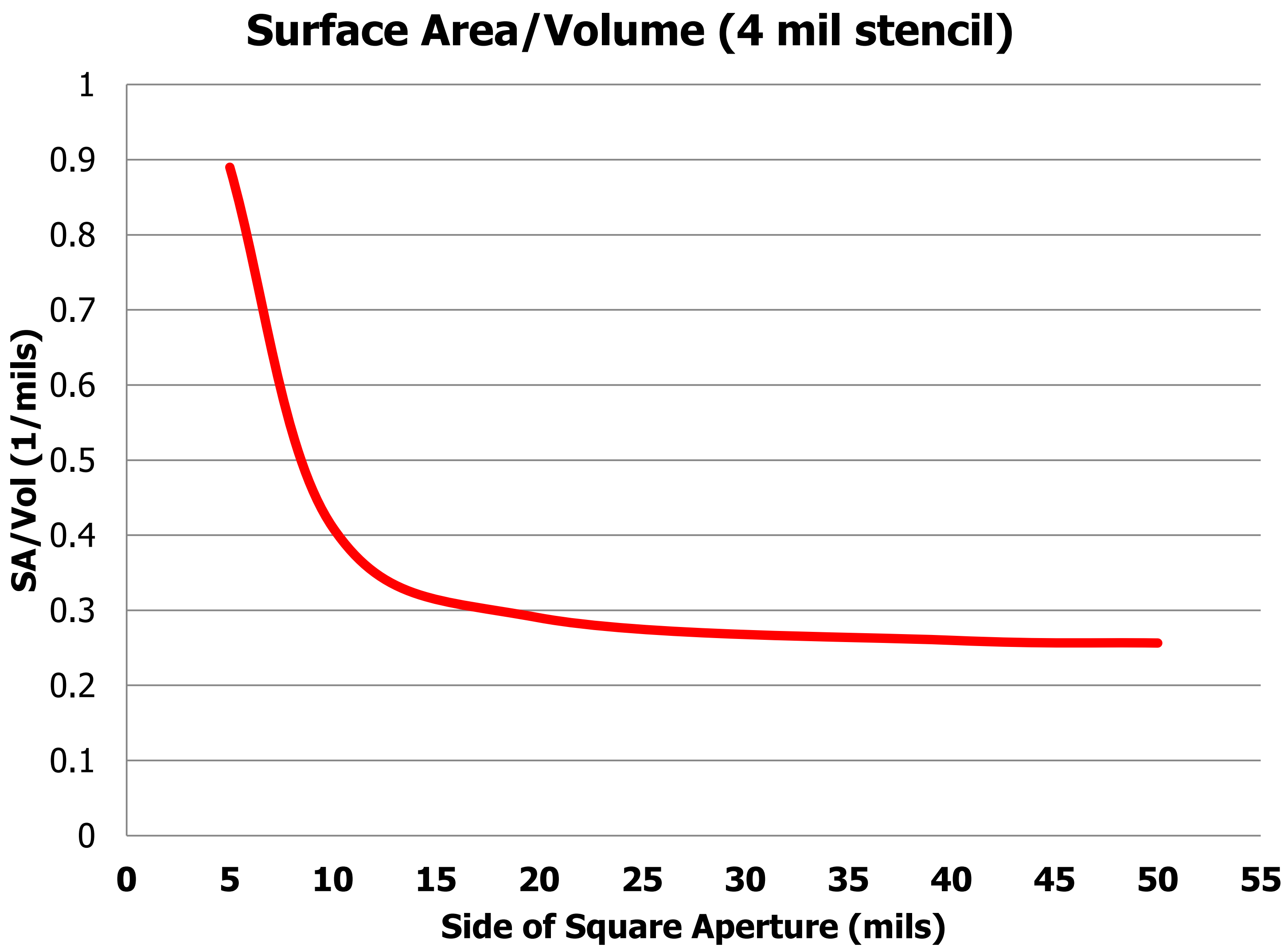
INDIUM CORPORATION

Graping

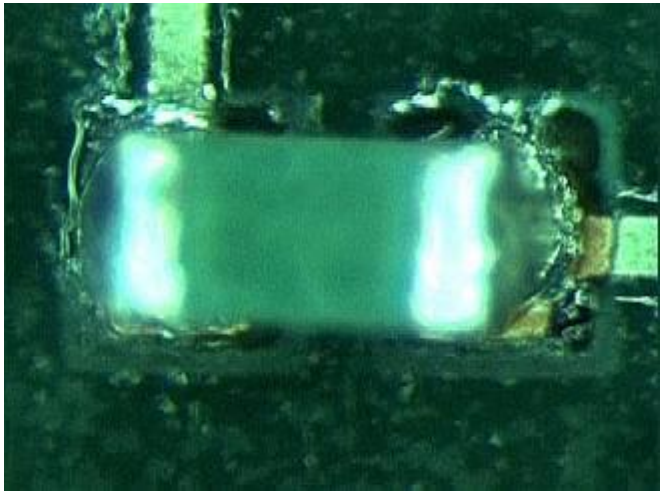


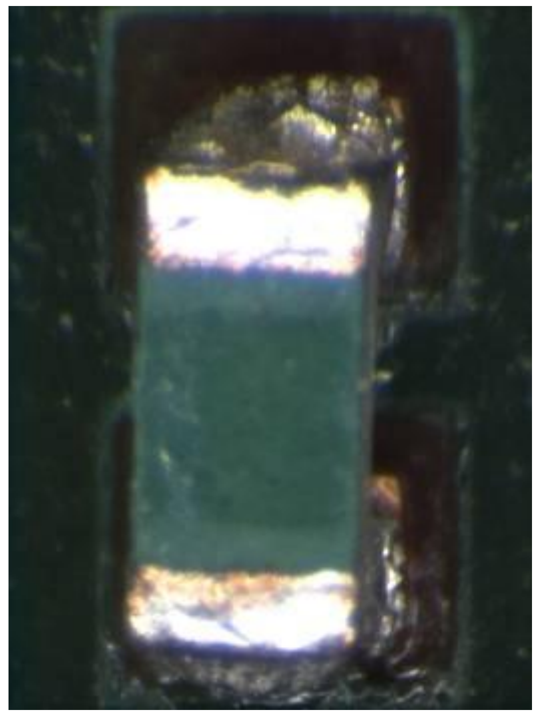
Graping

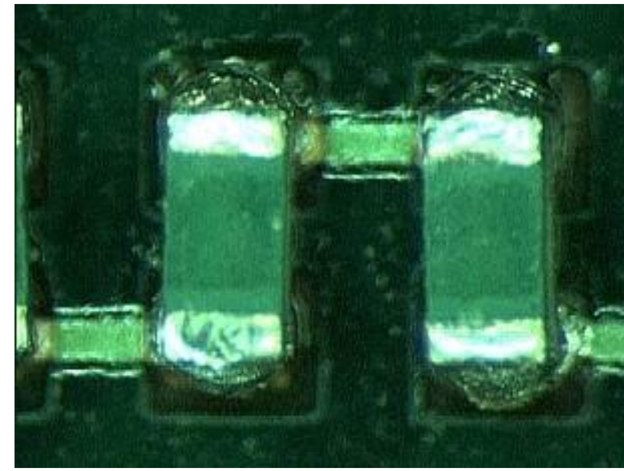
- Miniturization of electronics has given us 01005 passives and 0.4 to 0.3 mm pitch packages
- The resulting smaller solder paste deposits = surface powder oxidation
- Higher process temperatures (i.e. 227C vs 217C) may exacerbate graping (and tombstoning)
- Dopants such as P and Ge may help (control oxidation)

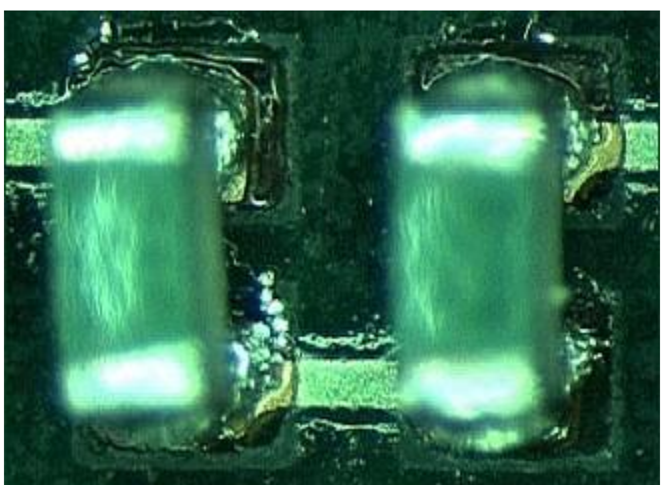

Surface Area/Volume (4 mil stencil)
SA/Vol (1/mils)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0 5 10 15 20 25 30 35 40 45 50 55
Side of Square Aperture (mils)

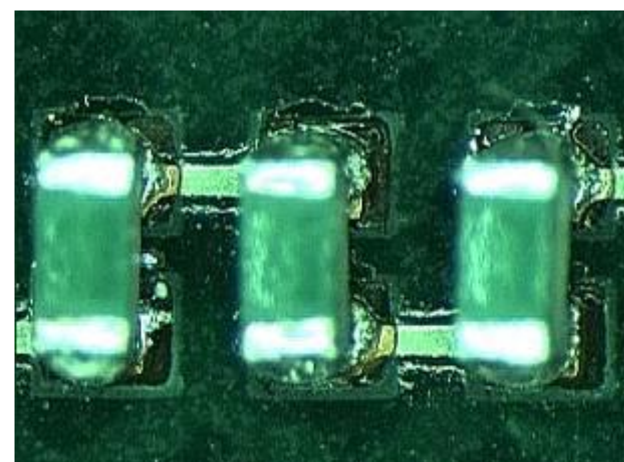
Small Deposit Coalescence Challenge



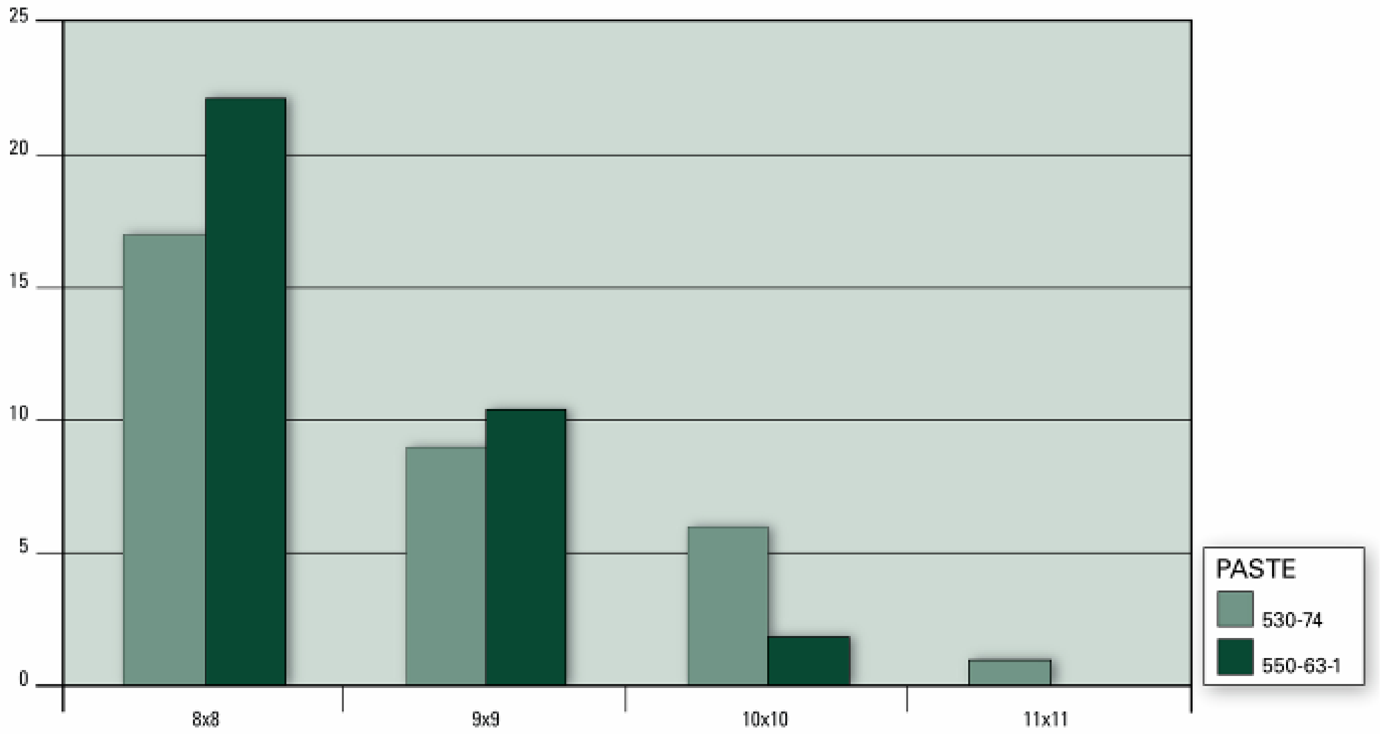








Graping vs. Aperture Size

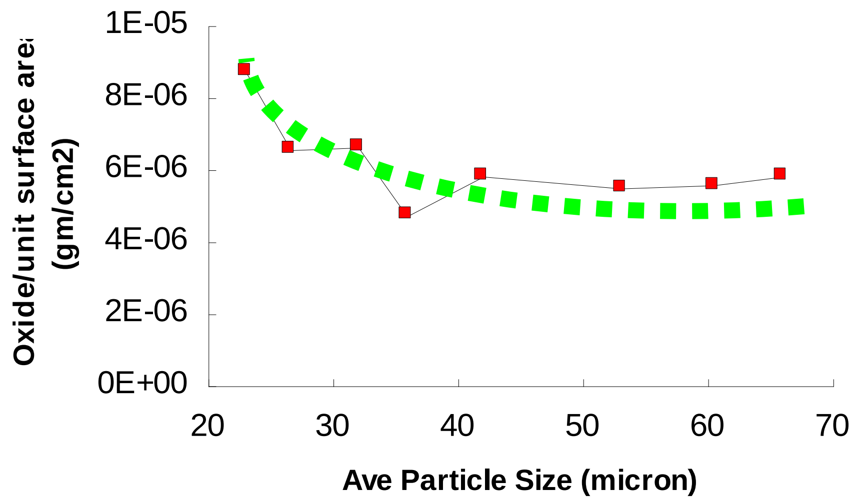


Smaller Apertures Require Finer Paste Particle Sizes

Powder Size		
	Diameter Range microns	
TYPE		
3	**25**	**45**
4	**20**	**38**
5	**15**	**25**
6	**5**	**15**

Oxidation Challenge

- Finer powder needed for finer pitch
- The higher surface area per unit volume aggravate oxidation issue
- Oxide thickness become higher for very fine powder due to high curvature thus high energy state
- Anti-oxidation dopants such as P, Ge, desired for alloying



Oxide layer thickness increases for fine powder

(Indium)

Microalloying

A Nickel Addition was found to be most effective

Microalloying

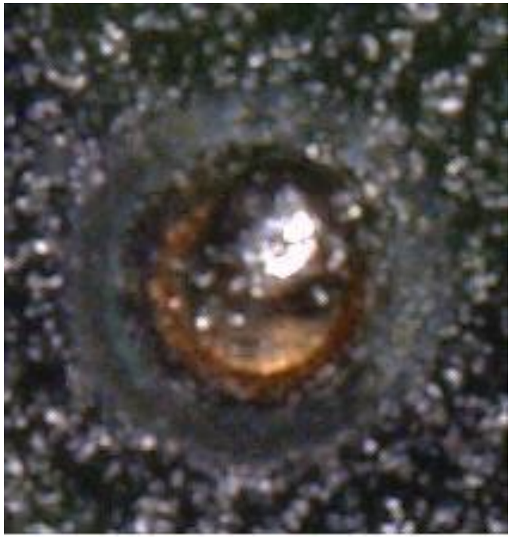
The Ge acts as an antioxidant and surface active agent

Sn-0.7Cu-0.05Ni

15 minute
Ramp to 340°C
30 minute cool

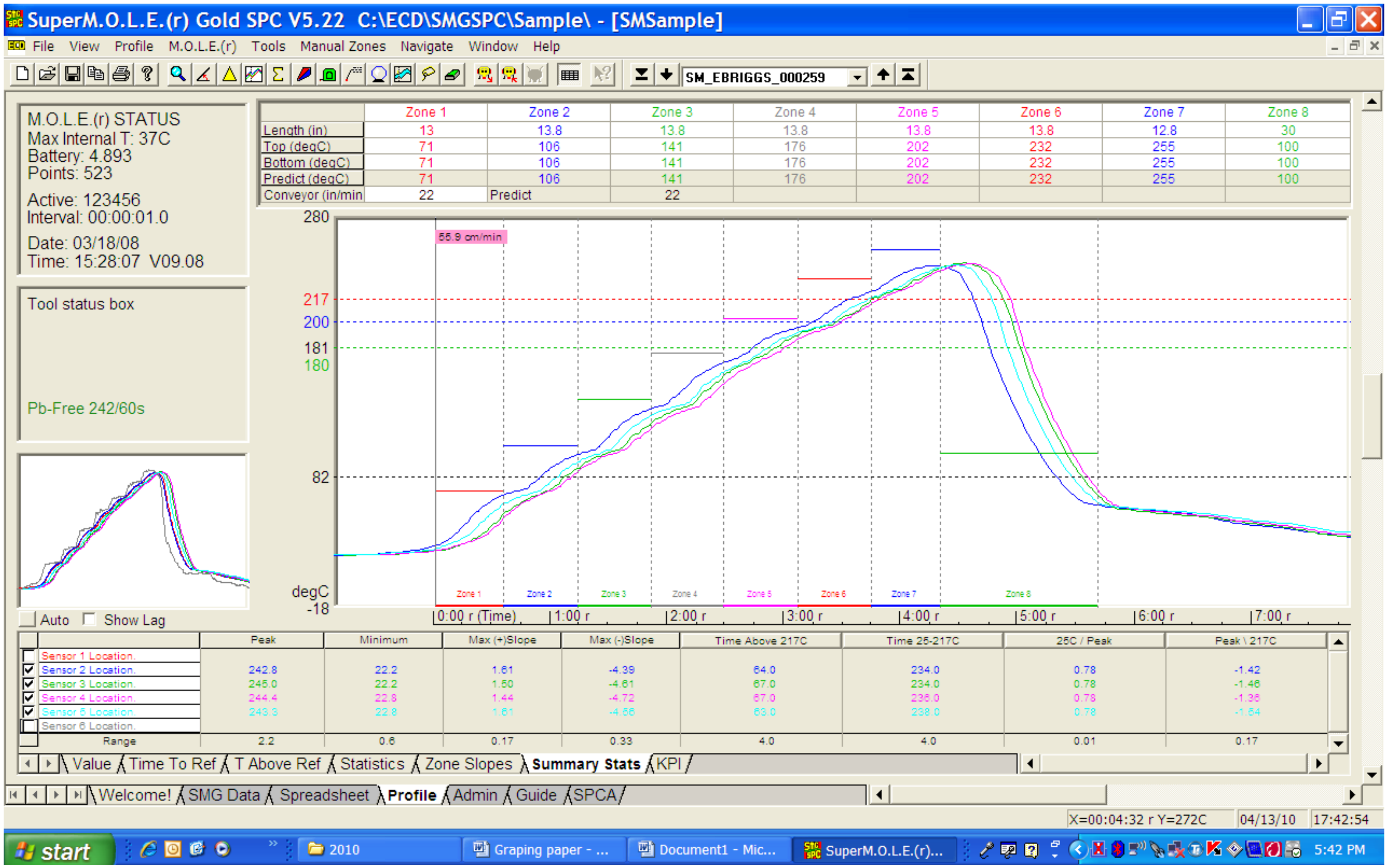
Sn-0.7Cu-0.05Ni+Ge

Particle Size Effect on Reflow Result

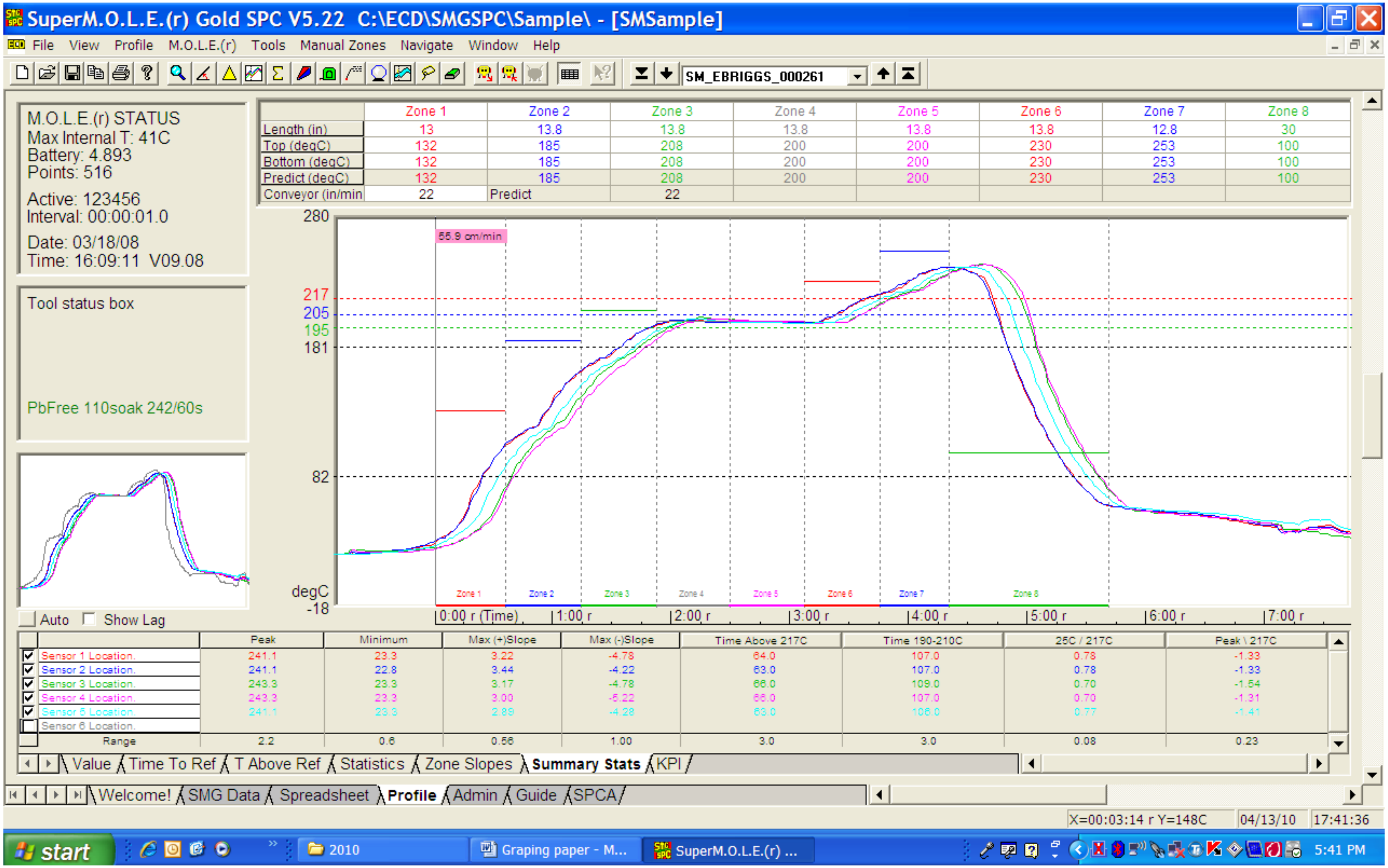


Typical results: Type 3 (left) vs. Type 6 (right) using the same no-clean flux chemistry and reflow profile (RTP).

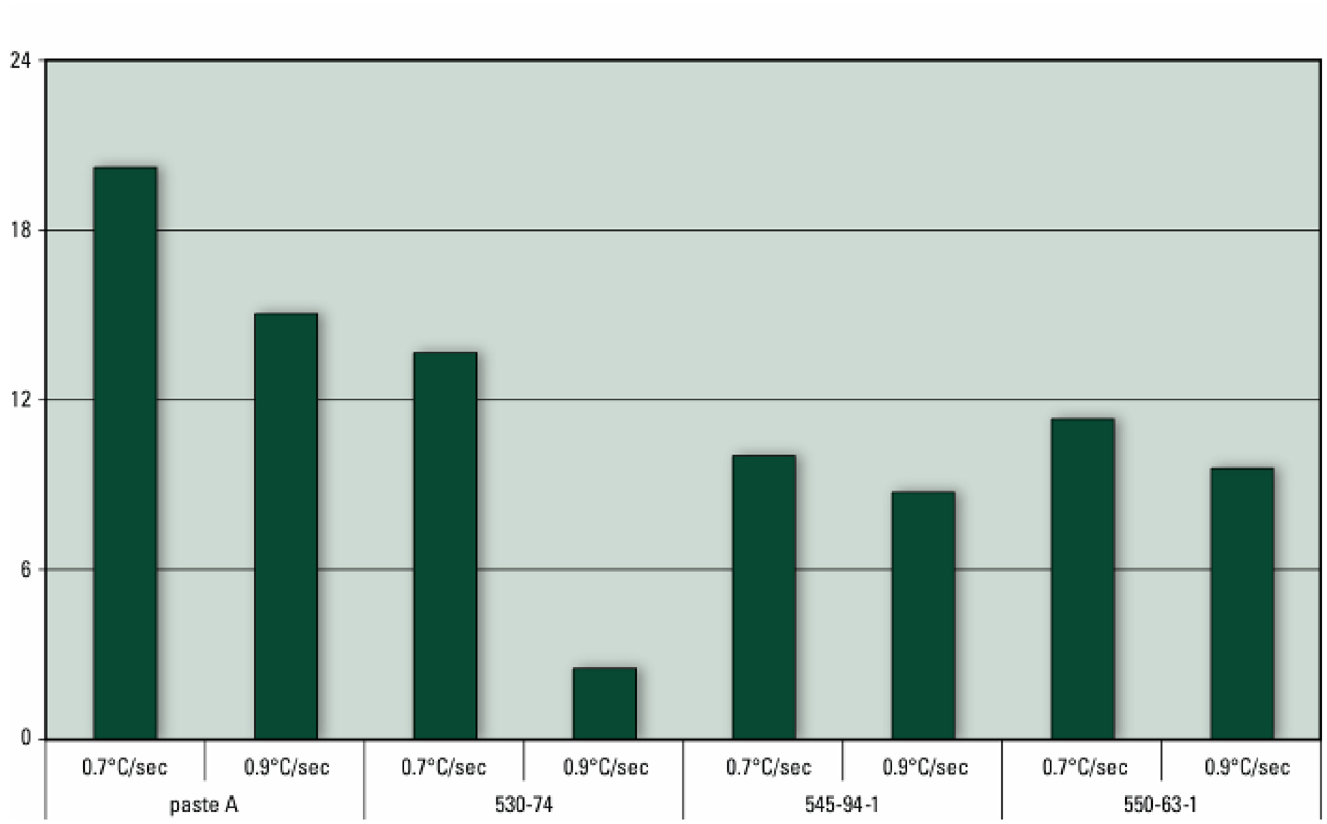
Ramp to Peak Profile



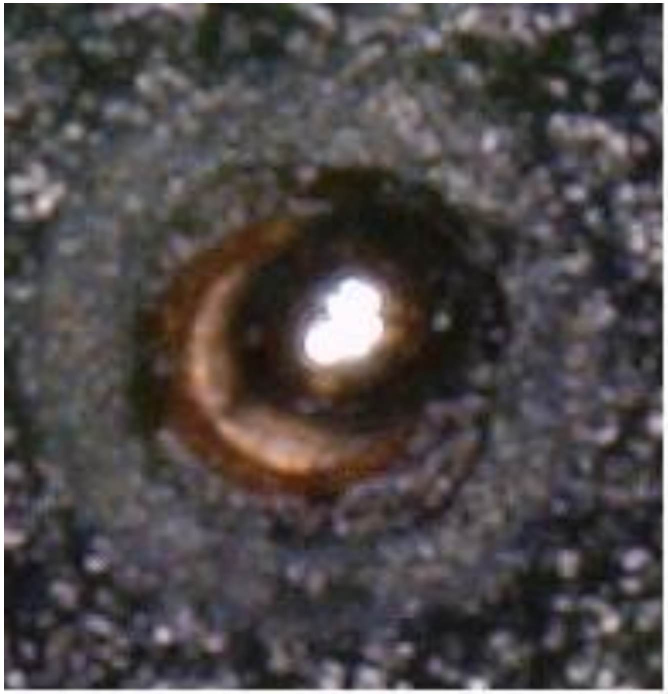
Soak Profile



Profile Optimization

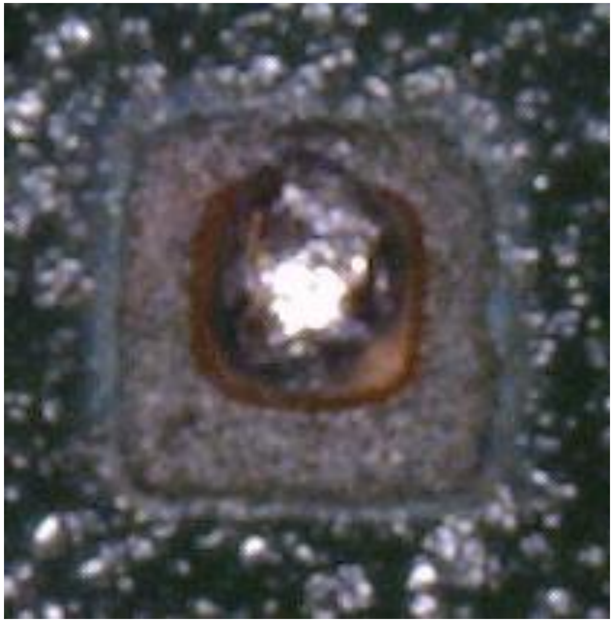


Ramp-to-Peak (RTP) vs. Soak



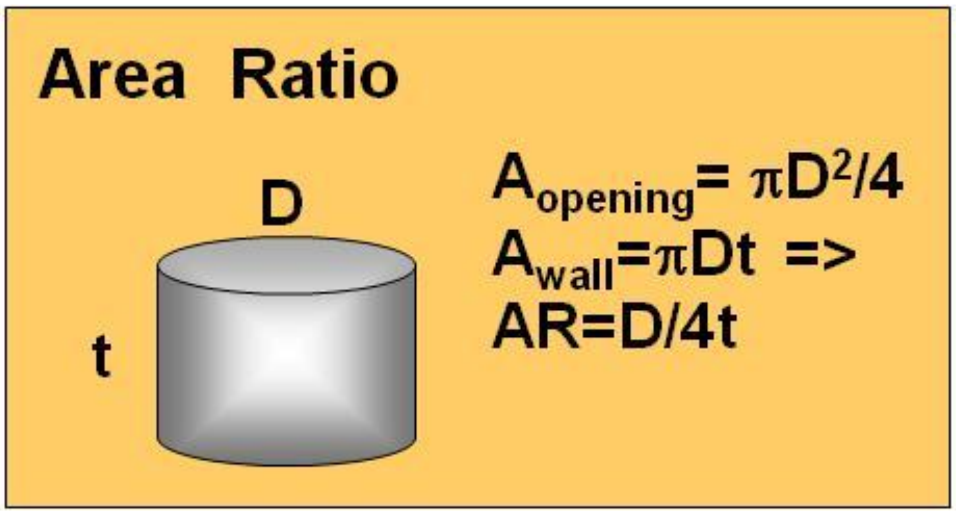
Typical results: RTP profile (left), soak profile (right) using the same Type 6 powder size and flux chemistry (no-clean),

Round Aperture vs. Square Aperture



Typical results: Circular aperture/pad (left), square aperture/pad (right) using the same Type 3 powder size, area ratio, flux chemistry (no-clean), and reflow profile (RTP).

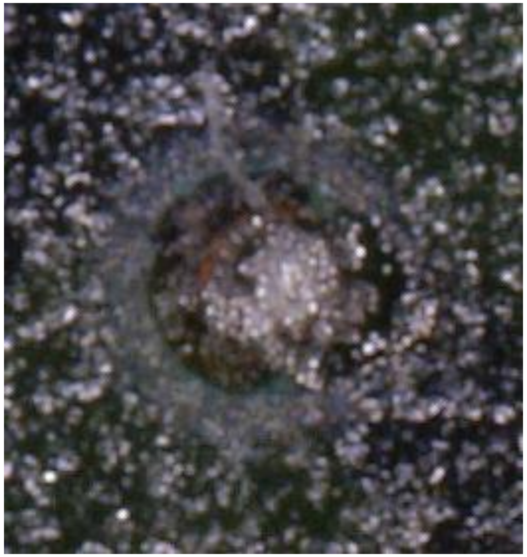
Why the Difference?



- AR > 0.66 for good printing
- Some modern pastes can print <0.50
- Should be verified experimentally

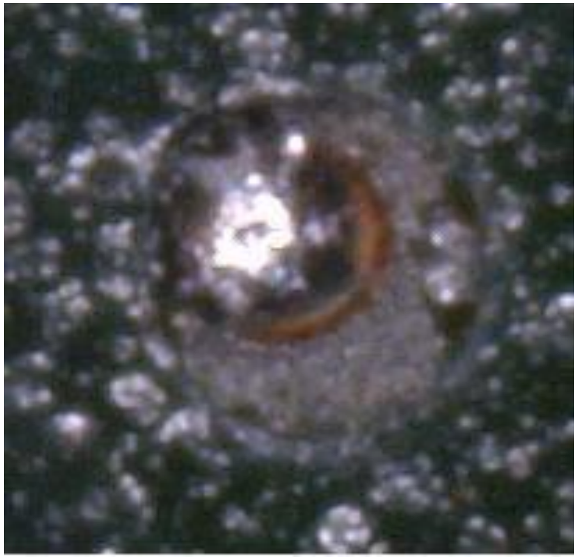
- AR for square:
  - $D^2/4Dt = D/4t$
- But area of circle = $\pi D^2/4 = 0.785\ D^2$
- D^2 for a square
  - >25% more volume
- Plus experiments show better transfer efficiency from square apertures
  - >40% more volume

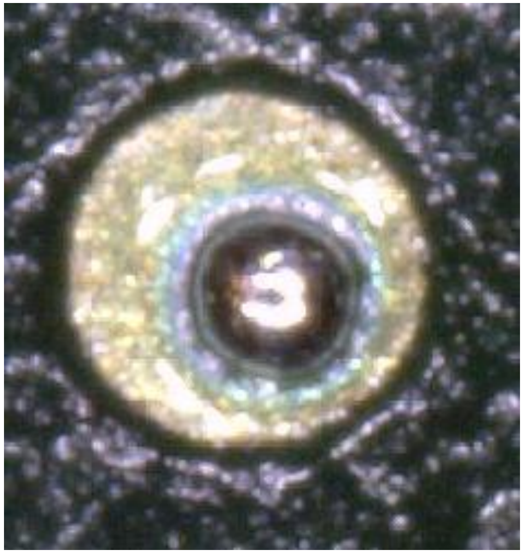
Water-Soluble vs. No-Clean



Typical results: Water-soluble (left) vs. no-clean (right) using the same Type 6 powder size and reflow profile (RTP).

Solder Mask Defined is Better



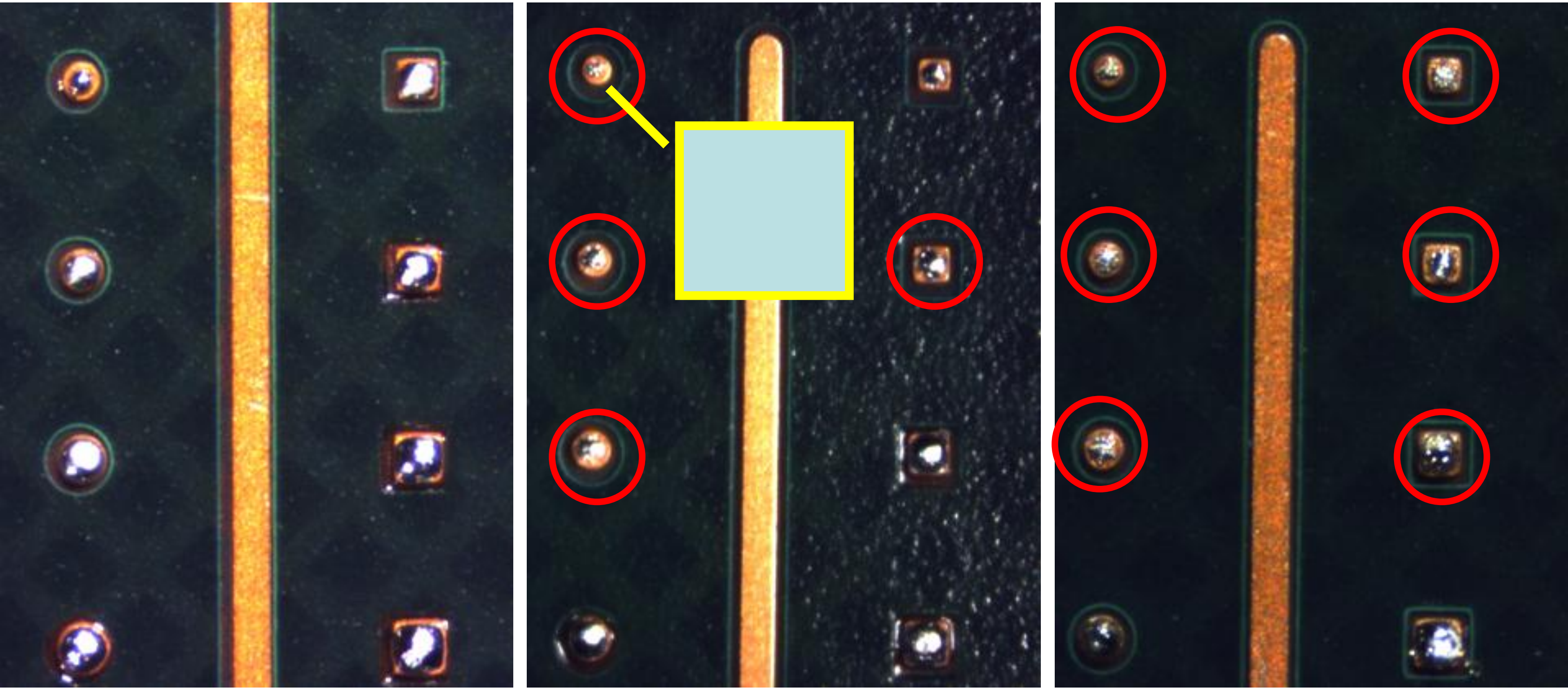


Typical results: Non-solder mask defined pad (left), solder mask defined pad (right) using the same Type 6 powder size, flux chemistry (no-clean), and reflow profile (RTP).

Graping Paste “A” vs. Others

The pads in red circle showed graping symptom

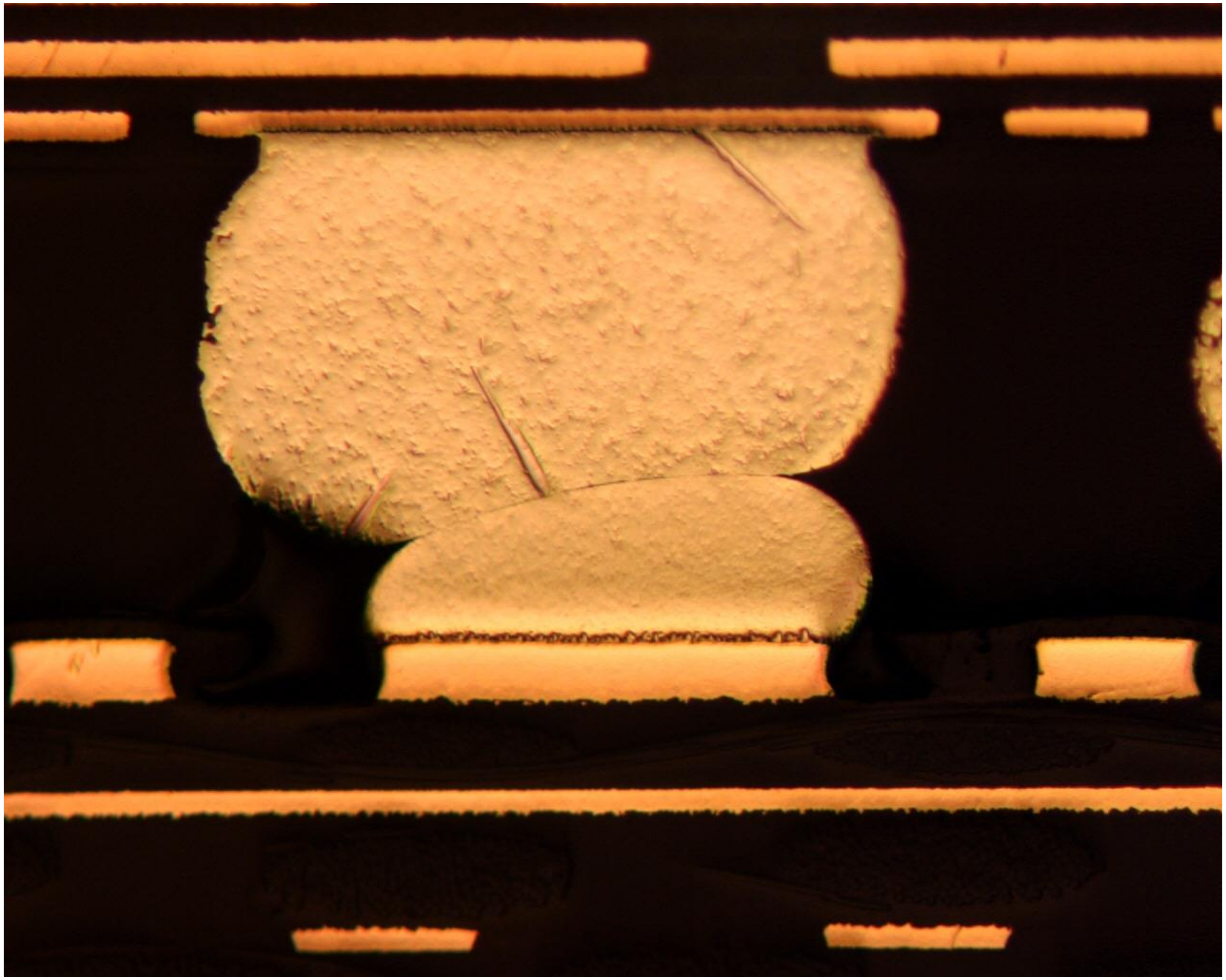
Paste A **S** **O**



To Minimize Graping

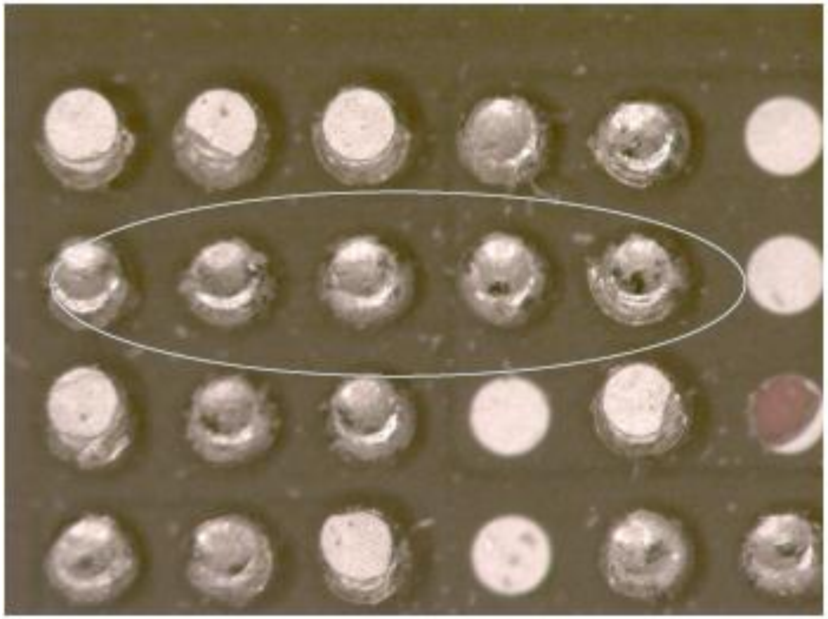
- Choose largest acceptable powder size
  – In most cases Type IV or courser
- Use a no clean paste
- Minimize time at high T
  – Ramp to peak
- Use square apertures, a little over size if possible to get the most amount of paste
- Use Solder Mask Defined Pads
- Choose a good paste

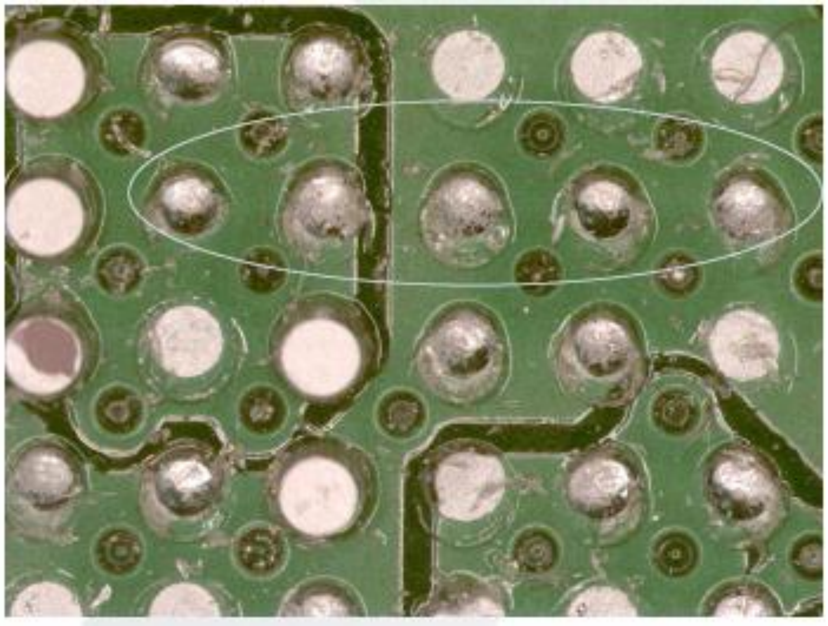
Head on Pillow (HoP)



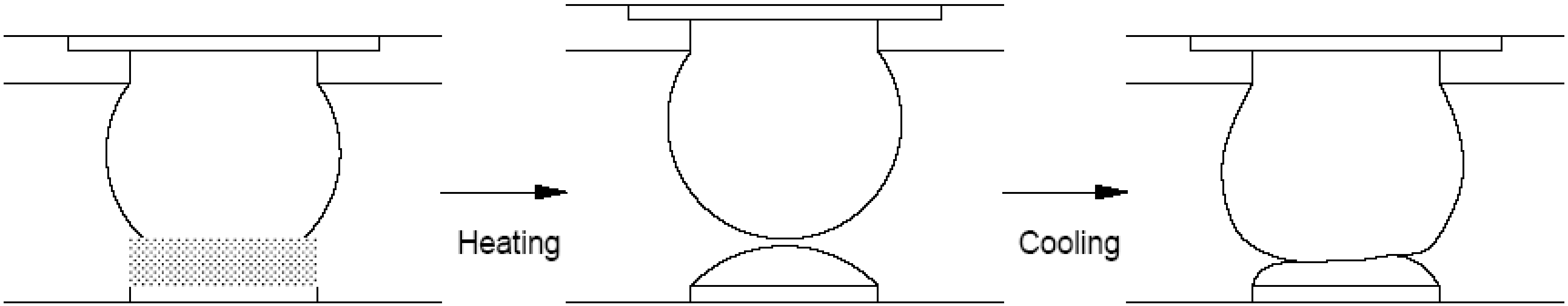
Overview

- Why is it an issue?
  - Still passes ICT & function testing
  - Cause of field failures





How HoP Happens

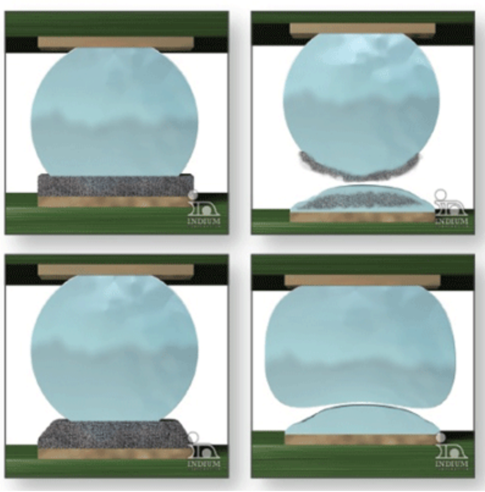


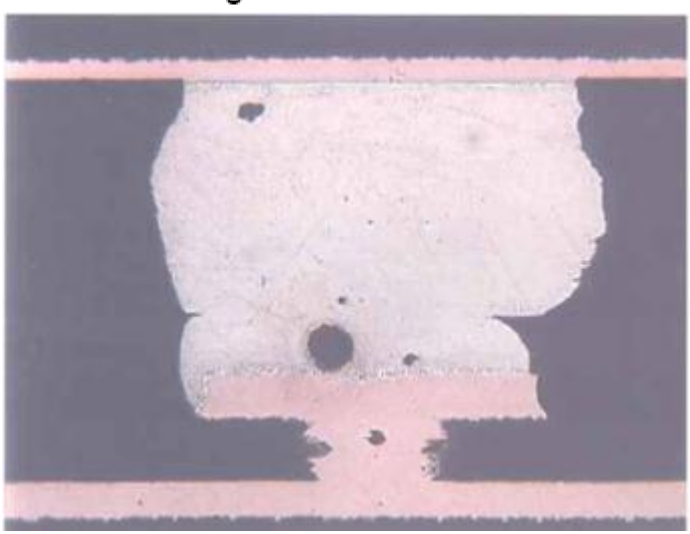
BGA placed on solder paste

Increased spacing due to warping. Both sides in liquid state.

Spacing closed down at cooling, contacting each other after solidification

Problem:



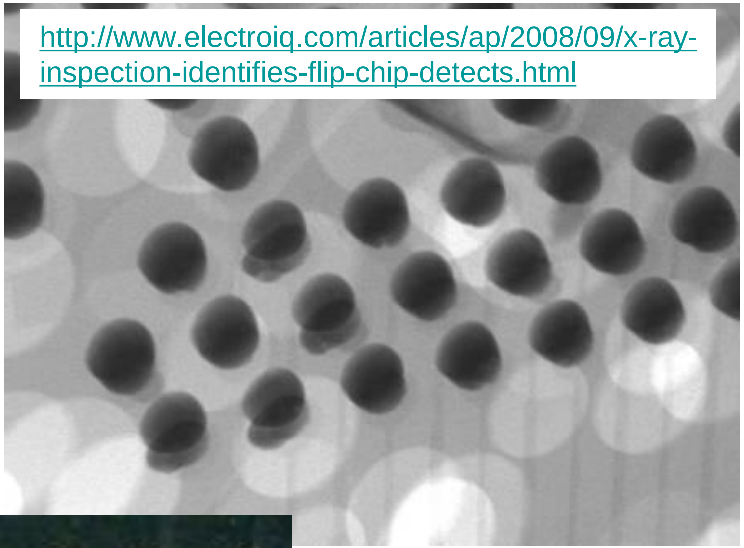


Types of HoP

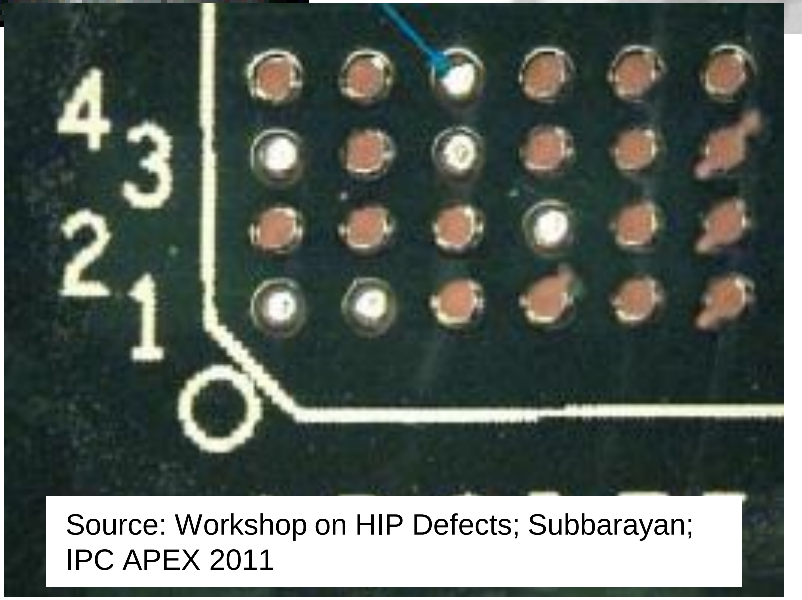
- Type 1: Excessive BGA Oxide or Contamination
  - The oxide film on solder ball is too thick for solder paste to break through to coalesce.
- Type 2: Excessive Warpage
  - Solder solidified already when the BGA ball is brought back in contact with solder dome on pad
- **Type 3: Warpage + Oxidation**
  - **Solder still in molten state when solder ball was brought in contact with solder dome on pad. However, the oxide film prevent the coalescence of two solder bodies.**

Detecting HoP

Source:http://ppsimanufacturing.wordpress.com/



http://www.electroiq.com/articles/ap/2008/09/x-ray-inspection-identifies-flip-chip-detects.html



Source: Workshop on HIP Defects; Subbarayan; IPC APEX 2011

Three Important HoP Trends

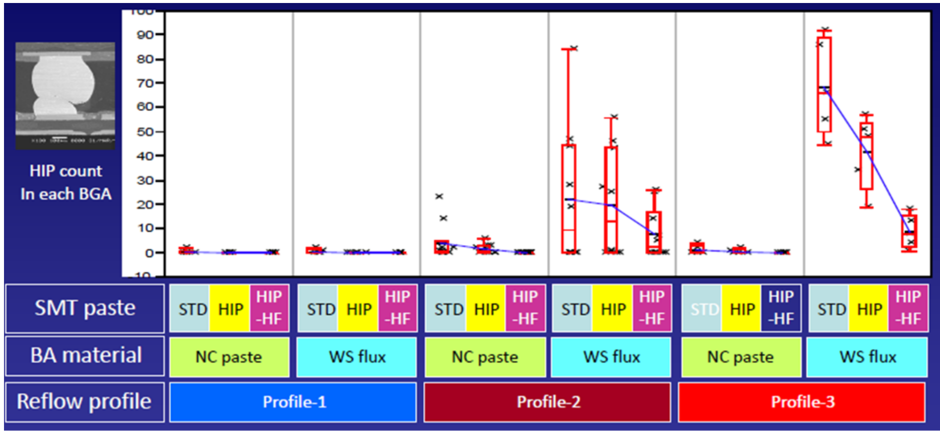
- Halogen-Free
  - Material Definition
  - Legislation
- Pb-Free and Mixed Alloys
  - Voiding and Reflow Temperatures
  - Drop Shock Resistance
  - Thermal Cycling
- Miniaturization (with #1 and #2 sprinkled in)
  - Printing
  - Graping
  - Head-in-Pillow

Investigation: Components

- Component Warpage
- Coplanarity
- Sphere Oxidation
  - Uncontrolled manufacturing
  - FIFO
  - Packaging
  - Storage
- Cleaning process after ball-attach
  - Contaminants from solution
  - Incomplete cleaning
  - Hydroxide formation
- Ball Alloy (match w/ paste)

Part	Lot #	Max Warpage Temp'	Range (Microns)	Average (Microns)	Std Dev
1	a	Var'	*80-100*	*91*	6
1	b	250	*73-90*	82	7
1	c	220	*73-90*	83	8
1	d	180	*47-90*	73	16
1	e	240	*61-107*	78	17
1	f	250	65-76	69	4
1	g	250	63-82	70	7
2	a	250	*96-106*	*101*	4
2	b	250	*101-114*	*107*	6
2	c	250	*85-91*	89	3
2	d	250	*79-92*	84	6

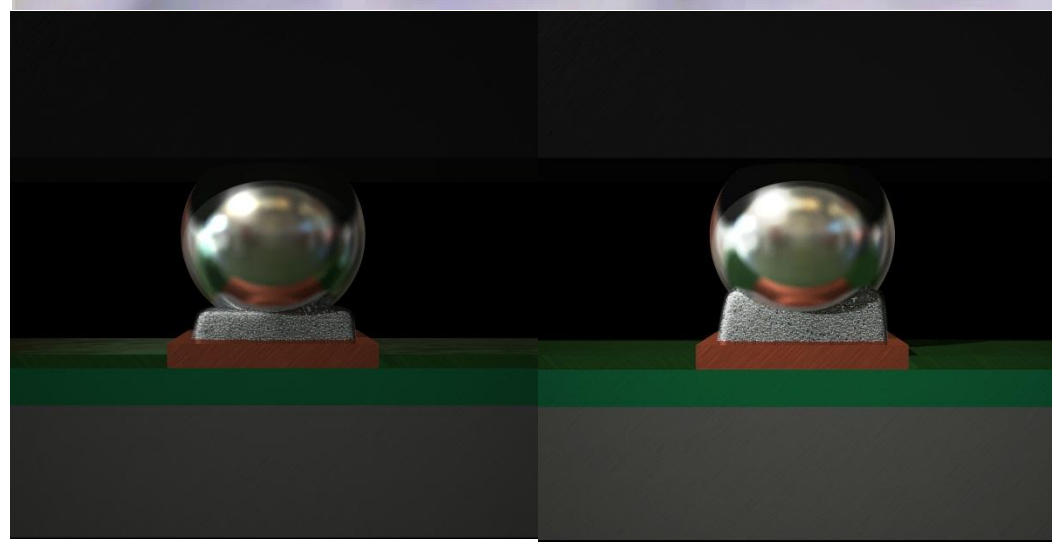
Source: *Head-On-Pillow Defect – A Pain in the Neck or Head-On-Pillow BGA Solder Defect*; Oliphant et al; APEX 2010



Source: *Head in Pillow: Are We Still Snoozing;* Shimanura et al; SMTAI 2010 Proceedings

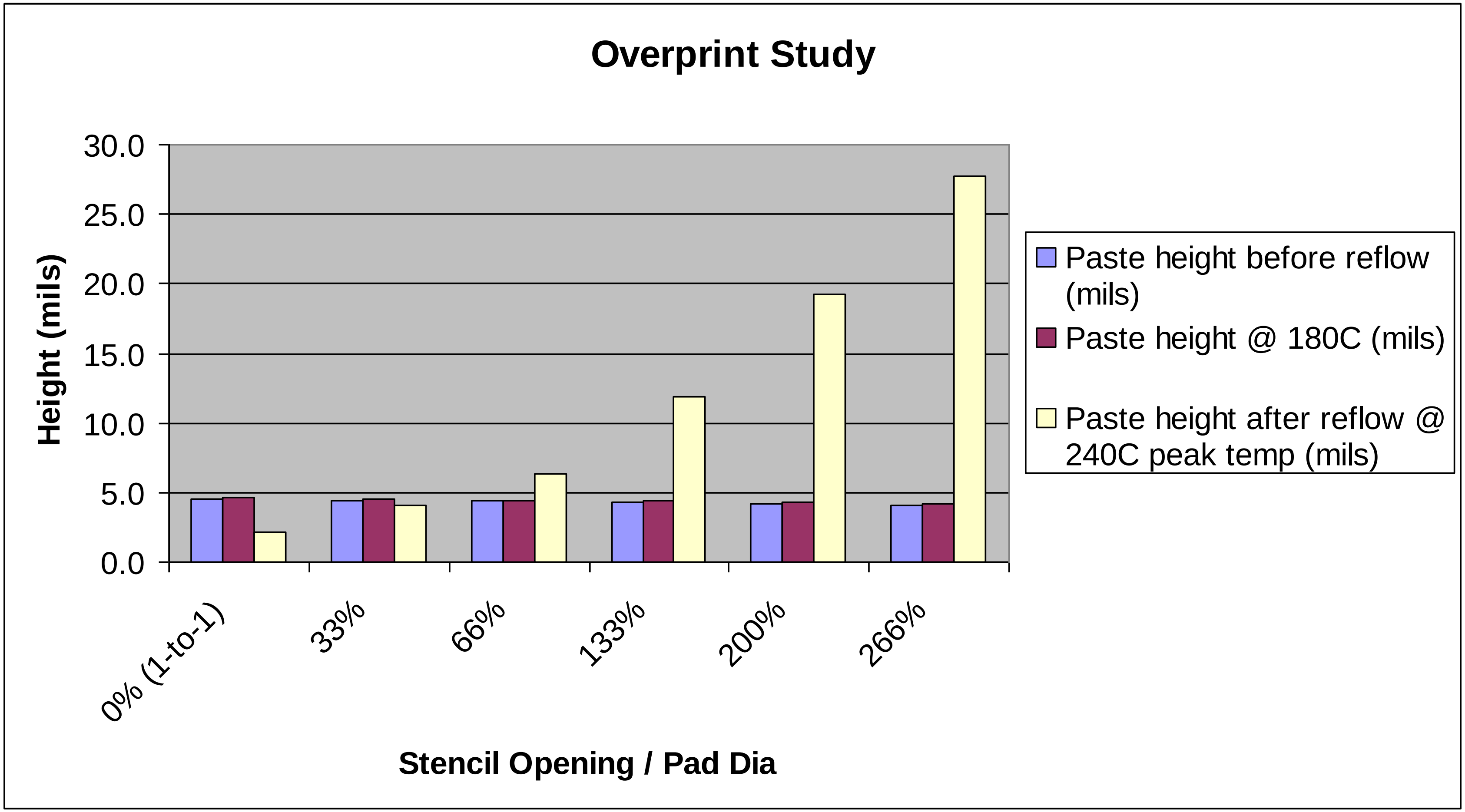
Investigation: Printing Process

- Setup
  - Poor registration
  - Improper board setup
  - Aperture area ratio
  - Stable board support and clamping system (vacuum)
  - Poor stencil design
- Materials
  - Transfer efficiency
  - Slump resistance

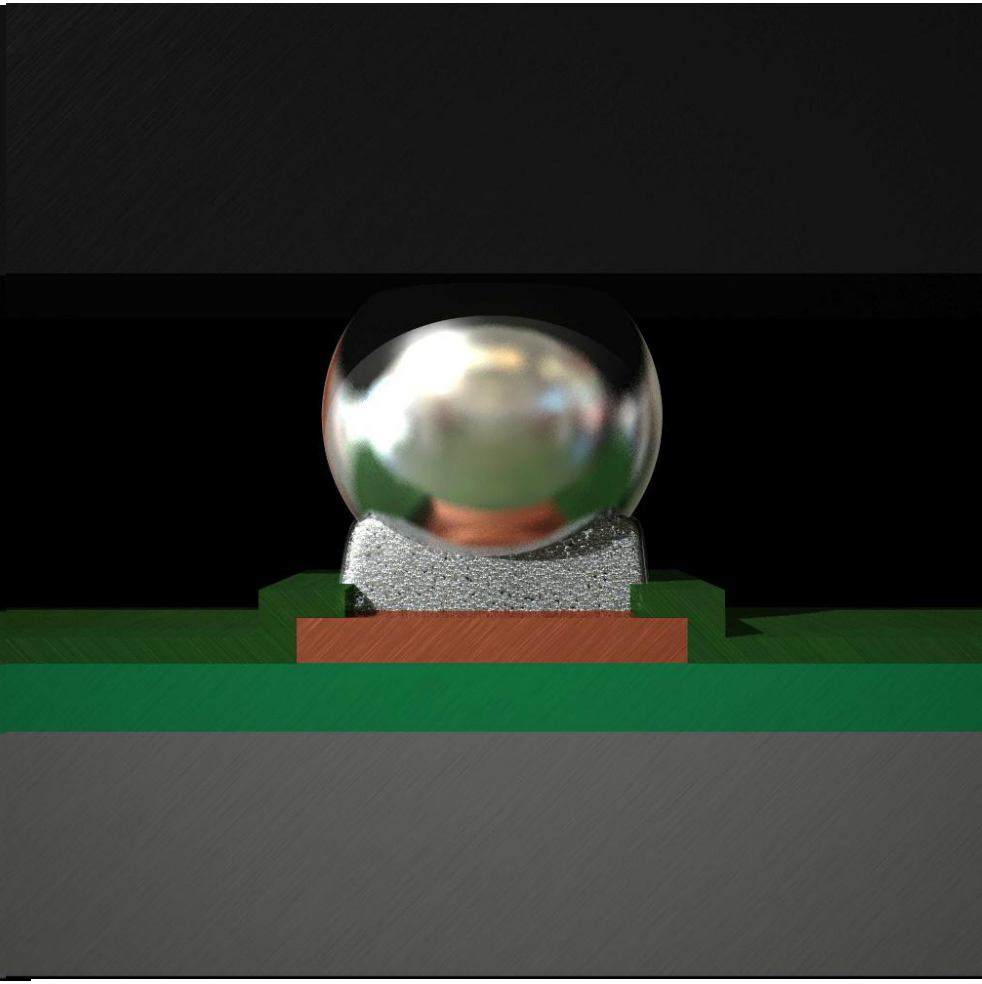


APEX EXPO IPC 2013 INFORMATION that INSPIRES INNOVATION

Over Printing

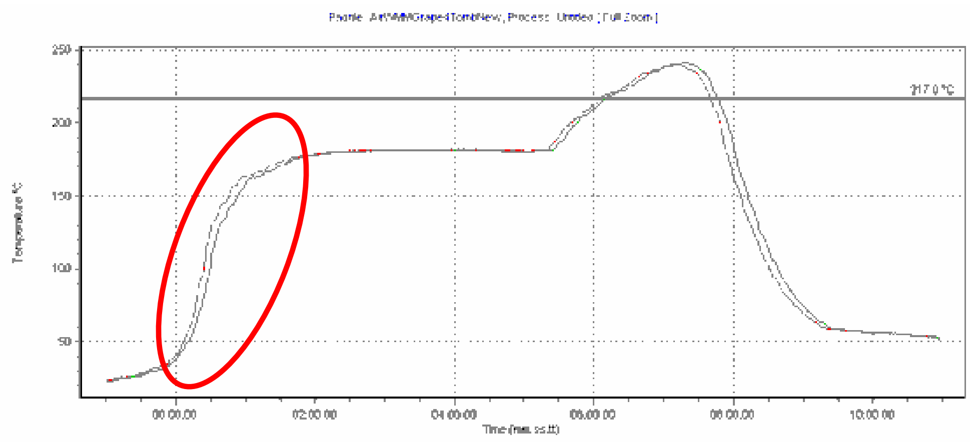


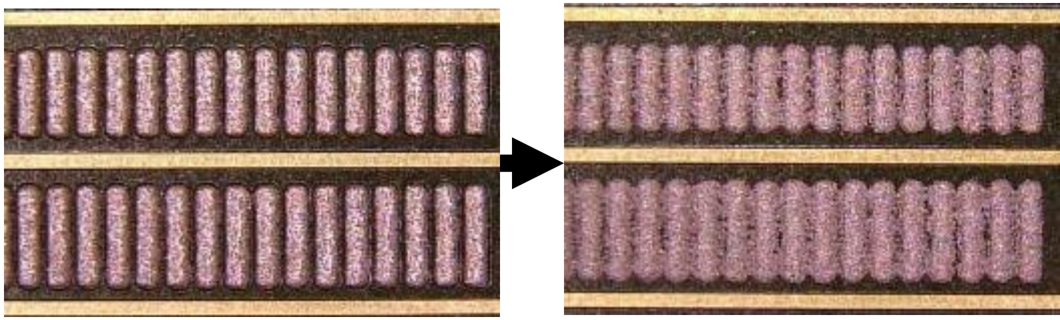
SMD vs. NSMD Pads



Investigation: Reflow - Preheat

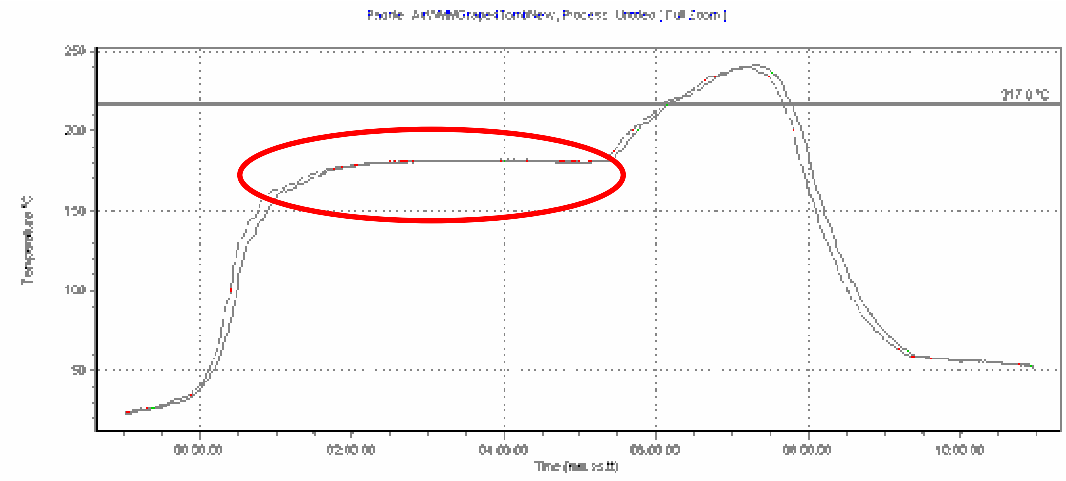
- Fast ramp rate increases slumping
- Slow ramp rate minimizes spacing between paste and solder ball
- Added Considerations:
  - Metal %
  - Powder size
  - Solvent
  - Print height

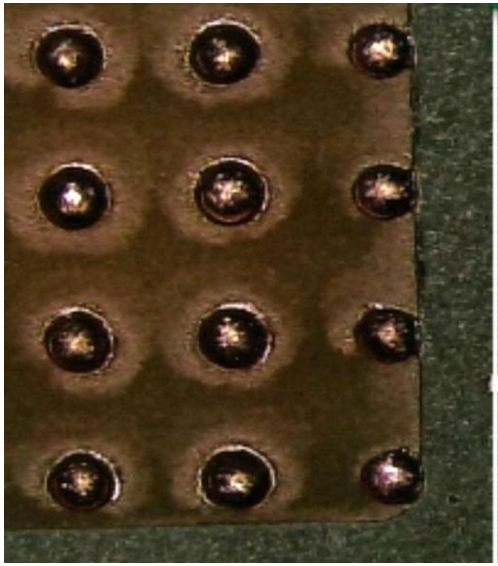




Investigation: Reflow - Soak

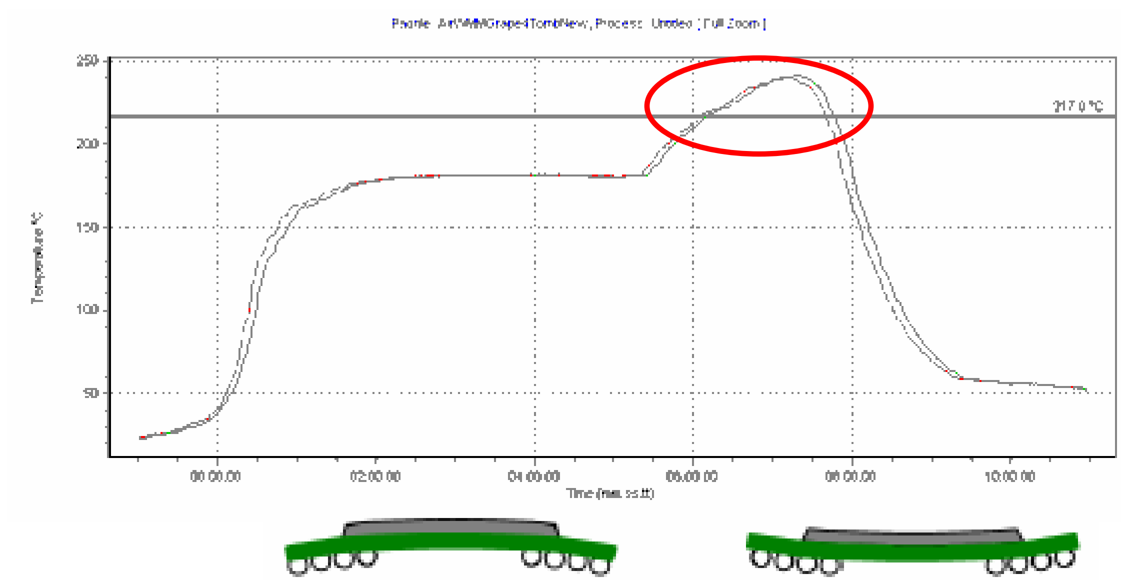
- Oxidation occurs the entire time that the board is in the preheat and soak stages of the profile
- Oxidation barrier of solder paste critical
- Other considerations:
  - Soak profile helps voiding
  - High air flow rates





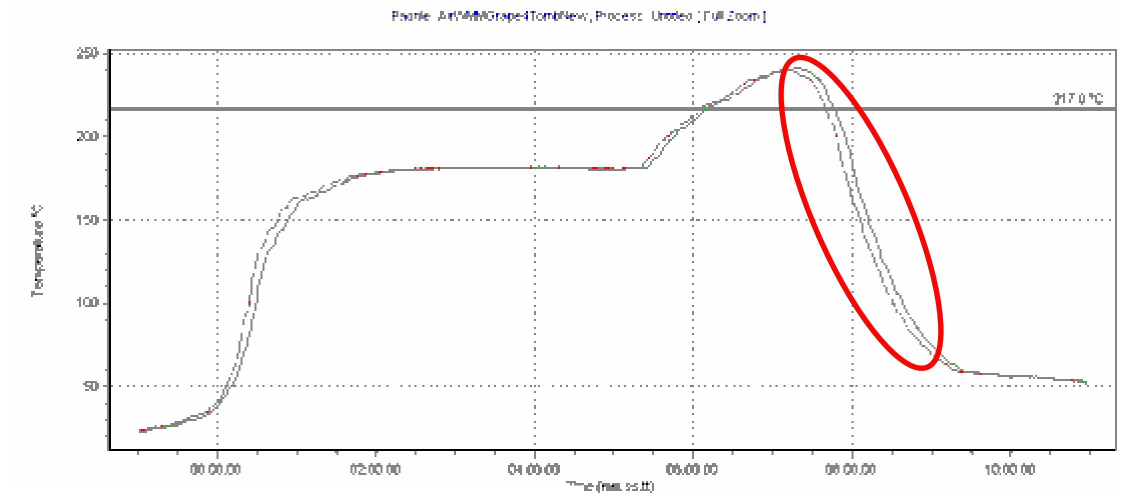
Investigation: Reflow - Peak

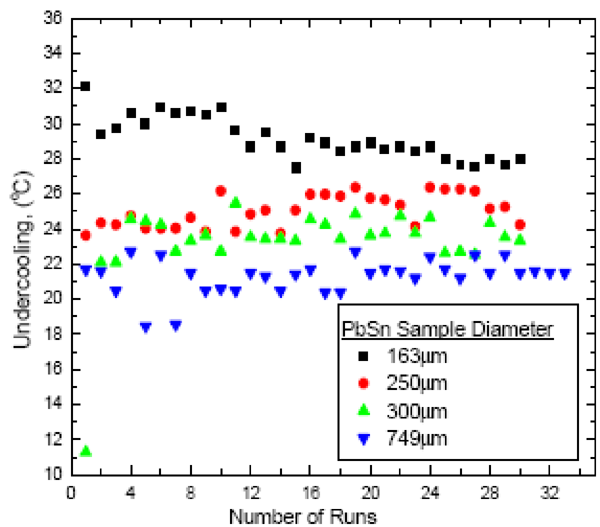
- Peak temperature affects the amount of warping
- TAL impacts the amount of oxides that form on molten solder surface
- Other considerations:
  - Intermetallic formation
  - Low Ag BGA's

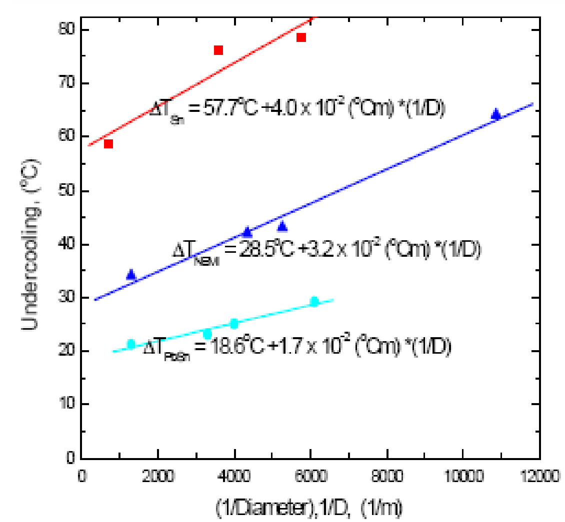


Investigation: Reflow - Cool Down

- Undercooling a positive attribute for HIP
- Closer to pure Sn the alloy is, the more undercooling
- Smaller balls, more undercooling
- Some confounding info for mixed alloys

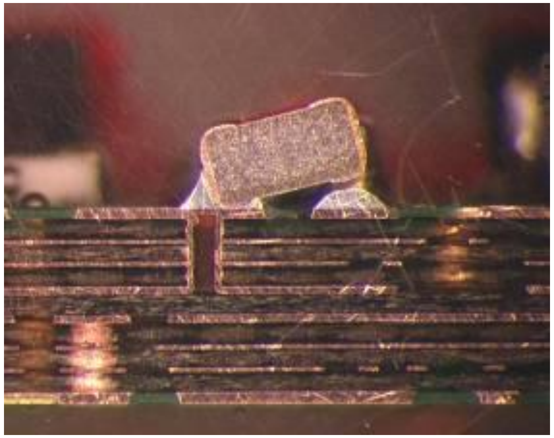






Source: Kinyanjui R; *Effect of Ball Size on Undercooling of SAC Solder Joints*; SMTAI 2005

- Nitrogen will improve the solder joint appearance and spread
- Nitrogen will minimize surface oxidation
- There is no evidence that a solder joint reflowed in nitrogen is any more reliable
- Nitrogen will dramatically increase tombstoning of small passive components



Investigation: Paste - Activators/Halogens

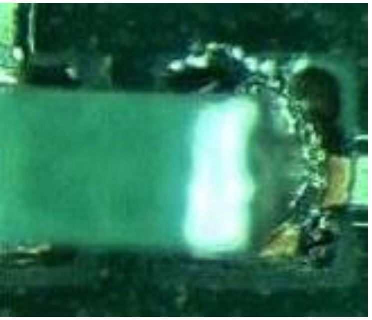
Halogen-Free

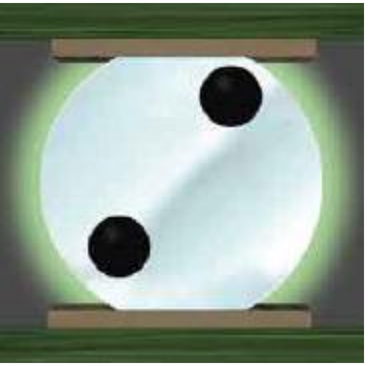
- It does not contain Cl, Br, F, I, At (although most just looking at Cl and Br)
- Concern is Environmental
  - Uncontrolled incineration
  - Dioxin formation
- Some Legislation Emerging
- Common in Flame Retardants
- Issues:
  - Do the halogen free PCB's impact end product reliability?

Halide-Free

- Should be halide ion free as it is defined in electronics as not containing ionic halides.
- Concern is Reliability
  - Corrosion
  - Dendritic Growth
- Common in Activators in flux
- Issues:
  - Is halide free actually more reliable than halide contained?
  - How do you test fluxes for halide content?

Investigation: Paste - Oxidation Barrier

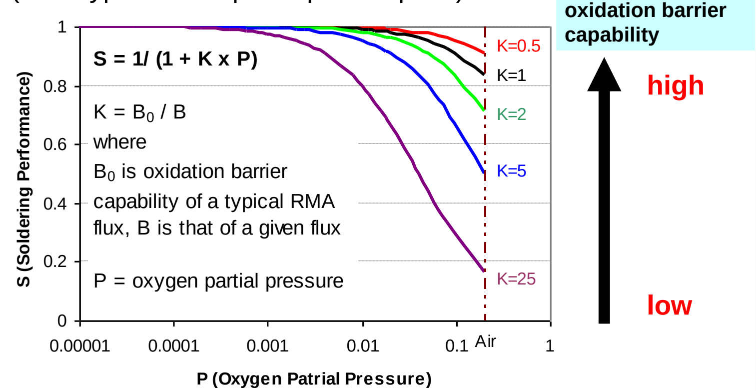




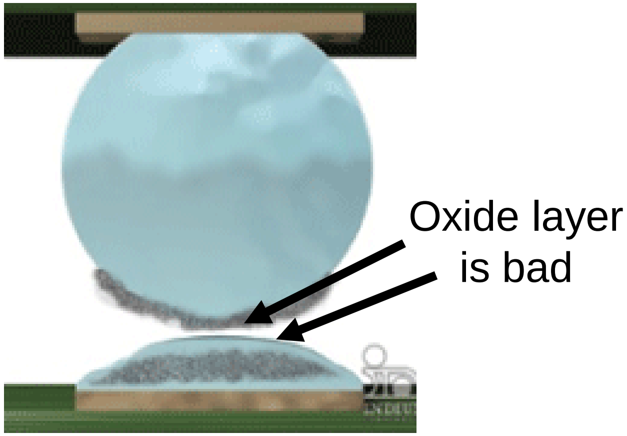
Composition of Fluxes

- **Activators**
  - Dissolve oxides off the metal surfaces & promote wetting
  - Halogens or organic acids
- **Resins/Rosins**
  - Tacky and viscous
  - acts as an oxygen barrier
- **Rheological Additives**
  - Create the thixotropic properties of solder paste
  - Key for Stencil Printing
- **Solvents**
  - Dissolves *activators*, *gelling agents,* & *resins* to create a homogeneous *paste flux*
  - Key to voiding and stencil life

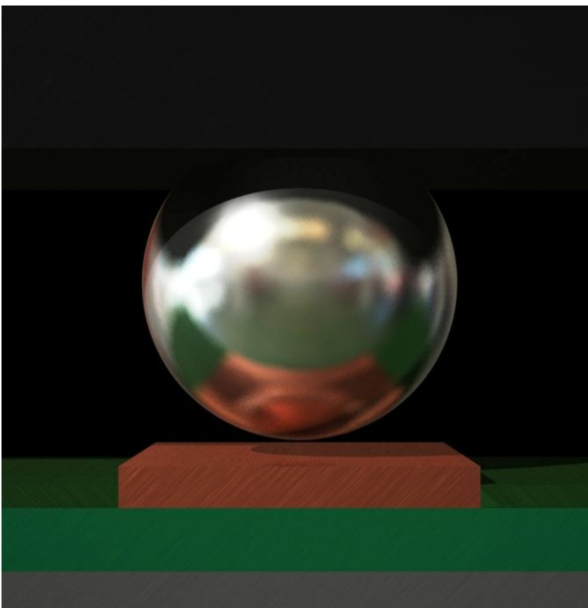
Either use nitrogen, or use flux with higher oxidation barrier (for a typical SMT paste print deposit)



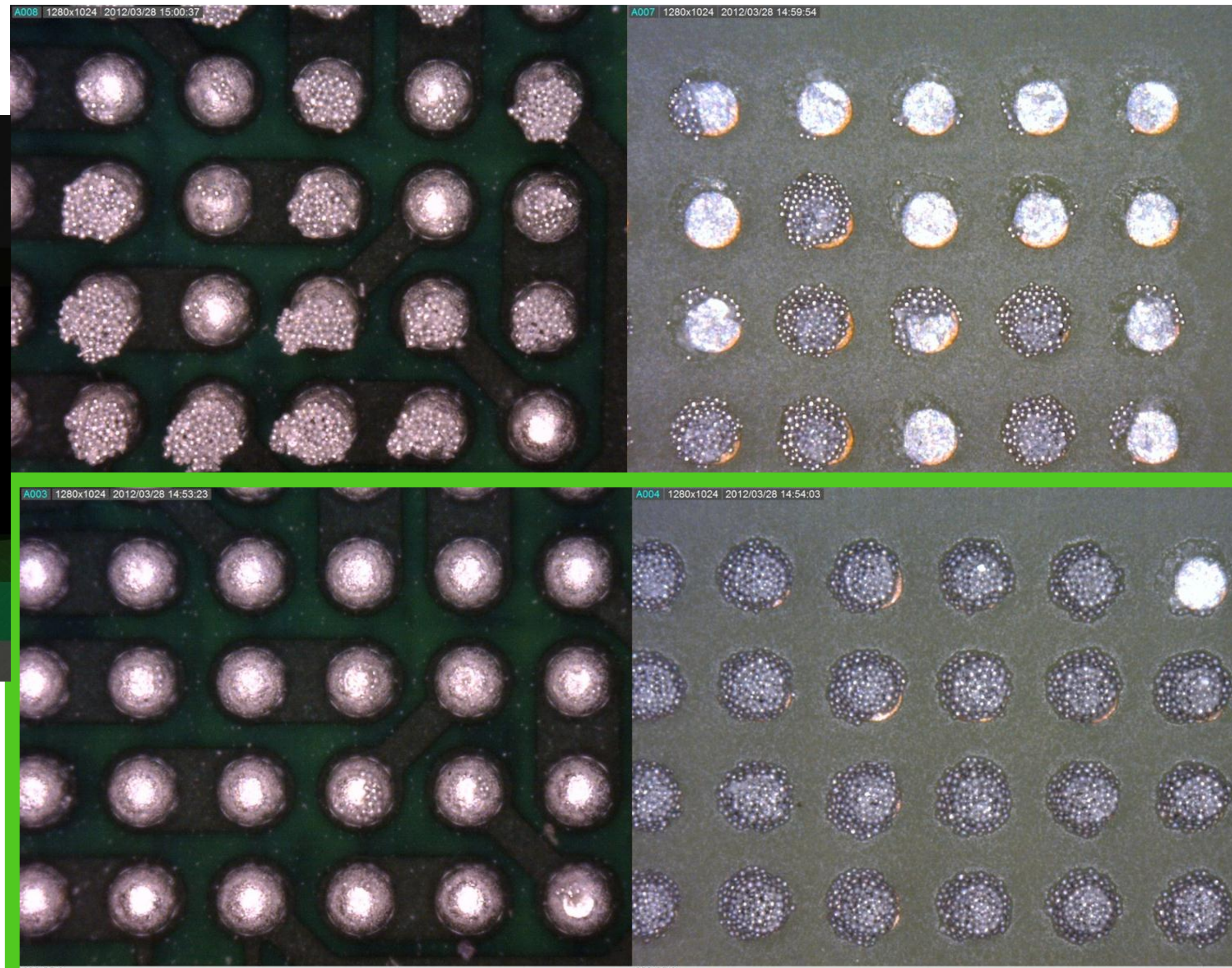
P. Jaeger and N.-C. Lee, "A Model Study of Low Residue No-Clean Solder Paste", in Proceeding of Nepcon West, Anaheim, CA, 1992.



Investigation: Paste - Pad Adhesion

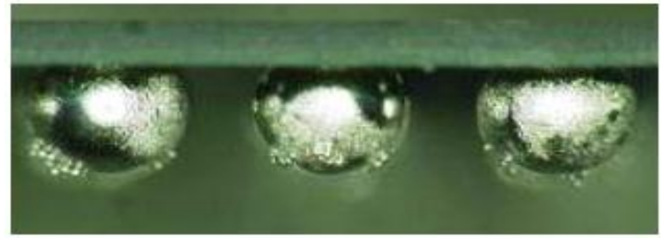


Component Board

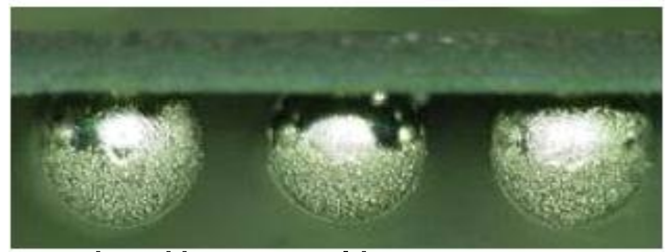


Investigation: Printing AND Dipping

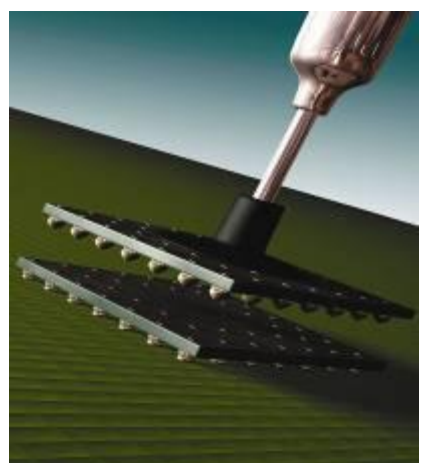
- Flux
  - Adds oxide barrier to sphere
  - Additional activity
- Paste
  - Same as flux, plus…
  - Accommodates more warp



Dipped into normal solder paste

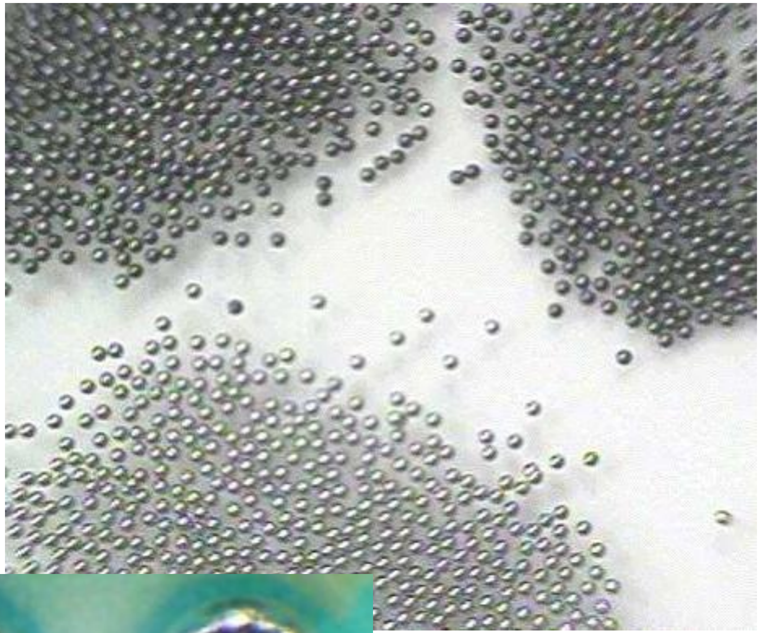


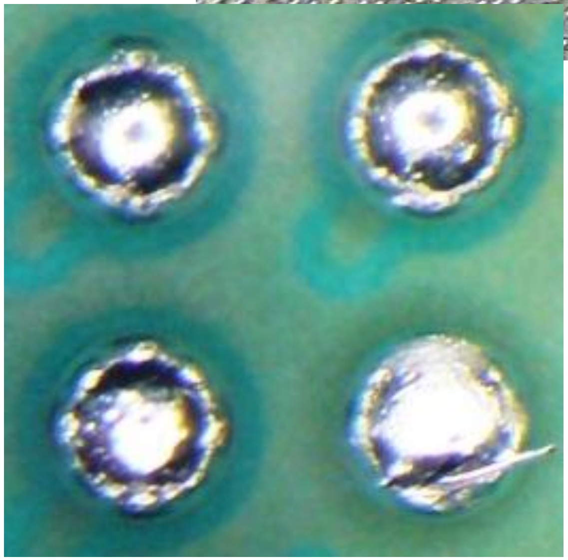
Dipped into PoP solder paste



Supplier Issues

- Sphere Oxidation
  - Uncontrolled manufacturing
  - Packaging
  - Storage
- Silver Segregation
  - Cases seen as high as 36% silver content at the surface.
  - Silver tailing
- Beyond solder paste control





Case Study

- Known Paste Solution
  - 93% yield (7% fall-out) current process, current paste
  - 100% yield (no fall out); current process, new paste
  - 300 boards / >1000 IO’s per board

- Currently in production
- Work with your solder paste supplier

- Random HIP Defects
  - Look for supplier / storage issues
- Edge / Center HIP Defects
  - Look for process issues (placement / warpage)
- Paste properties can overcome HIP defects
  - Look for high transfer efficiency
  - Look for “stringy” pastes
  - Look for a high oxidation barrier
  - Look for slump resistance
- You are not alone

HoP Mitigation