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# Lead-free Soldering Materials and Processes

## Requirements to Make Them Work

**Peter Biocca**
**Senior Market Development Engineer**
**Kester, Itasca, Illinois**

# This presentation is only a summary

- RoHS Globally - Latest Update
- Materials - Components and Boards
- Solders - Lead-free Choices
- Lead-free SMT Process
- Preventing Defects in SMT
- LF Wave Soldering Process
- Preventing Defects in Wave Assembly
- LF Hand Soldering and Rework

The information contained in this presentation is accurate as per the industry information available at the time of this revision. Please obtain the latest information for your process needs since lead-free assembly requirements may change.

# RoHS / WEEE Directives Re-Cap

- Reduce and eventually eliminate the use of prohibited substances at the source (RoHS)
  - Maximum permissible levels in a homogeneous material will be as follows:
    - **Cadmium (Cd)** **100 ppm**
    - **Mercury (Hg)** **1000 ppm**
    - **Lead (Pb)** **1000 ppm**
    - **Hexavalent chromium (Cr(VI))** **1000 ppm**
    - **Polybrominated Biphenyls** **1000 ppm**
    - **Polybrominated Diphenyls Ether** **1000 ppm**
- Recycle as much of the product as possible after its useful life, in order to minimize the issues of disposal (WEEE). Very much a recycling law.

# Exempt / Out of Scope?

Products that are exempt include:

- Network infrastructure
- High-end computing equipment

Products that are out of the legislation's scope include:

- Medical equipment
- Aerospace equipment
- Defense electronics
- Products used in national security
- Automotive electronics (covered by ELV legislation)

**Celestica presentation by Dan Shea, CMAP International Lead-free Conference, Toronto, Canada May 2006.**

## Risks of Relying on Exempt / Out-of-scope Status

Reasons companies who are out of scope / facing exemption should act now include:

- Exemption applies to lead *in solder*, not other 5/6
- Conversion costs delayed, not avoided
- Longer design / product cycles = need to start now!
- Non-compliant component obsolescence
- Premium on obsolete components
- OEM green leadership / branding
- Competitor sets lead-free proof point…possible deadline shift!
- Products with temporary exemptions or out of scope may still be impacted as suppliers move away from leaded offerings

**Celestica presentation by Dan Shea, CMAP International Lead-free Conference, Toronto, Canada May 2006.**

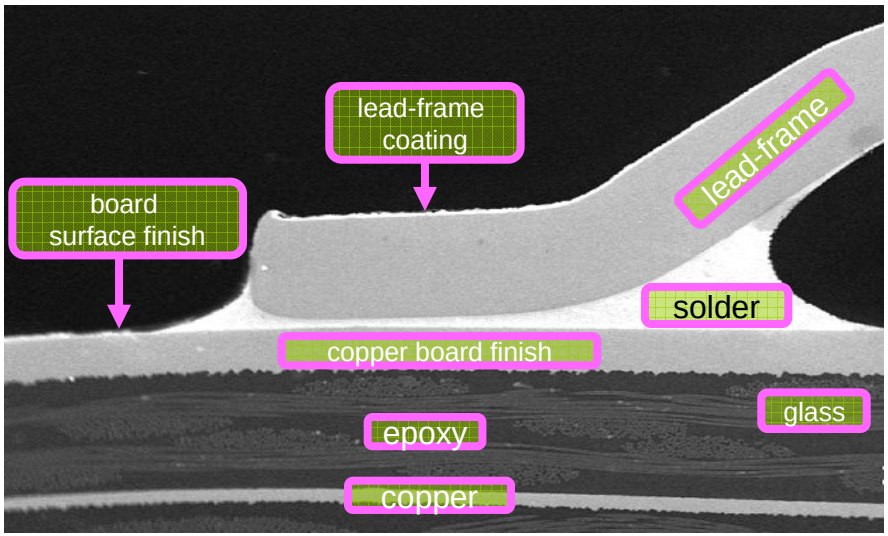
# EC Stakeholder Consultation 2002/95/EC

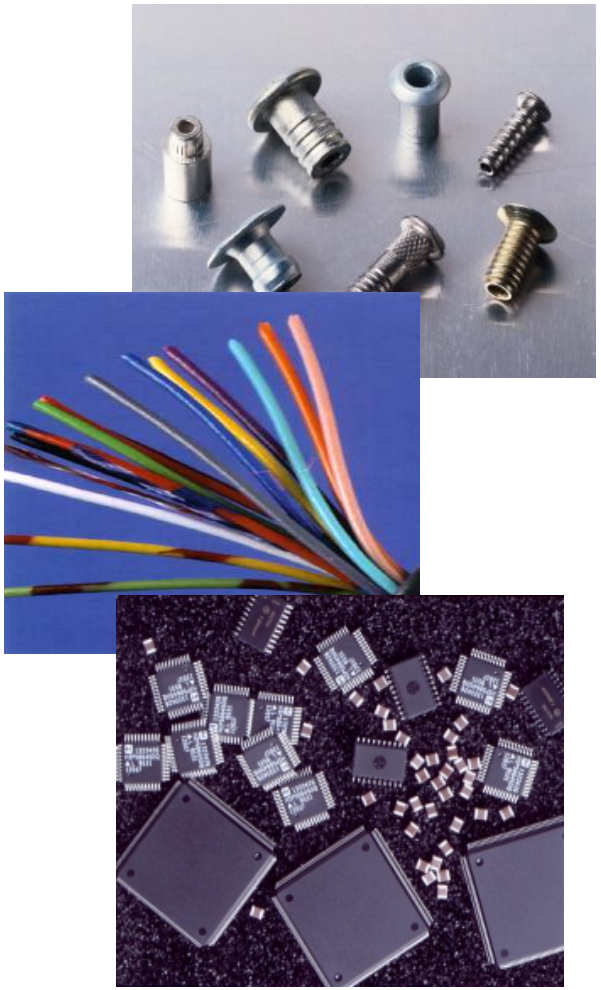
## Additional exemptions

- Lead in tin whisker resistant coatings for fine pitch applications
- Solders containing Lead and Cadmium for special applications
- Lead in connectors, flexible PCB's, flexible flat cables
- Low melting point alloys containing lead
- Applications of lead, mercury, cadmium, hex.chrome, PBDE, PBB's in aerospace and aeronautical applications

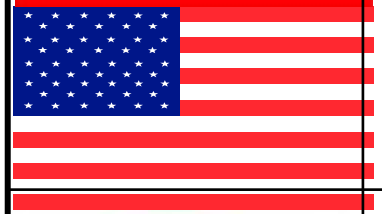
# RoHS Directive: Substance Limits

- Maximum Concentration Values in weight percent
  - 0.1% for Pb, Hg, hexavalent Cr
  - 0.01% for Cd
  - 0.1% for PBB and PBDE flame retardants
- Concentration is per **homogeneous material**
- '**Homogeneous material'** means a material that cannot be mechanically disjointed



# Not Just Europe

| | Regulation | Compliance Timing |
|---|---|---|
|  | Reduction of Hazardous Substances (2002/95/EC) | July 2006 |
|  | Regulation for pollution control of Electronics Products (RPCEP) | March 2007 |
|  | California RoHS-equivalency measures<br>52 bills pending in 20 states | January 2007<br>Various |
|  | JGPSSI Guidelines for Standardization of Material Declaration<br>JEITA Lead-free Roadmap | July 2003<br>End 2005 for assemblies |

Presented at the International Lead-free Conference, Toronto, Canada, May 2006.

IBM

Integrated Supply Chain

# Industry Challenges with China Environmental Product Regulations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| | |
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| Jim Wilcox | Endicott, USA |

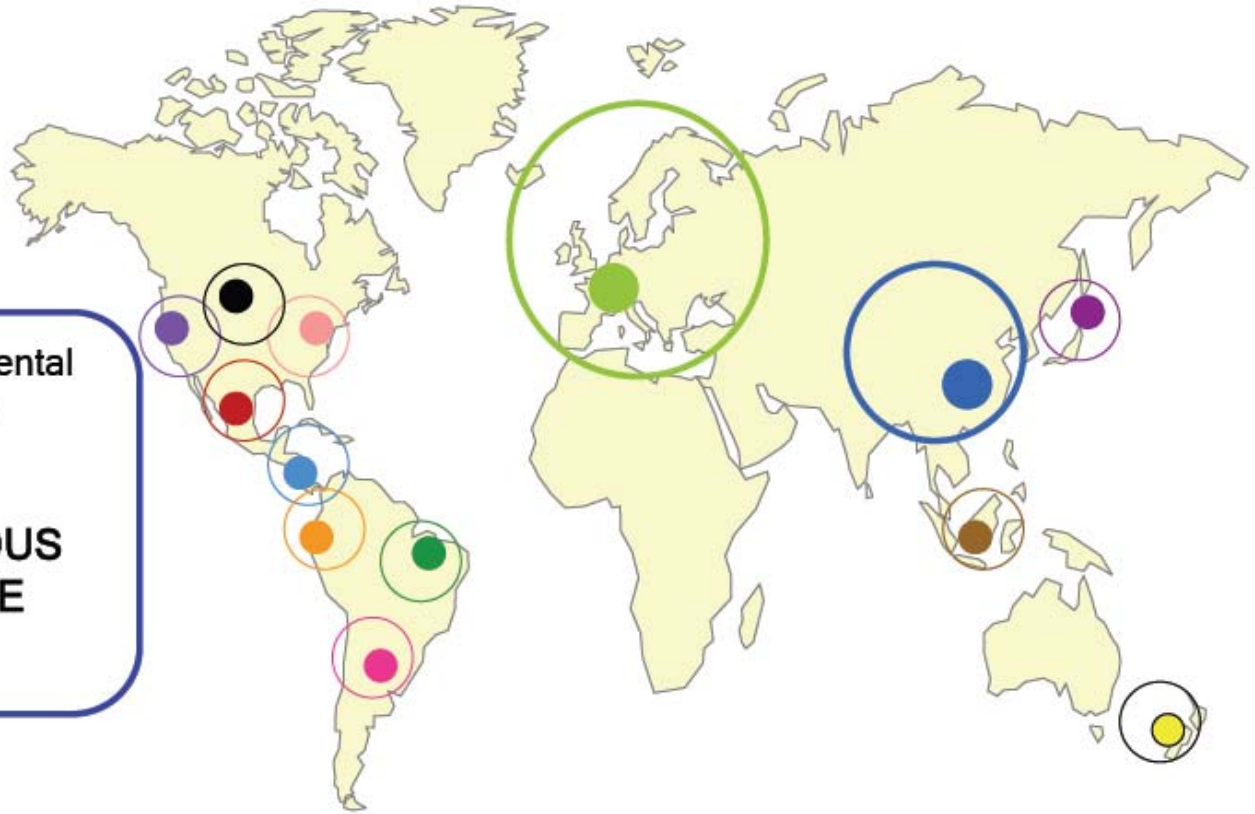


| May 29, 2006

# Key Elements of the Regulations

- The 6 standards are identified as PRC Electronics Industry Standards:
  - Marking / Labeling Requirements
  - Maximum Concentration Value (MCV) Limits
  - Hazardous Substance Testing Requirements
  - Pb-free Solder Materials
  - Product Catalogue Definition
  - Certification Requirements

# Regulation Convergence



## Global Electronics Market

Currently, many different environmental regulations are emerging globally - based on:

**RESTRICTION OF HAZARDOUS SUBSTANCES & END OF LIFE TAKE BACK**

| | |
|---|---|
| Europe: | European Union WEEE & RoHS Legislation |
| China: | Management Methods for Controlling Pollution |
| Korea: | Act for Resource Recycling of Electronic Products and Automobiles |
| Canada: | Provincial Regulations in 7 provinces |
| United States: | State Regulations in 37 states |
| Americas: | Mexico, Columbia, Brazil, Costa Rica, Argentina, Paraguay, Uruguay |

# Press-Release In the News, November 2006, California regulation.

**SACRAMENTO –** The **California Department of Toxic Substances Control** will hold a public workshop this week to solicit input and update stakeholders on the development of regulations prohibiting the sale of non-RoHS compliant electronic devices in California.

The workshop will be held Nov. 9, at the CalEPA Building in Sacramento. A remote videoconference will take place in Glendale, CA. All interested parties are invited to participate.

Email Linda Sargent at lsargent@dtsc.ca.gov or Cindy Chain-Britton at cchainbr@dtsc.ca.gov, or call 916-323-9219.

The event will also be accessible via a live audio webcast on the Cal/EPA website at http://www.calepa.ca.gov/broadcast/. Questions and comments may be submitted in real time and will be considered when DTSC finalizes the regulation proposal.

**Beginning in 2007, a California law will ban the sale of some electronic devices that contain certain hazardous substances.** The Electronic Waste Recycling Act (EWRA), which was signed into law in September of 2003, requires the DTSC to adopt regulations to prohibit covered electronic devices "from being sold or offered for sale" in California if they are prohibited from sale in the European Union under the RoHS Directive because they contain certain heavy metals.

As of December 2005, DTSC had identified eight categories of covered electronic devices in its regulations. The list of covered devices includes:

1. Cathode ray tube containing devices (CRT devices)
2. Cathode ray tubes (CRTs)
3. Computer monitors containing cathode ray tubes
4. Laptop computers with liquid crystal display s
5. LCD-containing desktops
6. Televisions containing cathode ray tubes
7. Televisions containing LCD screens
8. Plasma televisions.

The EWRA will restrict the use of lead, mercury, cadmium, and hexavalent chromium in electronic devices sold in California. The RoHS Directive was amended on Aug. 18, 2005, to add maximum concentration values for the six restricted substances. DTSC will incorporate the EU's MCVs for lead, mercury, cadmium, and hexavalent chromium in its regulations implementing the EWRA.

**DTSC's RoHS regulations will recognize any exemptions adopted by the EU for the use of lead, mercury, cadmium, or hexavalent chromium that apply to covered electronic devices.** DTSC will present the proposed RoHS regulations and solicit comments and suggestions from attendees.

# Summary
# Key Procurement Issues for RoHS

- Components
- Boards
- Solders and fluxes
- Wires and cables
- Metal fixtures and fasteners
- Plastic parts, casings etc…

# Lead-Free – IPC/JEDEC Definition


**Pb-free (lead-free):**

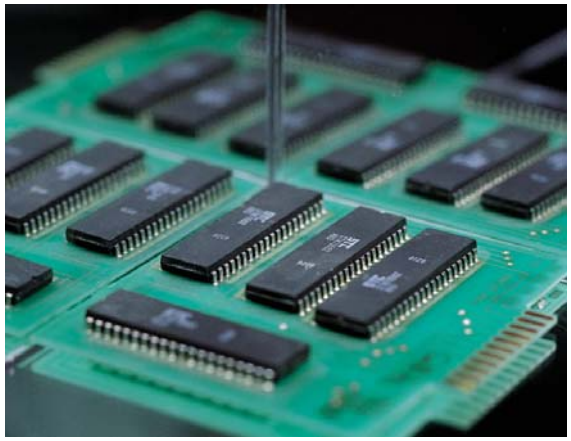
Electrical and electronic assemblies and components in which the Lead (Pb) level in any of the raw materials and the end product is **<= 0.1% by weight** and also meets any Pb-free requirements/definitions adopted under the RoHS Directive 2002/95/EC.

**Important Note:**

A ‘Pb-free’ component may not necessarily be compatible with Pb-free processing temperatures, as process-compatibility must be determined by the **“Maximum Safe Temperature”**

# JEDEC Standard JESD97 or IPC-1066

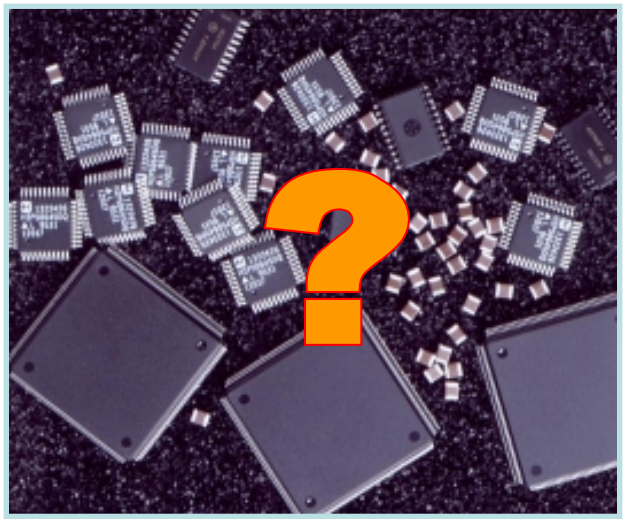
- Pb-free category:
  - Assigned to Pb-free components, boards, and assemblies indicating the general family of materials used for the 2nd level interconnect including solder paste, lead/terminal finish, and terminal material/alloy solder balls
    - e1: SnAgCu
    - e2: Other Sn alloys – no Bi or Zn (SnCu, SnAg, SnSb)
    - e3: Sn
    - e4: Pre-plated (Ag, Au, NiPd, NiPdAu)
    - e5: SnZn, SnZnx (no Bi)
    - e6: Bi
    - e7: Low Temp.< 150°C, In based, no Bismuth
    - e8, e9 unassigned
  - Tin-lead boards and components have no assigned label

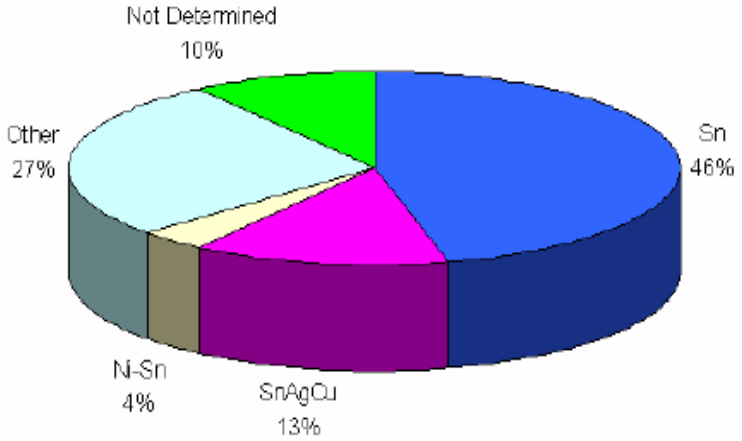
# Choosing the Materials
## For Pb-free and Directives Compliance

# Summarizing the Key Points on Components

- Lead-free termination finish
- RoHS compliancy, metal finishes and plastics
- Thermal compatibility
- Moisture sensitivity rating



# Component LF Finishes

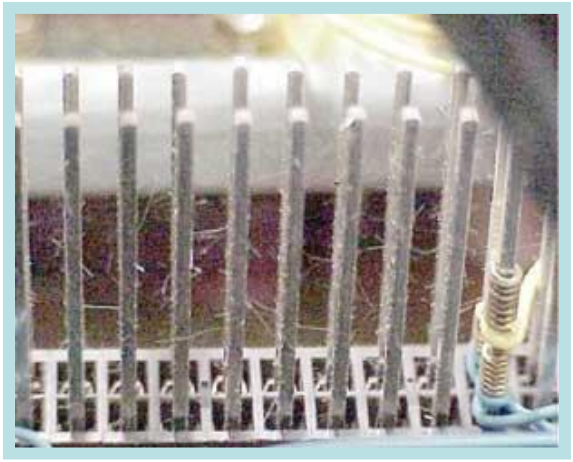



Note: If your not transitioning do check what you are getting.
Avoid surprises.

- Ni alloys: Ni/Kovar, Alloy 42, difficult to solder
- Pd/Ni: Palladium acts similar to Au – as a oxidation
  Pd/Ni/Ag inhibitor, different metallic combinations available
  Pd/Ni/Au Low ductility – Cracking a problem, More expensive
- SnBi: Can't mix with Pb, low mp phase at 97°C
- Pure Tin: Whisker potential, especially fine pitch components
- SnAg: Tight plating control required
- SnCu: Tight plating control required
- Many others finishes available

# Ways to Prevent Tin Whiskers

- Add a small amount of Cu or Ag to tin
- Use of nickel barrier between copper and tin*
- Use matte tin(larger grain deposits), instead of fine grain bright tin finish
- Use of thicker tin coat 8-12 micrometers
- Reflow of surface prevents whisker growth
- Anneal process



- Newer anti-whisker fine grain matte tin finishes,
  - example Technic Advanced Technologies, TechStan EP

* Studies seem to indicate this to be the most effective way to minimize whiskers.

# IPC/JEDEC J-STD-020C

## Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices

Higher processing temperatures for lead-free assembly increases risks of:

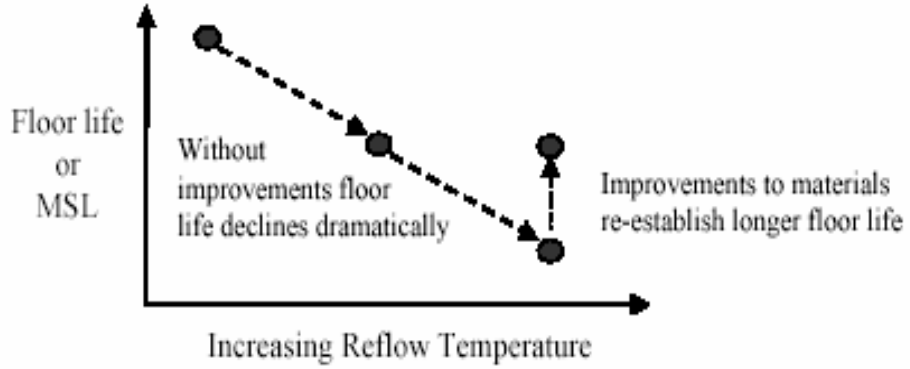
- Internal delamination
- Internal cracks
- Bond damage, die lifting, thin film cracking, popcorning
- Cratering
- External package cracks

- **Establishes new lead-free max. processing temperatures**
- **Minimum and Maximum thermal profile requirements**
- **Moisture Sensitivity Level (MSL rating) classification criteria**

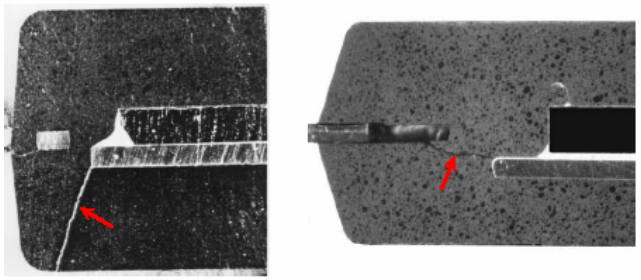
# Impact of Lead-free on MSD

## Results of Improvements to Materials (PBGAs)

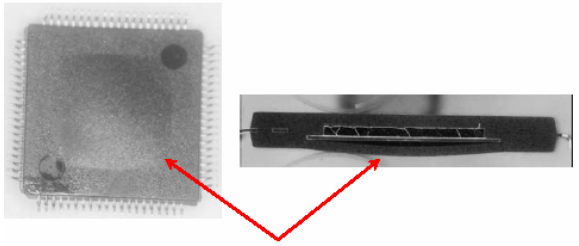
| JEDEC Moisture Sensitivity Level | | Previous Materials | | | New Pb-free Process Compatible Materials | | |
|---|---|---|---|---|---|---|---|
| Level | Floor Life | 225°C | 240°C | 260°C | 225°C | 240°C | 260°C |
| 2A | 1 Month | Pass | Fail | Fail | Pass | Pass | Pass/Fail |
| 3 | 1 Week | Pass | Pass | Fail | Pass | Pass | Pass |
| 4 | 3 Days | Pass | Pass | Pass | Pass | Pass | Pass |




"Popcorn Effect" Type I Crack

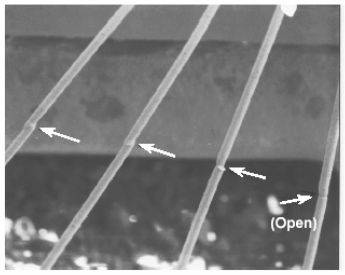


Package Warpage



Die Paddle Belly Bulge: LQFP

Bond Wire Damage

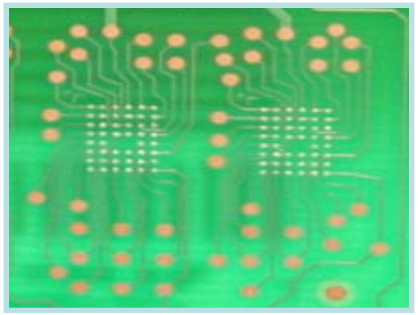



Wires sheared by package crack.

Ref : Pb-free IC Component Issues and IPC/JEDEC Specification Update, Rick Shook, Agere Systems

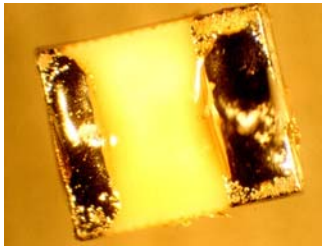
# Summarizing Key Points on Boards

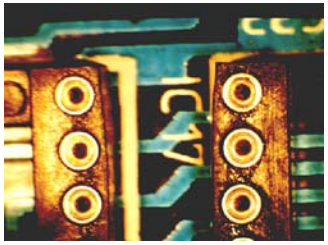
- Lead-free board finishes
- RoHS compliancy for laminates
- RoHS compliancy for solder mask
- Thermal compatibility, up to 260°C
- Changes to Tg and Td

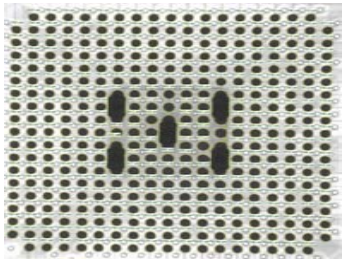


# Component-Board Process Compatibility

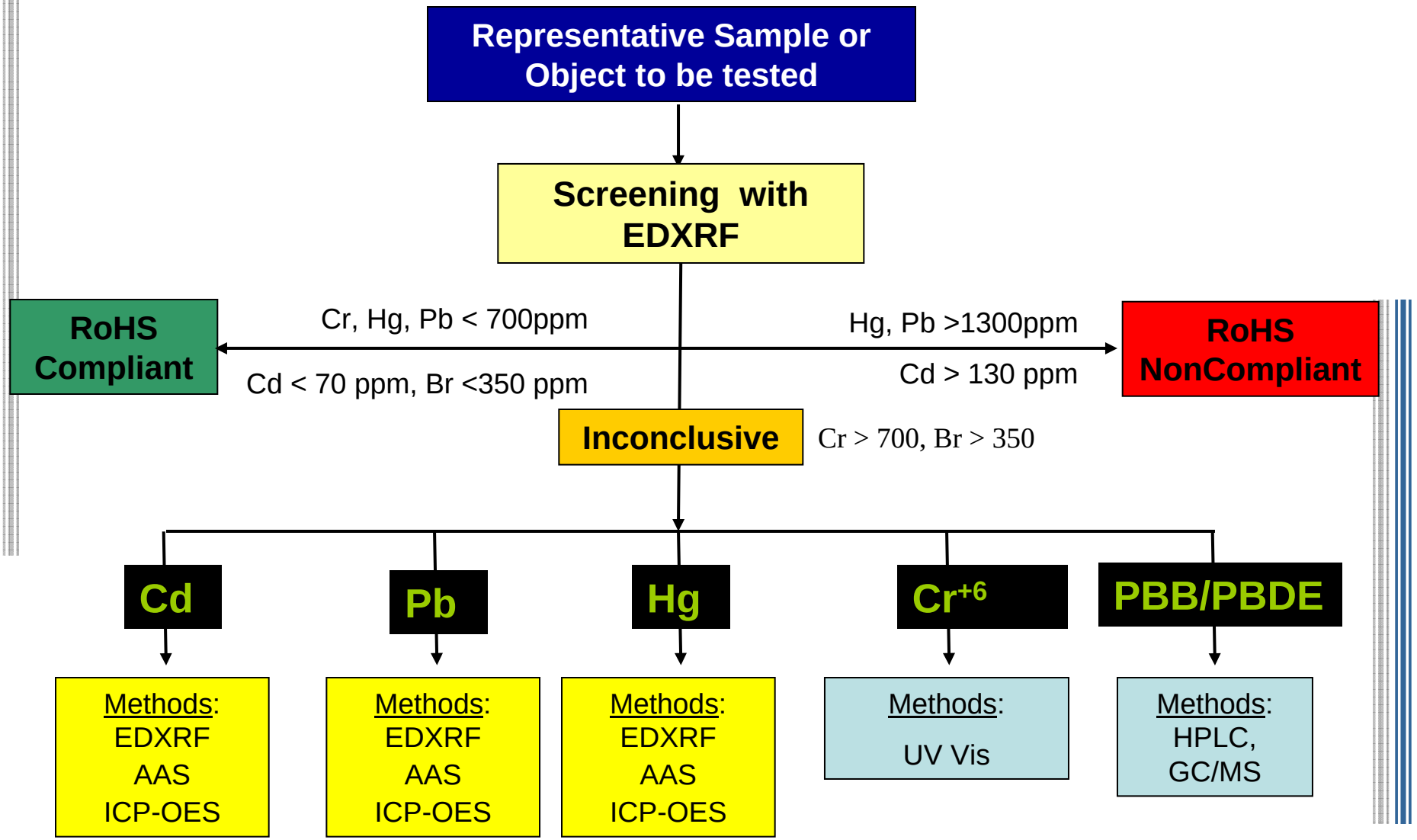
- Termination and board finish choices
- Thermal compatibility
- Plastics, molding compounds for components, etc
- RoHS compliancy, all levels
- Moisture sensitivity levels of SMD's
- Availability, Cost
- Shelf-life and logistics





# Proposed Test Flow Procedure or RoHS Substances



# Electronic Related Applications XRF

- **“Due Diligence”**
  - Verify Certificates of Analysis and Supplier Declaration
  - Spot check your “high risk” vendors
  - Reduce amount of money spent on outside lab testing

- **Identification of prohibited material**
  - Analysis of Pb and other elements for prevention of tin Whiskers
  - RoHS Exempt products
    - *Medical*
    - *Military*
    - *Long-Life applications*


**X-ray Fluorescence Unit**

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# Lead-Free Solder Selection

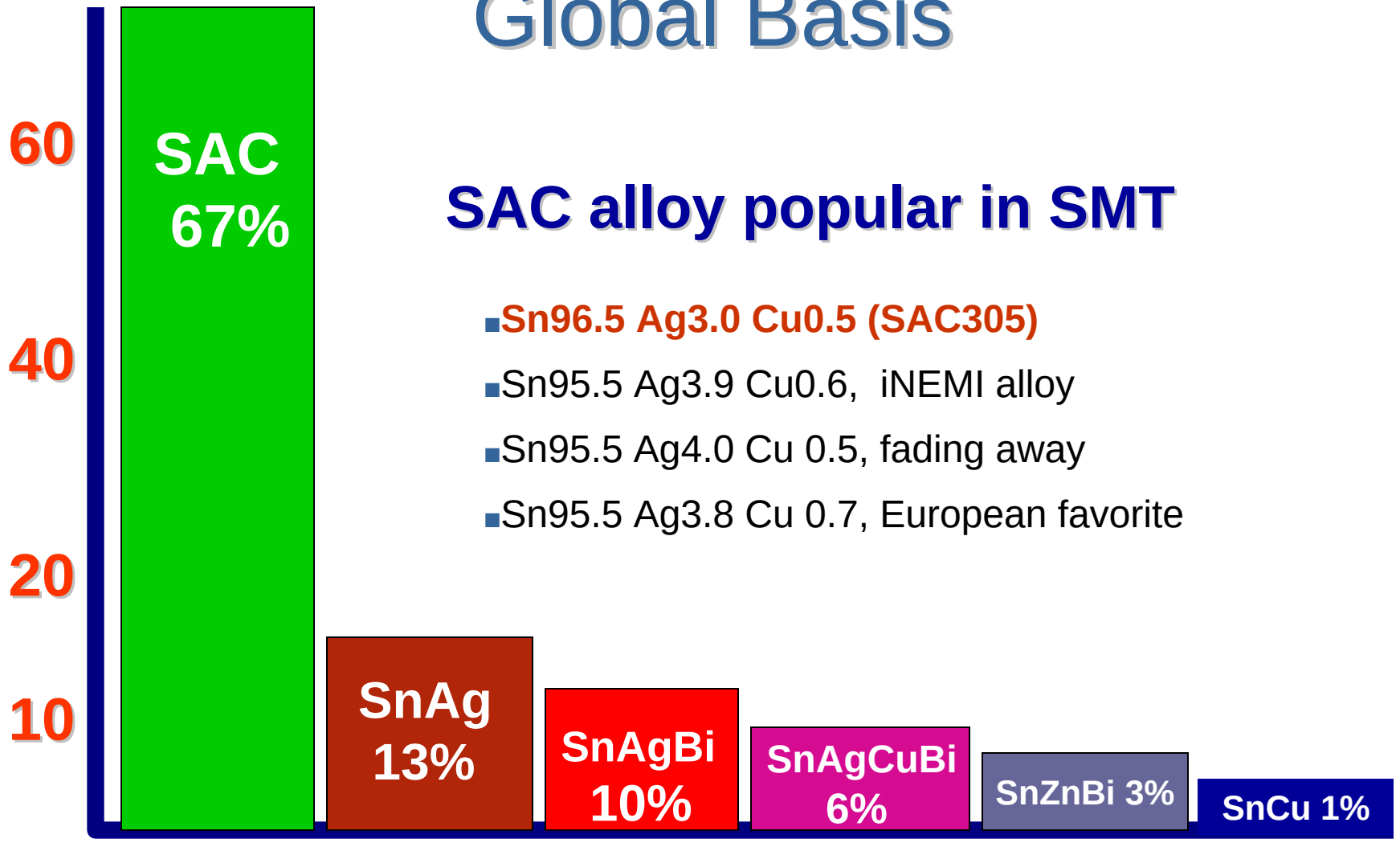
# Alloy Selection Overview

- Alloy selection, choosing the solder to suit the end in mind
- Must consider MP, alloy strength, ductility, reliability data, availability, patents, etc.
- Current trends are toward SAC system for SMT
- Current trends are toward SAC or Sn/Cu system for wave soldering

# Common LF Alloys

- SnAgCu (or “SAC”) family (MP = ~217C)
  - Many available varieties with different proportions of Sn, Ag & Cu
- Sn96.5 Ag3.5 (MP = 221C)
  - Sn/Ag Eutectic alloy
- Sn99.3 Cu0.7 family (MP = 227C)
  - Sn/Cu Eutectic alloy, plus Nickel or Germanium, Bismuth
- Sn99 Ag0.3 Cu0.7 (MP = 217-227C)
  - Lower cost “SAC” alloy due to lower Silver content

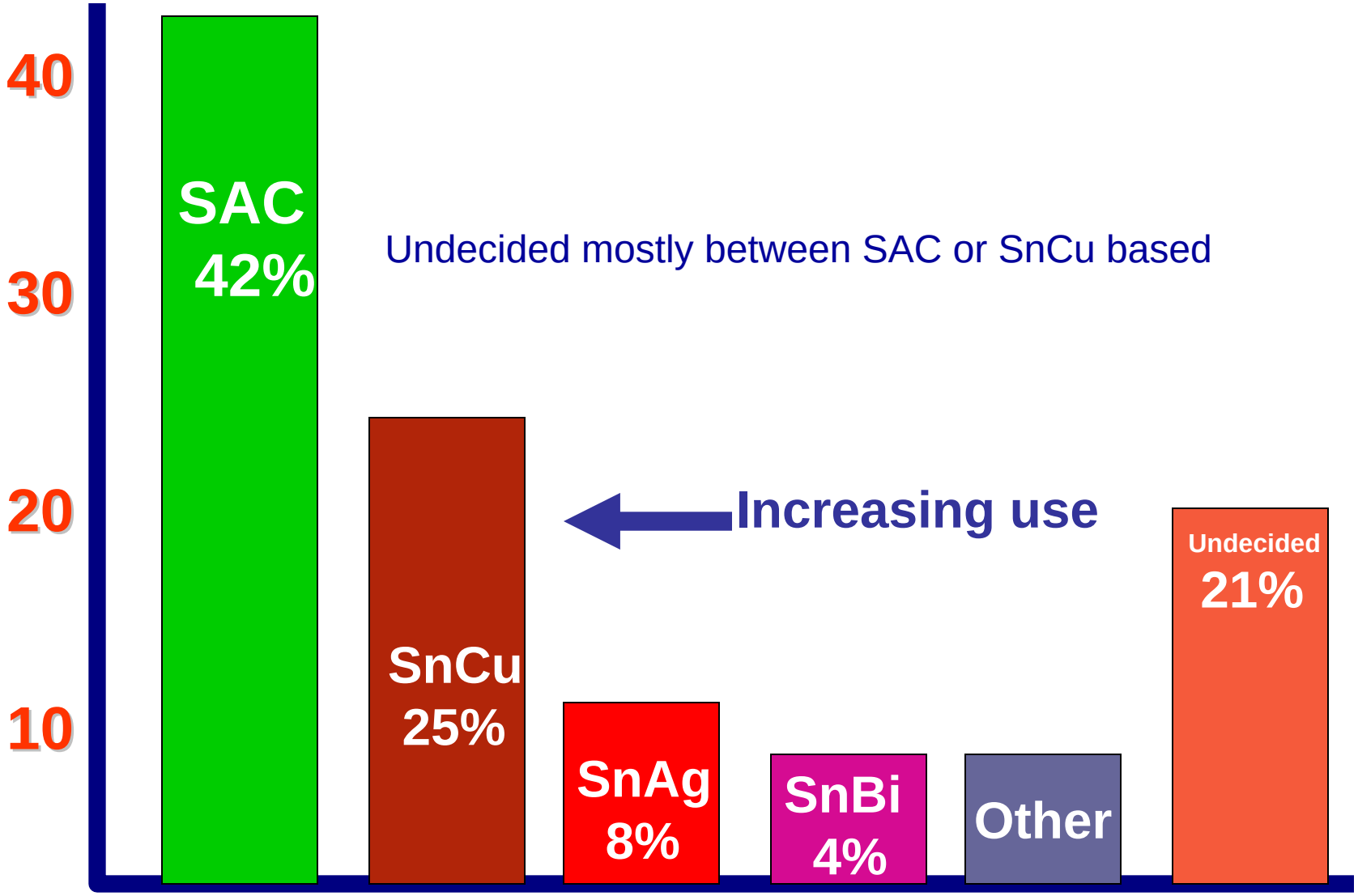
# Reflow Solder Selection on a Global Basis




## SAC alloy popular in SMT

- **Sn96.5 Ag3.0 Cu0.5 (SAC305)**
- Sn95.5 Ag3.9 Cu0.6, iNEMI alloy
- Sn95.5 Ag4.0 Cu 0.5, fading away
- Sn95.5 Ag3.8 Cu 0.7, European favorite

# Global Wave Solder Selection



# SAC305 for Wave

- Sn96.5 Ag3.0 Cu0.5 (MP ~217C)
- Popular wave soldering alloy
- Highest cost
- More data available
- Good reliability
- Cosmetic issues

# SAC0307 for Wave

- Sn99 Ag0.3 Cu0.7 (MP 217-227C)
- Lower-Silver version of traditional SAC alloys for lower cost
- Originally used as a plumbing solder, little data for electronics applications
- Could be worth considering in some applications as a replacement for SAC305 with lower cost

# Sn/Cu based solders for Wave

- Sn99.3 Cu0.7 eutectic point of this binary system (MP 227°C)
- Low cost alternative to SAC305 for wave
- SnCu with additives, Nickel, Gallium, Cobalt, Bismuth
  - SnCuNi an option, several alloys here
  - These materials are lower in cost and reliability data is still being collected

# Alloy Selection Rework

- Rework:
  - Match rework alloy to alloy used to produce original joint
- Other Hand Soldering:
  - Match alloy to whatever is already used on the board

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# Just a word on "Surface Shrinkage Effects"

## As mentioned in J-STD-610D, Chapter 5

## Typically seen with SAC solders in wave, selective and hand-soldering



### 5.2.11 Soldering Anomalies – Hot Tear/Shrink Hole

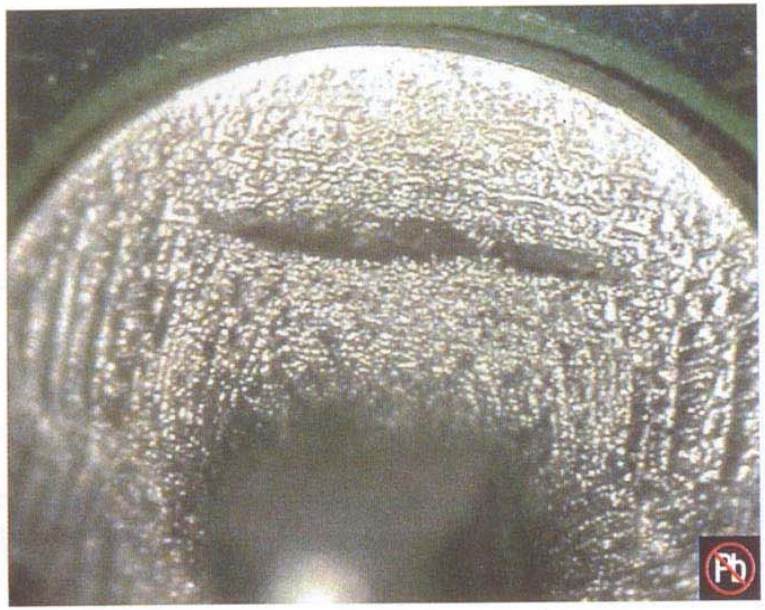



Figure 5-67

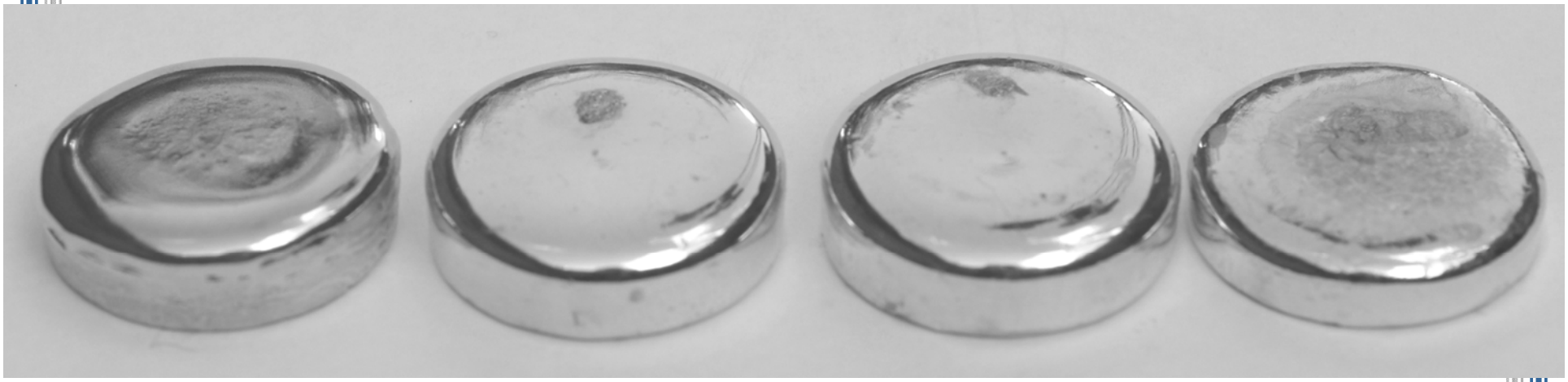
**Acceptable - Class 1,2,3**

- For connections made with lead free alloys:
  - The bottom of the tear is visible.
  - The tear or shrink hole does not contact the lead, land or barrel wall.

**Defect - Class 1,2,3**

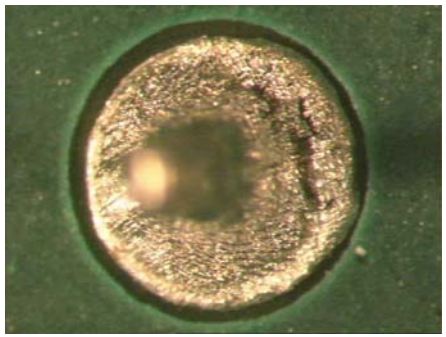
- Shrink holes or hot tear in connections made with SnPb solder alloys:
- For connections made with lead free alloys:
  - The bottom of the shrink hole or hot tear is not visible.
  - The tear or shrink hole contacts the lead or land.

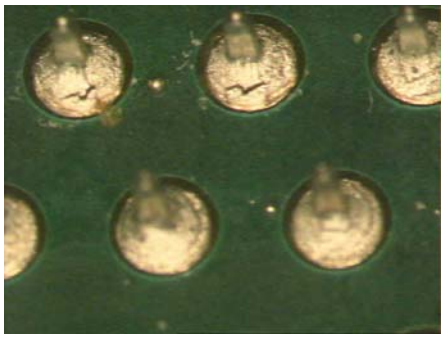
# Not seen in SnCu based solders such as K100, K100LD, SN100C



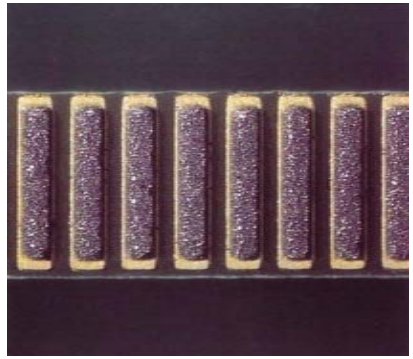
63/37 K100 K100LD SAC

# Solder Shrinkage SAC305





**After 500 thermal cycles, iNemi Lead-free Wave Project 2006.**

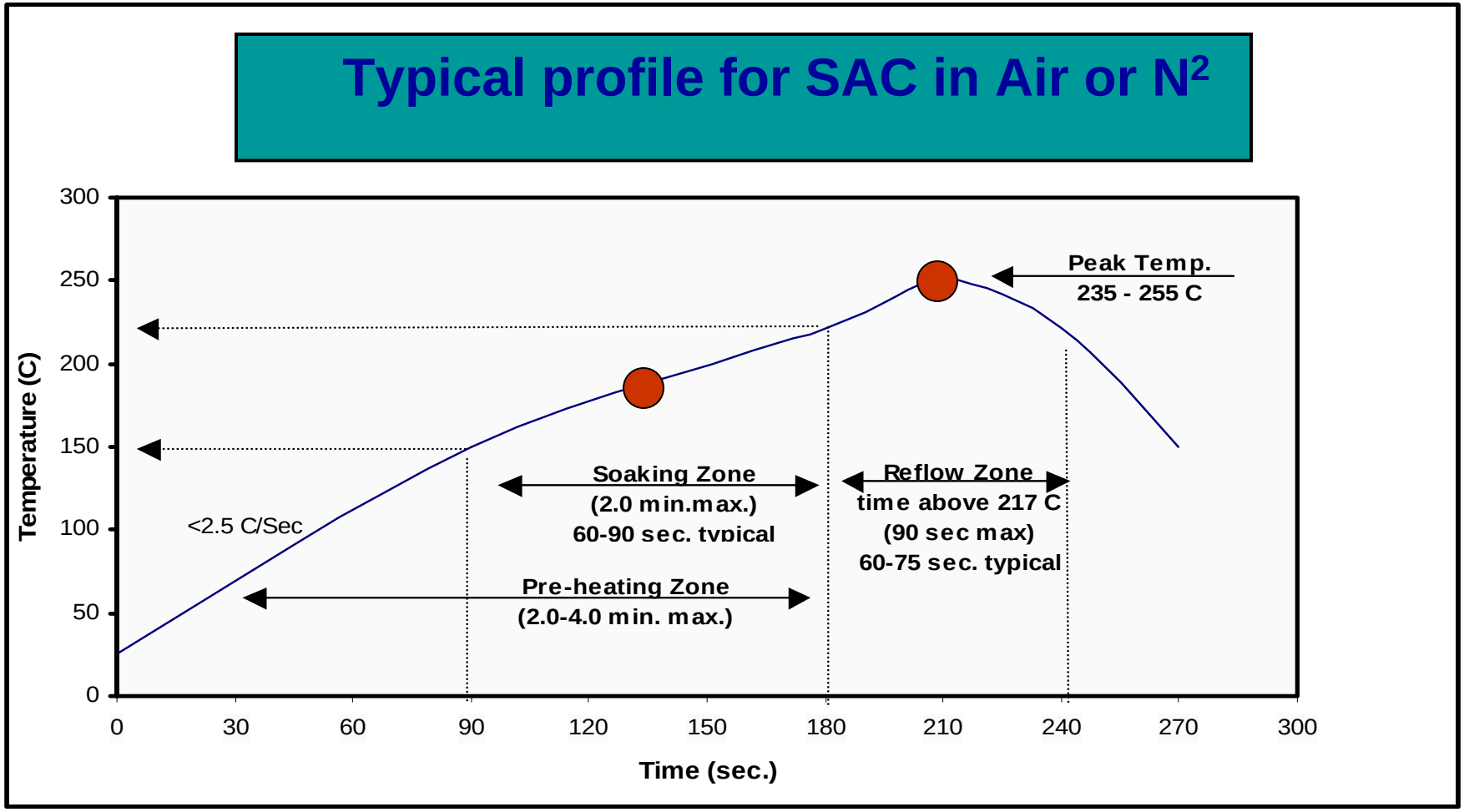


# Lead-free SMT Assembly

# SMT Impact on Manufacturing

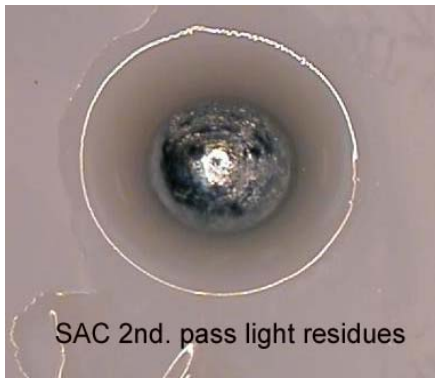
- Screen Printing and Paste Dispensing
  - Little change, rheological properties do not change, lower metal %
- Pick & Place Equipment
  - Little impact.  Better placement accuracy may be needed due to less  “self centering” of  lead free alloys when molten
- AOI
  - Recalibration; joints are duller in appearance and less reflective
- Reflow
  - Significant impact due to higher melting alloy temperatures
  - Inspection, changes due to cosmetics and wetting characteristics
  - ICT changes due to no-clean flux residue hardening

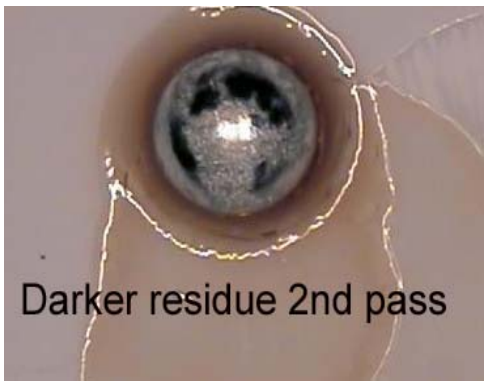
# Lead-free Reflow Profile



# New LF Solder Paste Flux are Required

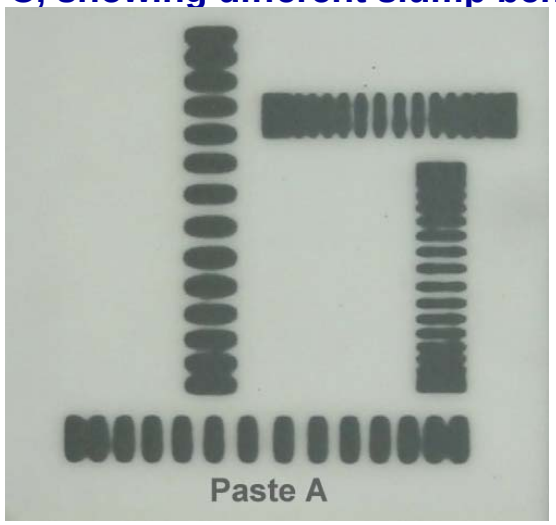
- New activators
- New resins
- New gelling agents
- Better surfactants
- Oxidation inhibitors
- Alloy specific fluxes

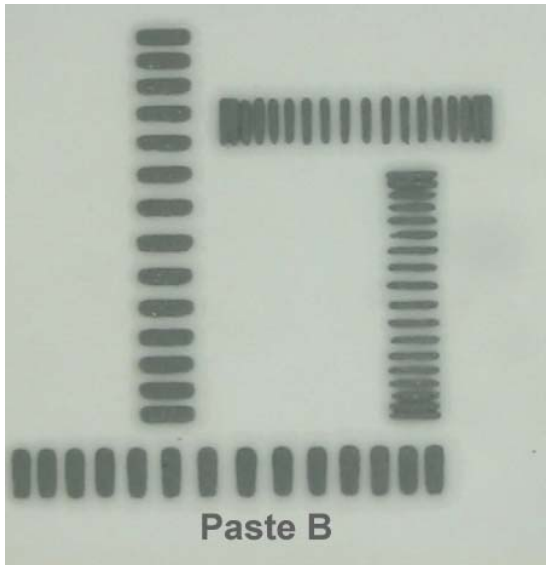



**Residue impacts ICT, cosmetics and cleaning and sometimes reliability**

**Below two lead-free SAC pastes heated to 180°C, showing different slump behaviors**



# Solder Paste Qualification
# Ask for more information

- Print speed
- Abandon time
- Stencil life
- Tack life
- **Solder ball potential**
- **Slump behavior**
- **Metallization Spread**
- **Reflow window**
- **Voiding potential**
- **Double reflow**
- **Cleanability, if W/S**
- **Pin testability, if N/C**

**Little change**

**Change**

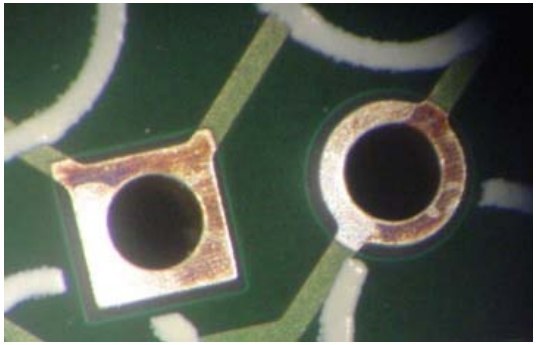
**Choose the right paste for the job**



Same alloy, flux class, powder size but different finishes

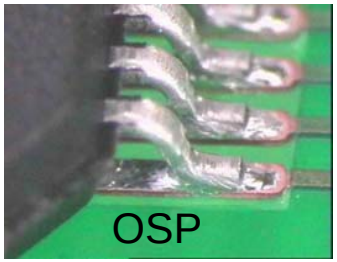
# The Impact of Board Finish

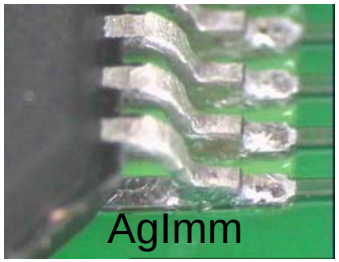
- Immersion Ag
- Immersion Sn
- ENIG
- Copper OSP
- HASL Lead-free
- Plated SnAg, SnCu



Silver Tarnish

| | HASL | OSP | ENIG | Pd | Tin | Silver |
|---|---|---|---|---|---|---|
| Flat | no | √ | √ | √ | √ | √ |
| Solderjoint | Cu-Sn | Cu-Sn | Ni-Sn | Ni-Sn | Cu-Sn | Cu-Sn |
| Contact | E-test, ICT | no | E-test, ICT, keypad | E-test, ICT, keypad | E-test | E-test, ICT, keypad |
| Wirebond | no | no | Al | Au, Al | no | Au, Al |
| Cost | $ | 0.7 x $ | 3 x $ | 5 x $ | 0.8 x $ | 0.8 x $ |
| OEM's | all | all | most | few | 30 | 150 |
| Fab's | most | most | 200 | few | 40 | 250 |
| Reflows | 6 | 2 | 6 | 6 | 2-3 | 6 |
| Shelf-Life | 18 mos. | 6 mos. | 24 mos. | 24 mos. | 6 mos. | 12 mos. |
| Compliant Pin | + | - | - | - | ++ | + |

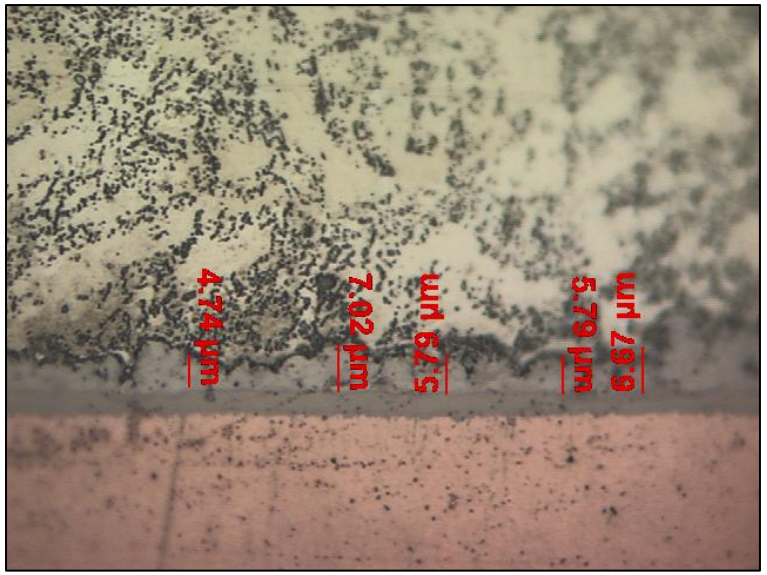


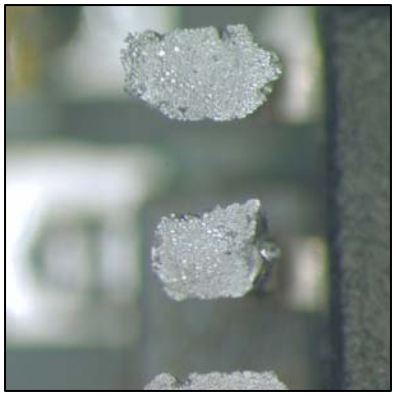

Copper Oxidation

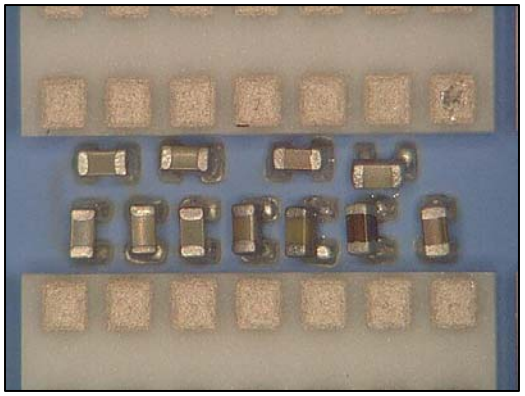
# Lead-free Profile Modification

- Longer TAL ( Time Above Liquidus) results in improved wetting
- Higher peak temp equals improved wetting
- Wetting very much alloy and surface dependent
- Flux activity is a critical element
- Drawbacks of longer TAL
  - IMC growth
  - Residue effects
  - Joint cosmetics




Top, intermetallic bond thickening





Left, excessive preheat, deactivation

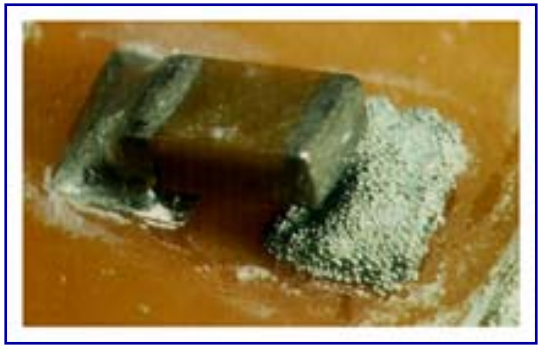
# SMT Variables and Impact on Defects

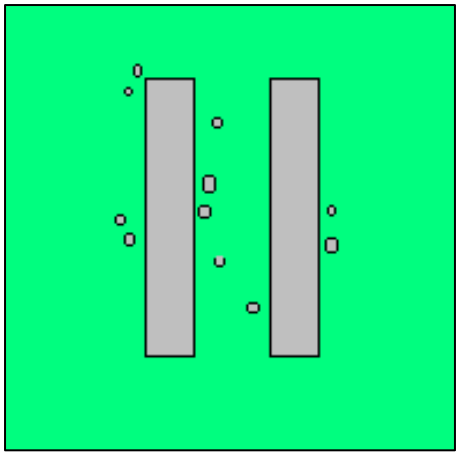
- Components and board solderability
- Storage conditions and handling
- Stencil design
- Solder paste alloy/flux selected
- SMT environment
- Printer and  settings
- Component placement
- Reflow equipment and profile
- Cleaner and cleaning solution if w/s
- Pin tester, pins and pressures

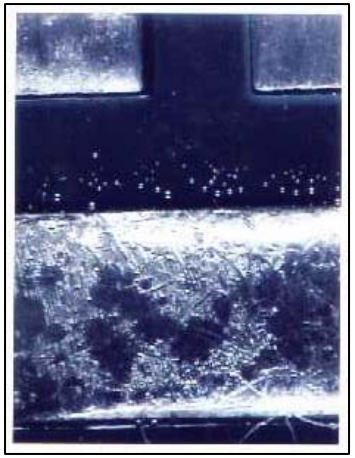
- Off-pad solderballing
- Mid-chip solderballing
- Tombstoning
- Bridging on fine-pitch
- Open joints
- Cold solder joints
- Voids

# Solderballs

- Away From Pad Area, Random Solder Balls:
  - Moisture Absorption by Solder Paste. Commonly Caused by Refrigerated Paste Opened Prior to Returning to Ambient Temperature.
- Around Pad Area:
  - Paste Contains “Fines” (Extra Fine Powder), Carried Away by Flux During Heating.
  - Hot Slump Behavior
  - Excessive Preheating; Flux deactivation
- Oxidized Solder Powder, Flux Medium Too Weak to Remover Oxide Layers, Poor Hot Slump.
- Printing Defects:
  - Paste Buildup on Underside of Stencil.
  - Excess Paste Deposit.
  - Poor gasketing of Stencil.
  - Excessive Squeegee Pressure.

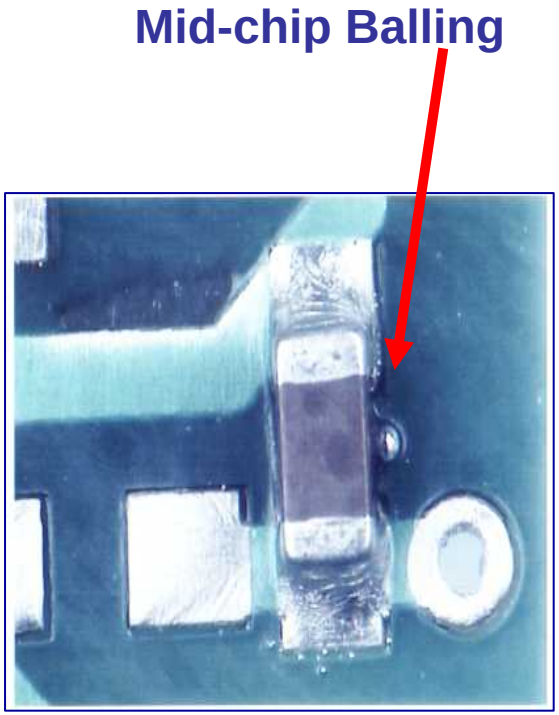






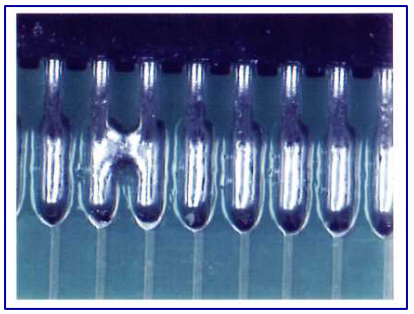
# Solder Beading

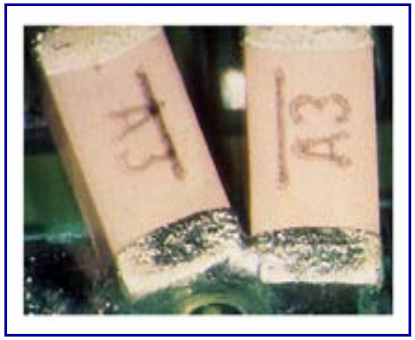
- Excess Solder Paste Slump During Preheat Stage
- Metal Loading Percentage of Paste Too Low
- Preheat Temperature Too High or Too Long
- Paste Deposition Excessive
- Stencil Aperture to Pad Ratio
- Component placement pressure



# Bridging

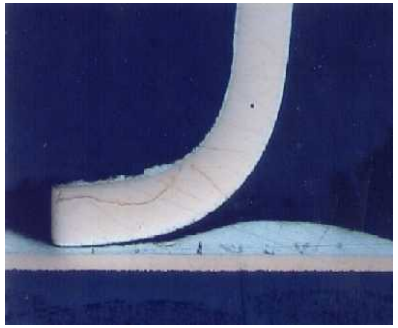
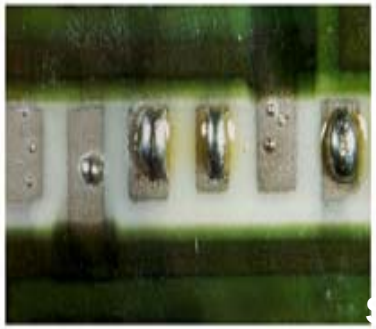
- Excessive solder paste slump.
- Solder paste deposition excessive.
- Poor resolution of paste deposit.
- Paste smearing on bottom side of stencil.
- Component placement pressure too high.






**Bridging of two chip capacitors**

# Non-Wetting

- **Poor solderability of pads or component termination, oxidation**
- **Contamination of pads or component termination**
- **Preheat time/temperature too long, deactivation of flux medium**
- **Flux activity insufficient**

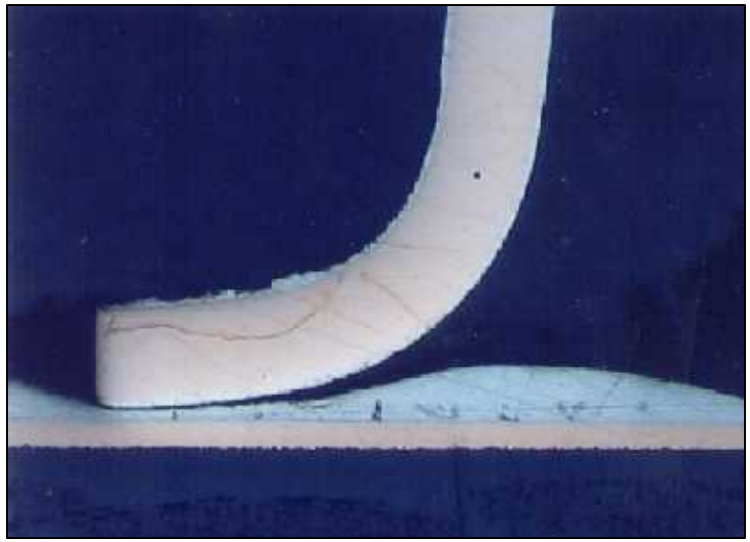
# De-wetting

- Base metal difficult to solder
- Solderable coating too thin
- Base metal contamination
- Improper treatment of base metal prior to plating or tinning process.
- Time above liquidus too long or too high peak temperature

# Tombstoning Solutions

- Adjust placement machine (offset)
- Increase pre-heat soak
- Insure uniformity of solderability
- Less active flux medium
- Increase placement down force
- Insure adequate paste volume
- Use alloy with slight pasty range

# Open Joints



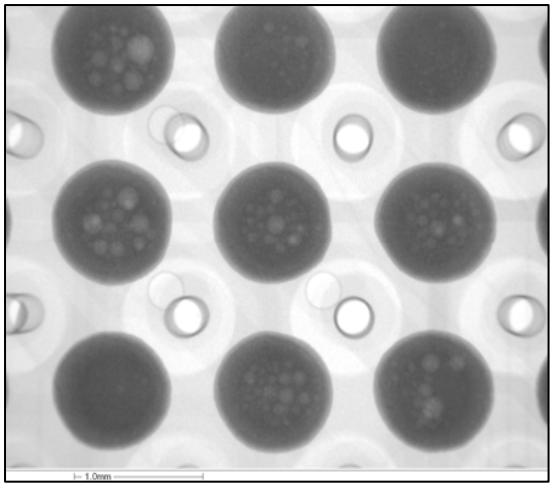
## Causes

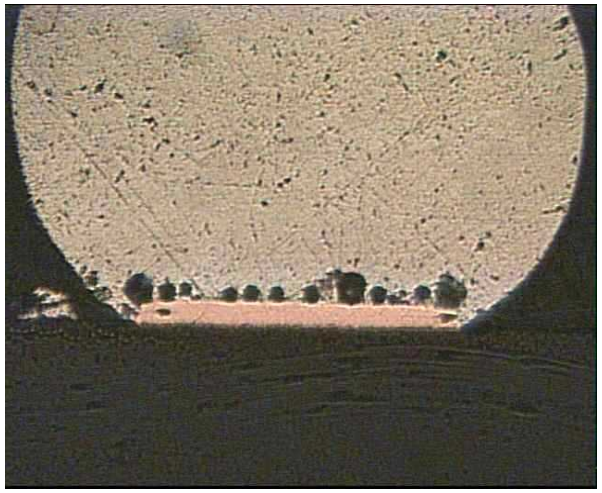
- Damaged component leads
- Poor solderability
- Insufficient flux activity
- Flux thermal stability

## Solutions

- Better handling/placement
- Reduce pre-heat input
- More active or higher solids content medium

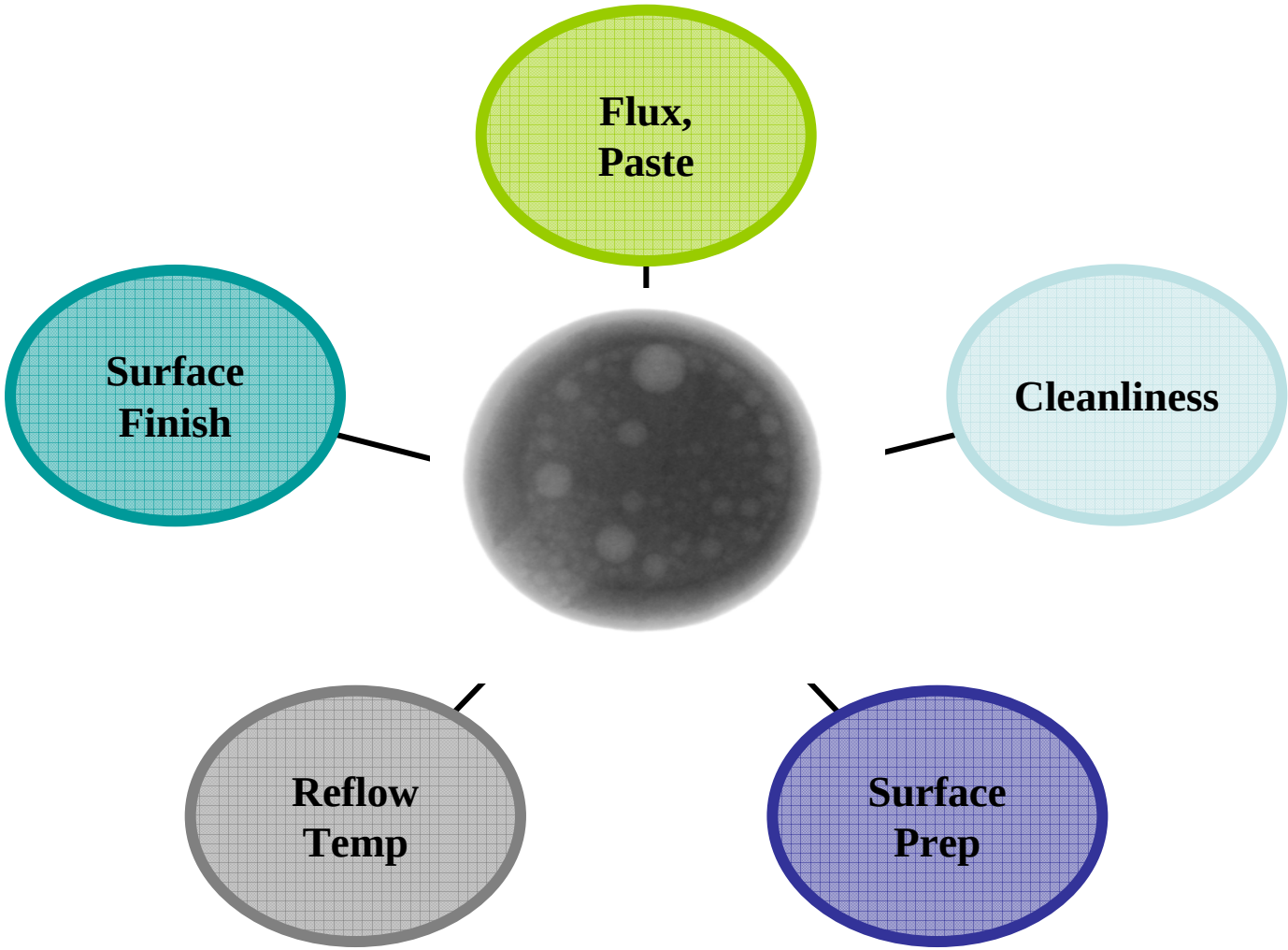
# Voiding Causes



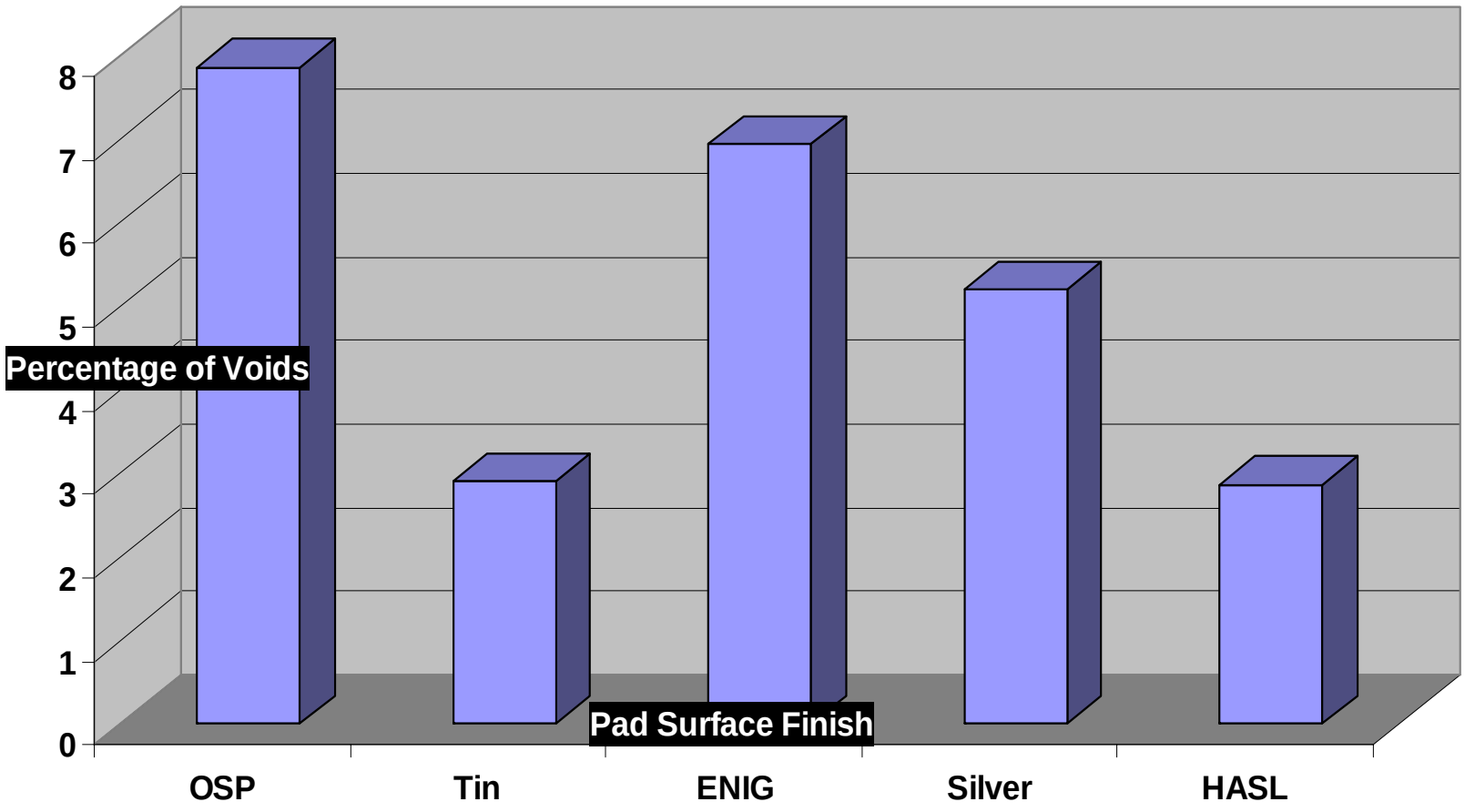


- Alloy flow rate
- Metallization
- Incorrect profile; more soak time required
- Insufficient time above liquidus temperature
- Flux chemistry, resin and solvent choices
- Component design, entrapment of flux by-products
- Plating chemistry, organic content, plating thickness

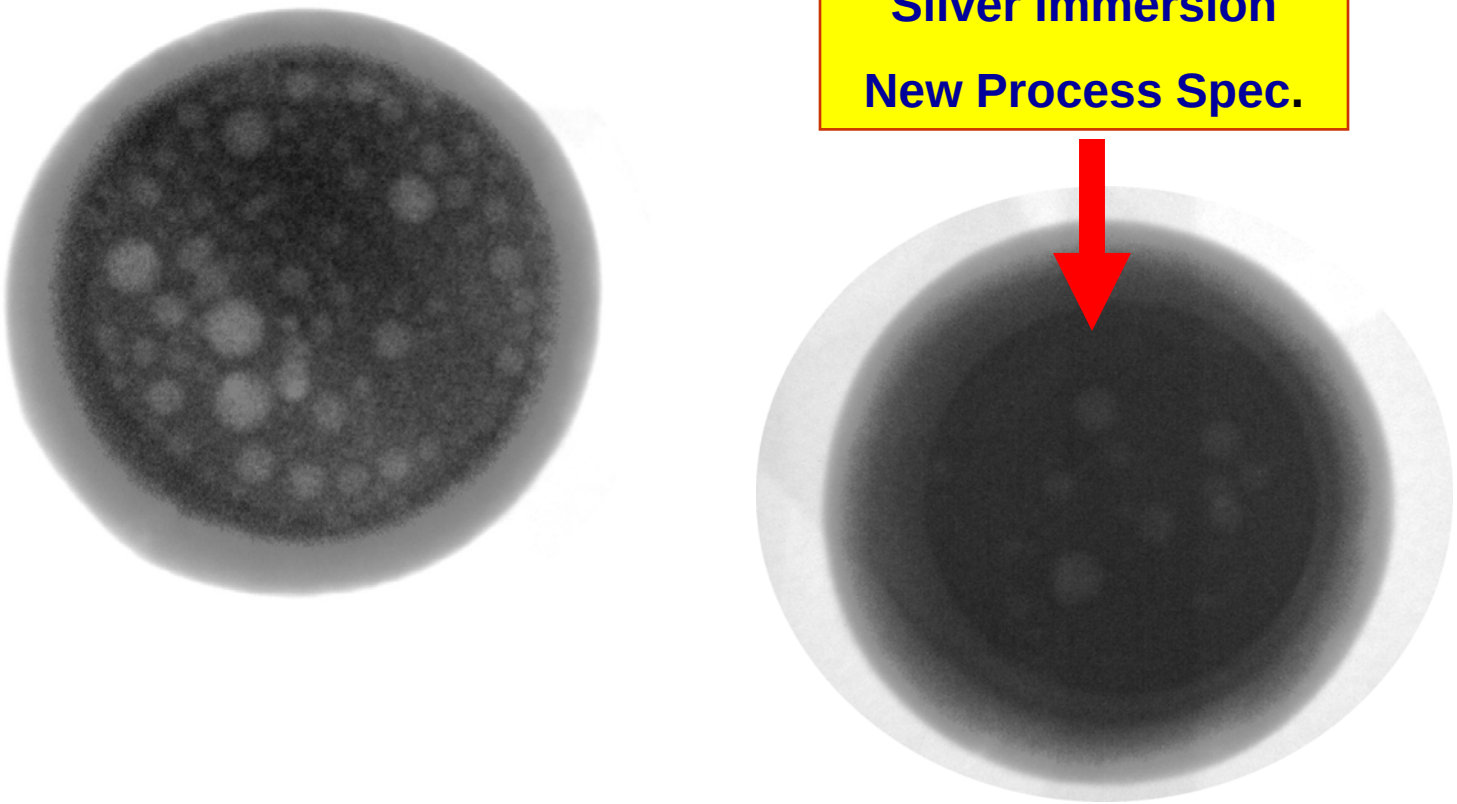
# Conspiracy of factors and many causes



# Dage, SMTA Int'l 2004

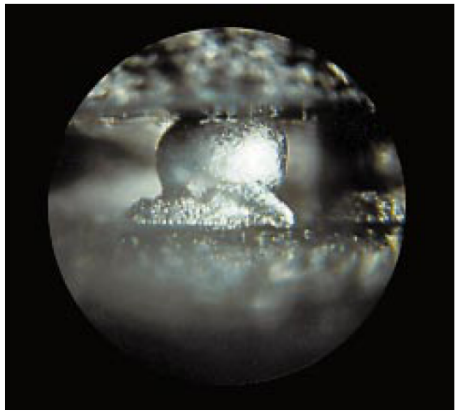


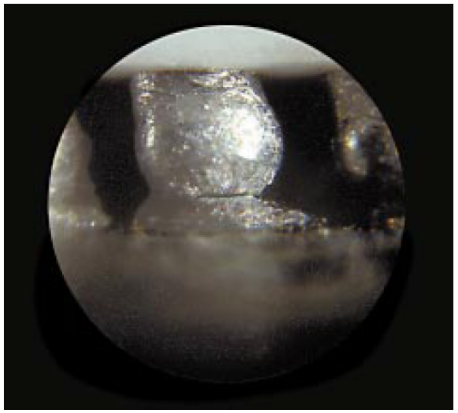
# Assembly Confirmation modified plating chemistry for Ag Imm

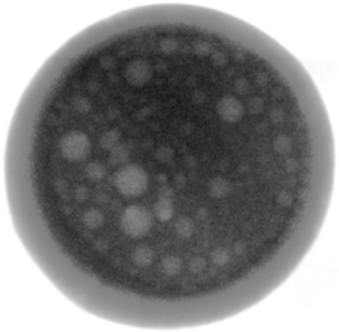



MacDermid Study, 2006

# IPC-610D, BGA assembly with lead-free solders







**Acceptable - Class 1,2,3**

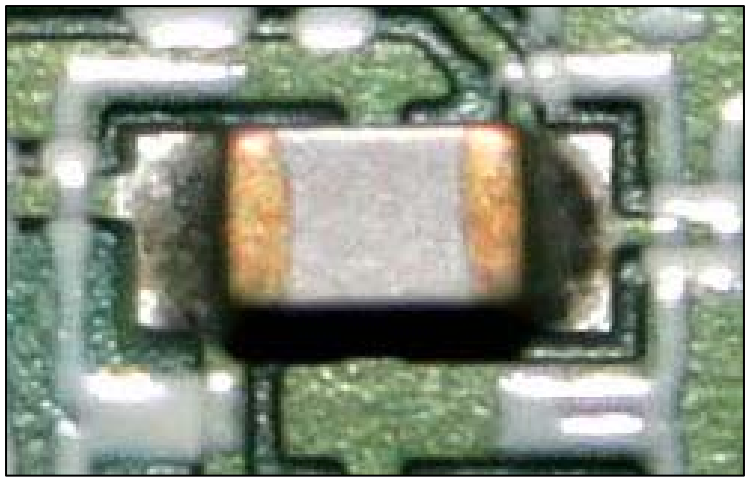
- 25% or less voiding of the ball x-ray image area.

**Defect - Class 1,2,3**

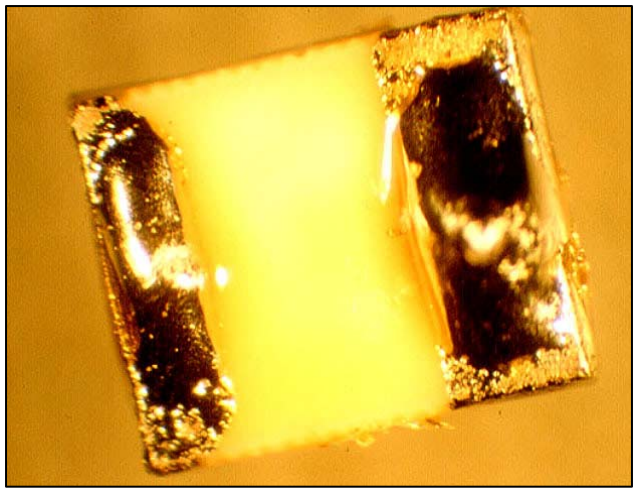
- More than 25% voiding in the ball x-ray image area.

- Biggest problem area with lead-free solders
- Insufficient wetting or ball collapse issues
- Thermal profile is critical, verify temperature at ball site
- Voids and micro-voids issues
- X-ray and endoscopic examination recommended

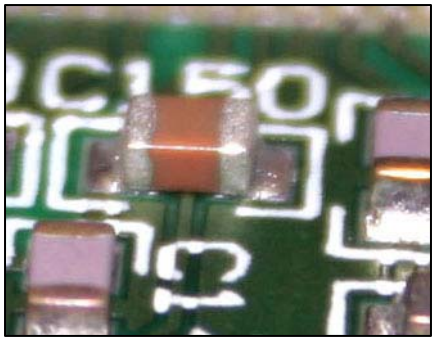
# Termination Issues



Discoloration of terminals SAC305



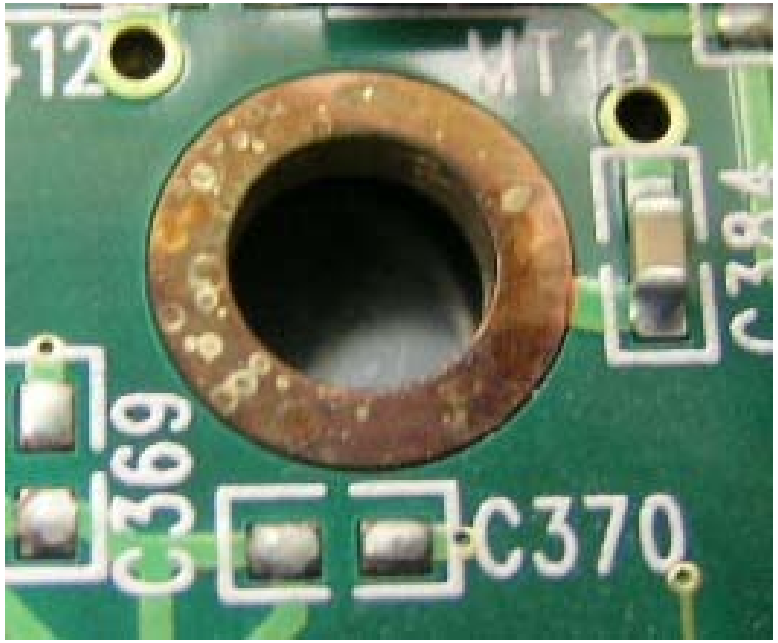
Leaching of base metals



**No discoloration with 63/37**

- Excessive peak and time above liquidus
- Parts incompatibility to a lead-free process
- Metallization impurities, discoloration only

# ENIG Discoloration, Profile Related



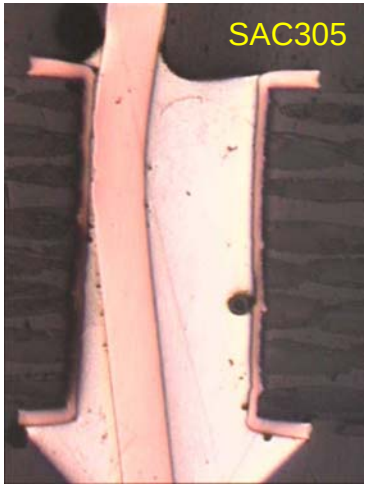

**First SMT Assembly with SAC305 profile and then waved with SAC305, Cleaned in straight DI water 120°F**

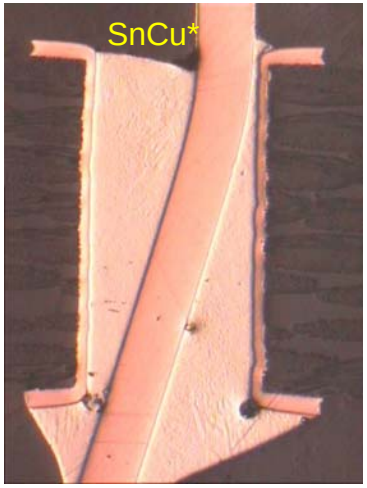
- ❑ Water contamination, flux reactions
- ❑ Gold thickness
- ❑ Excessive temperatures in reflow
- ❑ Gold, plating impurities

# Lead-free Wave Soldering

# Wave Soldering – Solder Behaviors

| | SnPb | SAC | SnCu based |
|---|---|---|---|
| Wetting Speed | Fast | Medium | Slow |
| Contact Time | Shortest | Longer | Longest |
| Pot Temperature | 465-510 ºF | 500-525 ºF | 510-535 ºF |
| *Dross Formation | 1x | 1.8x | 2x |




Similar wetting with modifications to the process

Note: SnCu with additives used

# Solder Properties - Most Popular Alloys

| | K100*LD* | SnCu* | SAC305 |
|---|---|---|---|
| **Melt Point** | ~227C | ~227C | 217-220C |
| **Pasty Range** | 0 | 0 | 3C |
| **Appearance** | Shiny | Shiny | Dull |
| **Shrink Holes** | No | No | Yes |
| **Copper Dissolution (Sn63 = 1)** | 0.8 | 1.0 | 2.1 |
| **Pot Management** | Easiest | Easy | Difficult |
| **Reactivity to Equipment** | Low | Low | High |
| **Suggested Pot Temperature** | 255 – 265°C | 255 – 265 °C | 250 – 260 °C |
| **Approximate Relative Cost (Sn63 = 1)** | 1.5 | 1.5 | 3.0 |
| | | | |

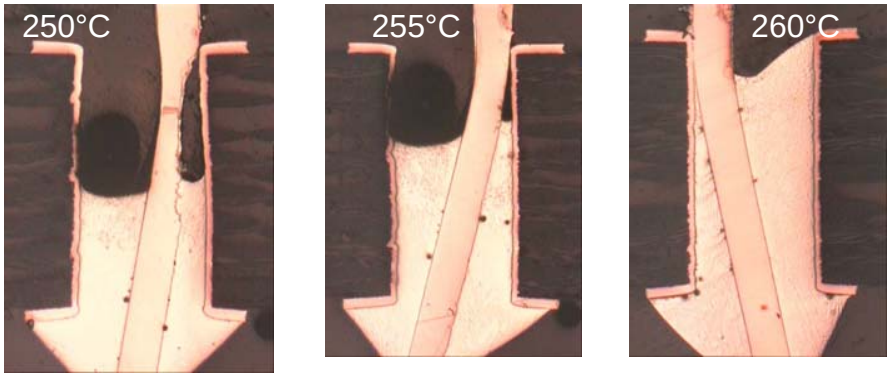
* With minor additives

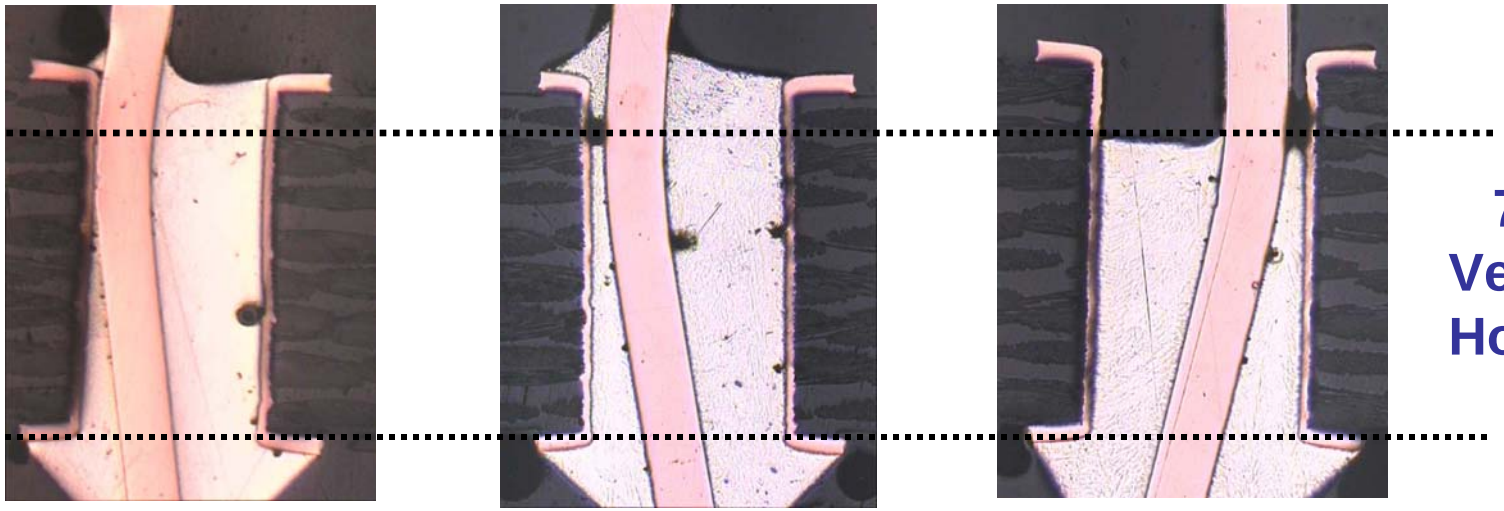
# Lead-free Liquid Flux Compatibility

| | VOC-Free (water is solvent) | Alcohol-based |
|---|---|---|
| No-Clean, Low Solids, No Rosin | Best for LF * | Not suitable for LF |
| No-Clean, Low Solids, With Rosin | N/A | Suitable for LF |
| Organic Acid (Water washable residues) | Best for LF * | Suitable for LF |
| Rosin-based | N/A | Suitable for LF |

* Best selections for lead-free wave soldering

# Impact Solder Pot Temperature and Finish



75 % Vertical Hole fill

Ni/Au

Ag Immersion

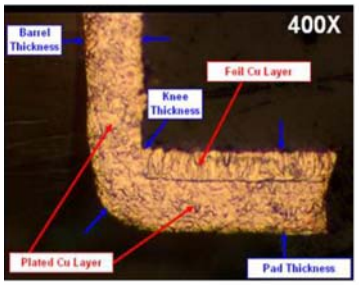
Copper OSP

Pure tin leads, SAC at 250°C, 1 Meter/minute, ROL1 Flux

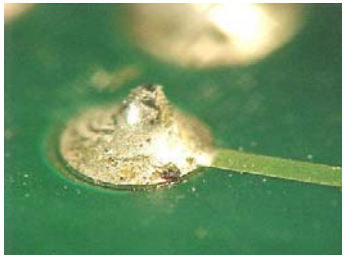
# K100LD has the Lowest Copper Dissolution

- Minimizing Copper Dissolution is critical with the conversion to lead-free soldering.
- Lead-free alloys dissolve Copper and other metals faster than leaded solder.

| Alloy | Relative Rate of Copper Dissolution |
|---|---|
| **K100*LD*** | **0.8** |
| Sn63 | 1.0 |
| SnCu+Ni | 1.0 |
| SAC+Bi | 1.6 |
| SAC305 | 2.1 |
| SnCu | 2.2 |
| SnAg | 2.3 |
| Pure Tin | 2.4 |



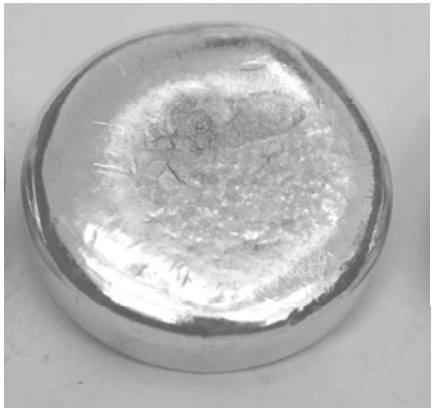




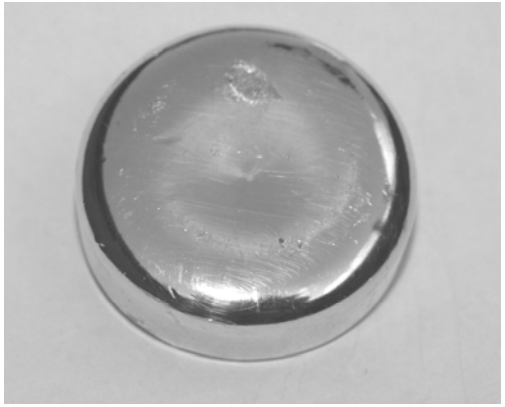
**Dissolution of lead with SAC solder**

# Dullness

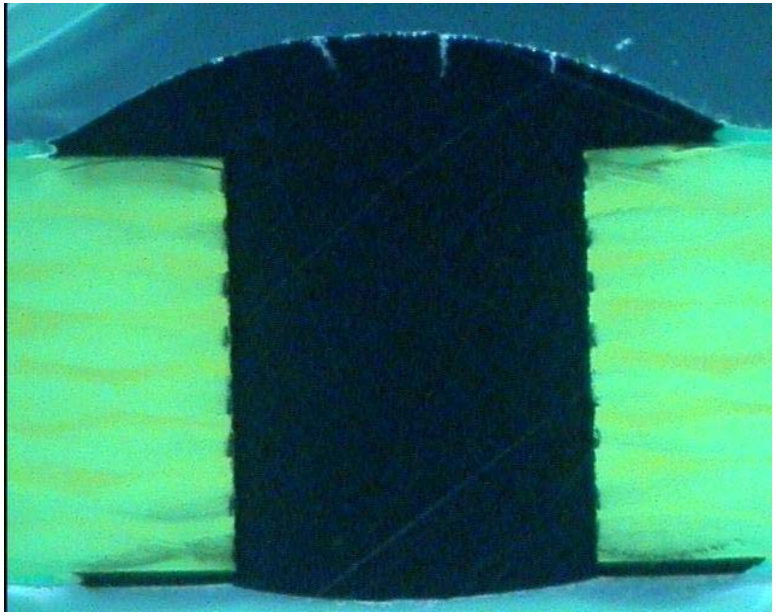
- Many lead-free alloys produce matte-finish, dull solder joints
- This dullness comes from a small amount of surface shrinkage when the alloy cools.
- This surface shrinkage (also known as “hot tears” or “shrink holes”) can result in cracking that goes somewhat beyond the surface



**SAC305**



**K100LD**

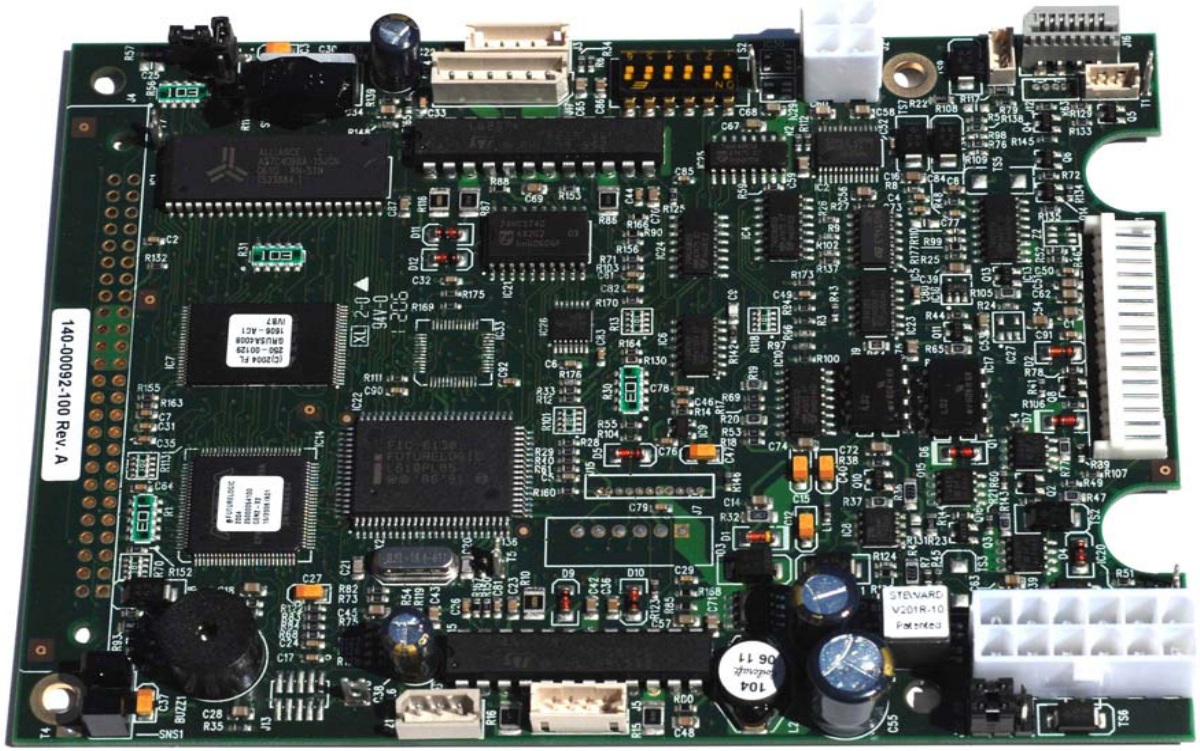


**SAC305 Shrinkage Cross-section**

## SMT Dynamics, Anaheim CA

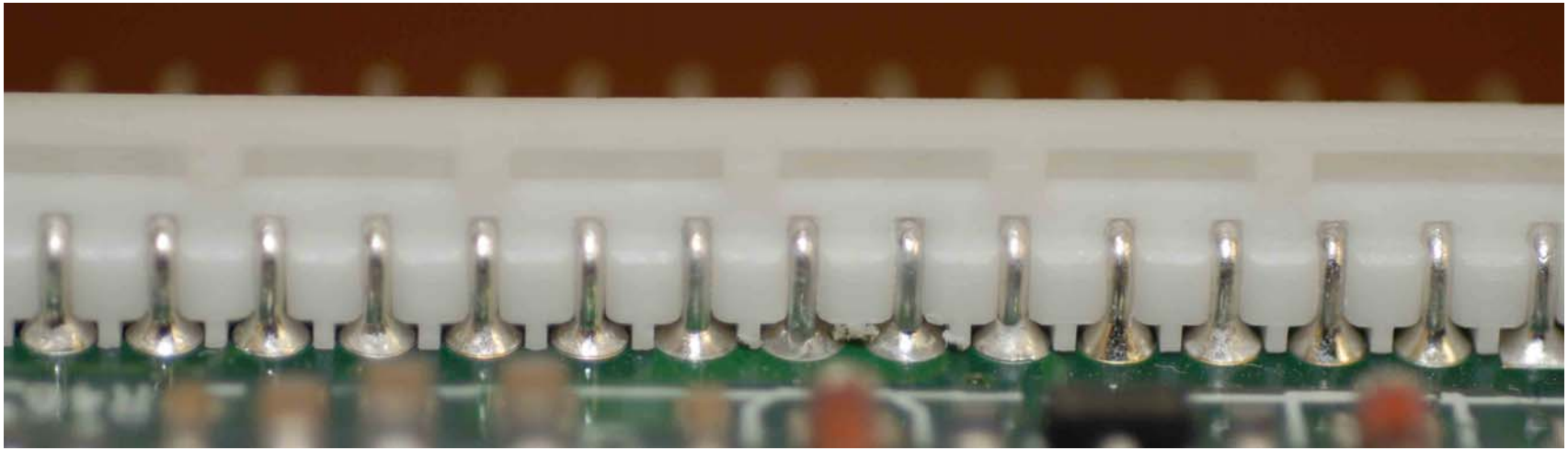
## SnCu (K100) with 2235 Flux; SAC305

## R520A and K100, 331 Flux 66 core wire




**FutureLogic Thermal Printer ENIG Board 300,000+ assembled**

# K100 Wave Soldered Connector 0.063” thick ENIG PCB



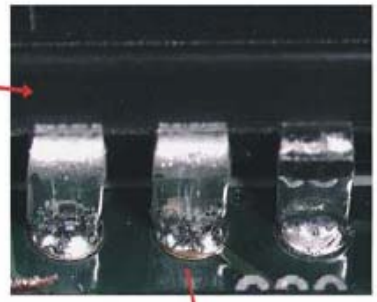
# FutureLogic Board

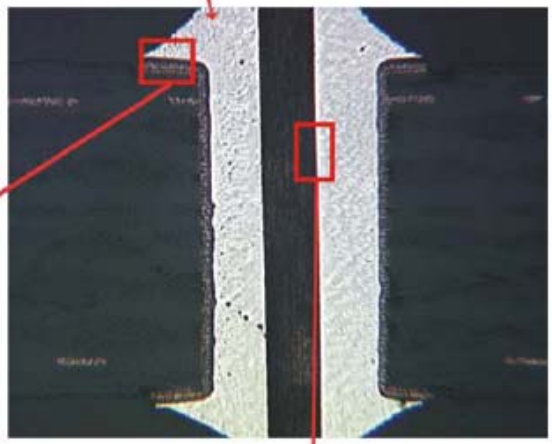
**Tests Done**

X-Ray

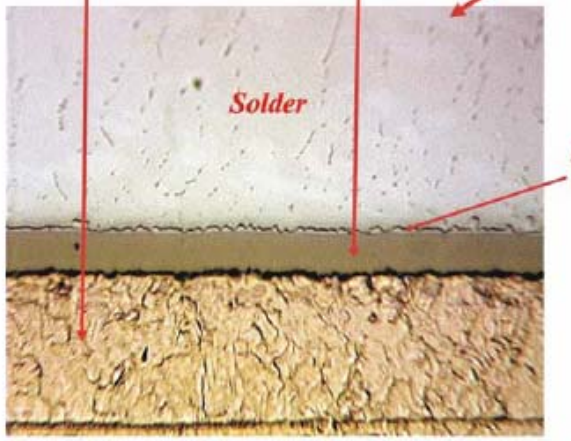
Cross-sections

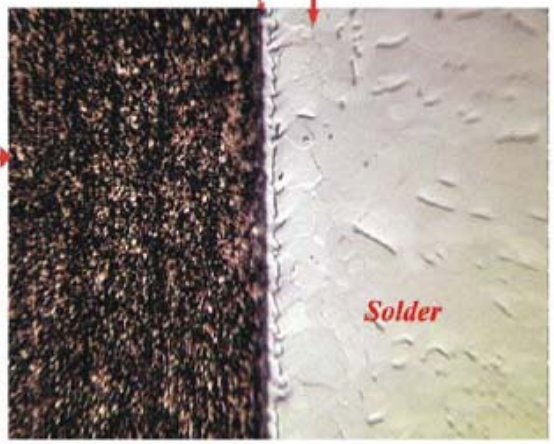
IPC 610 Inspection





The photomicrograph (below) reveals an adequate Ni/Sn intermetallic compound (IMC) reaction layer between the solder and the Ni barrier plating on the Through-hole walls.

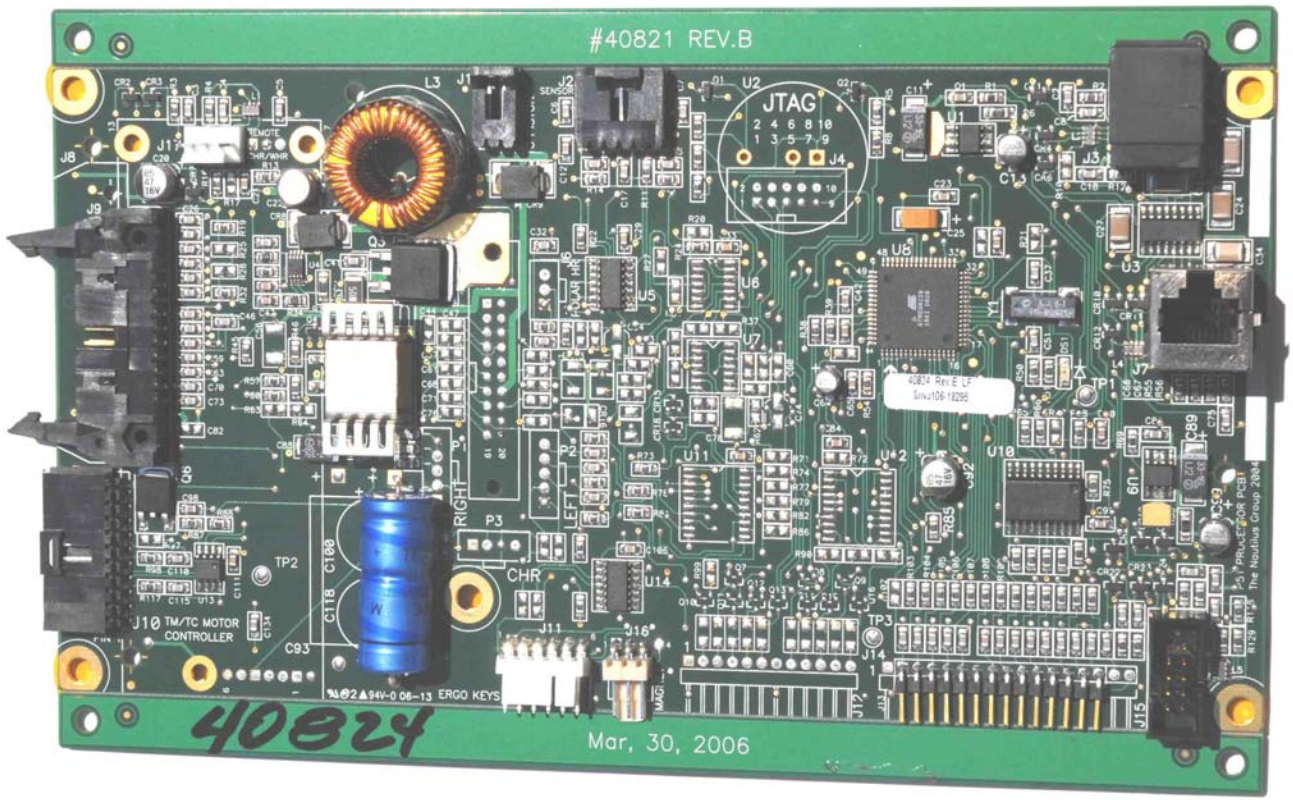



The photomicrograph (right) reveals a good Cu/Sn intermetallic compound (IMC) reaction layer between the solder and the Cu connector.

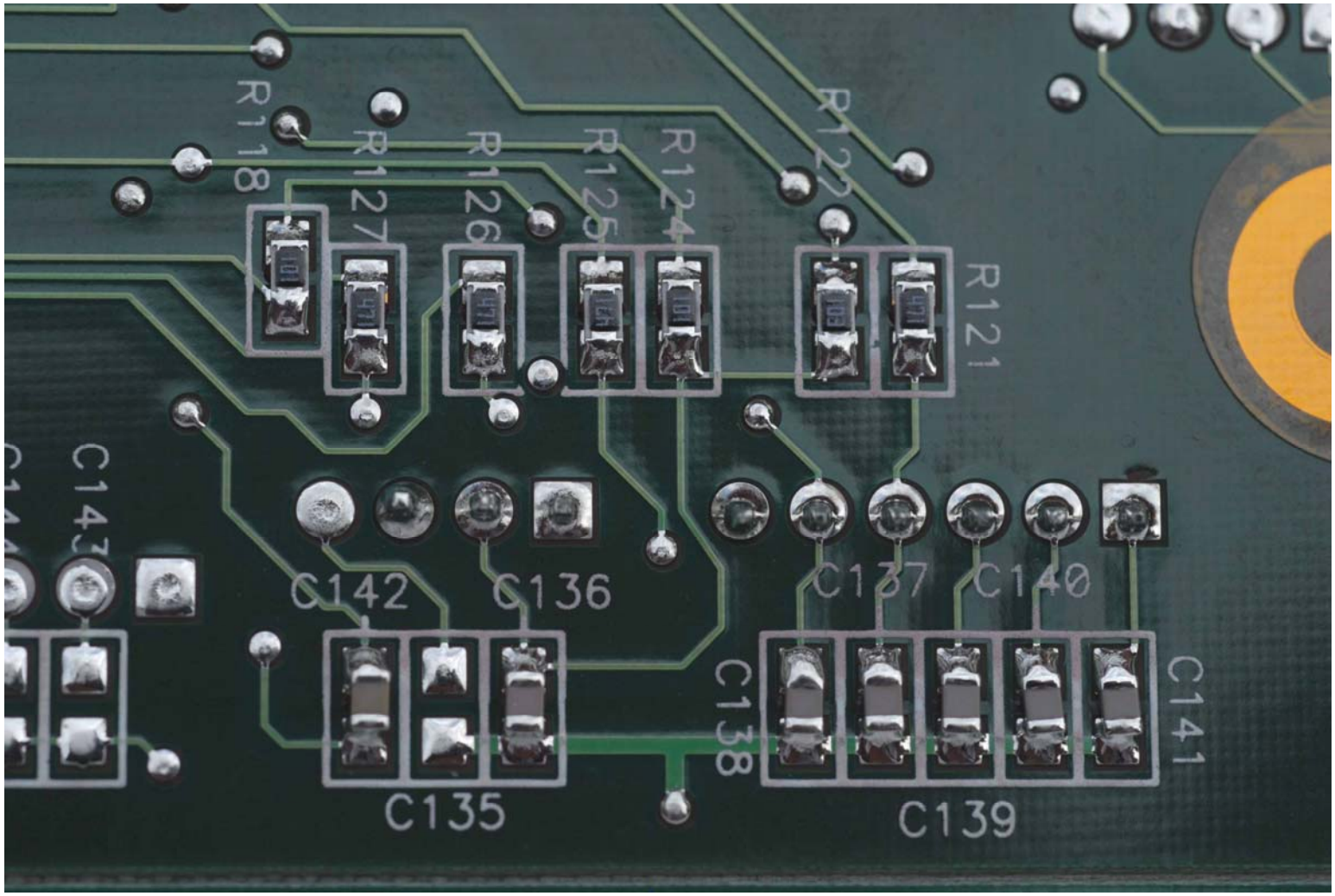
# Ayrshire Electronics LF Implementation

- They built 3 board types for Nautilus Europe with Kester K100LD bar, 2235 flux and SAC305 EM907



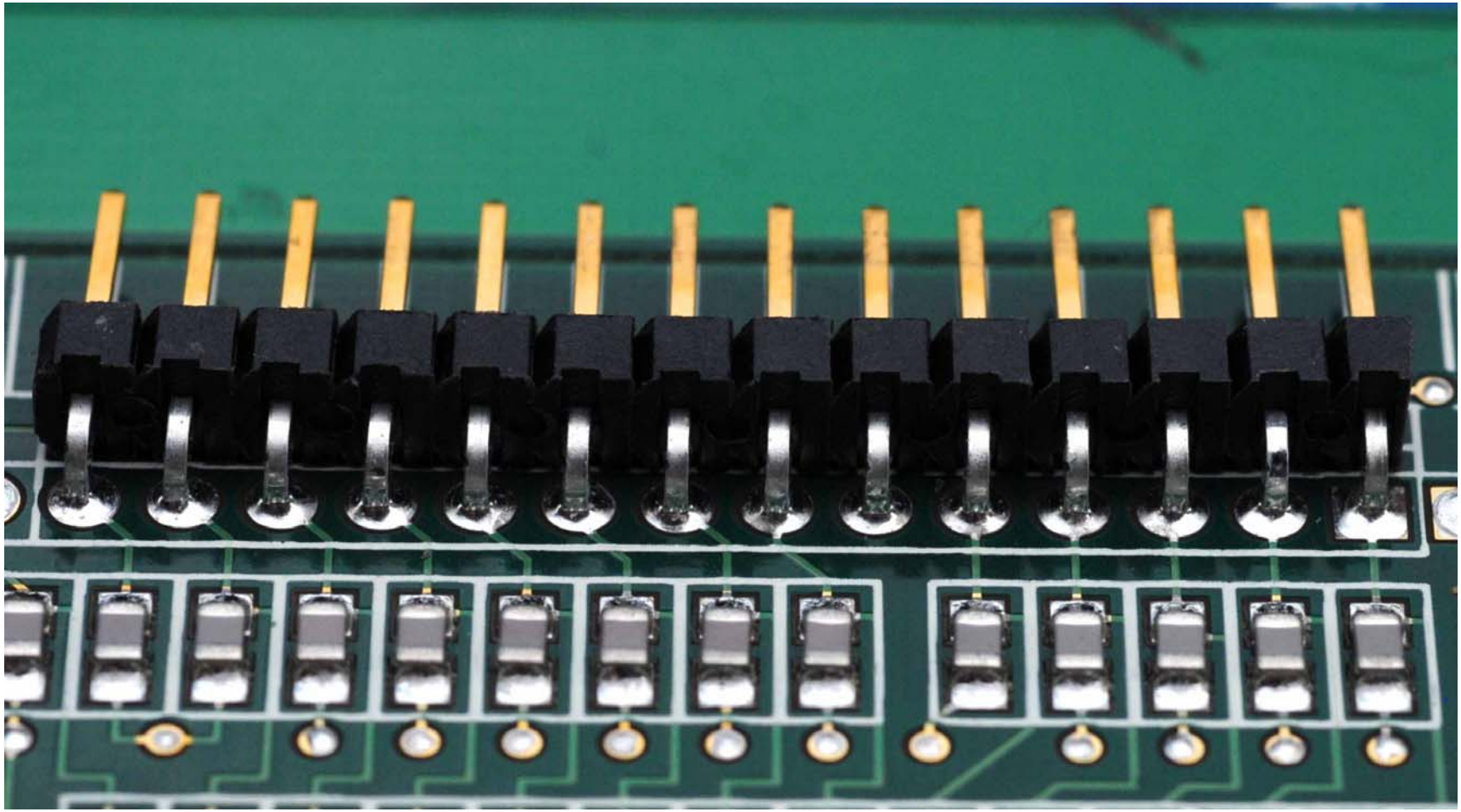

**Mixed technology board with top and bottom-side SMDs, 0.063” SN100CL**

# Bottom-side SMDs and PTHs done with K100LD and Kester 2235




**The boards exhibited no defects and bright joints**

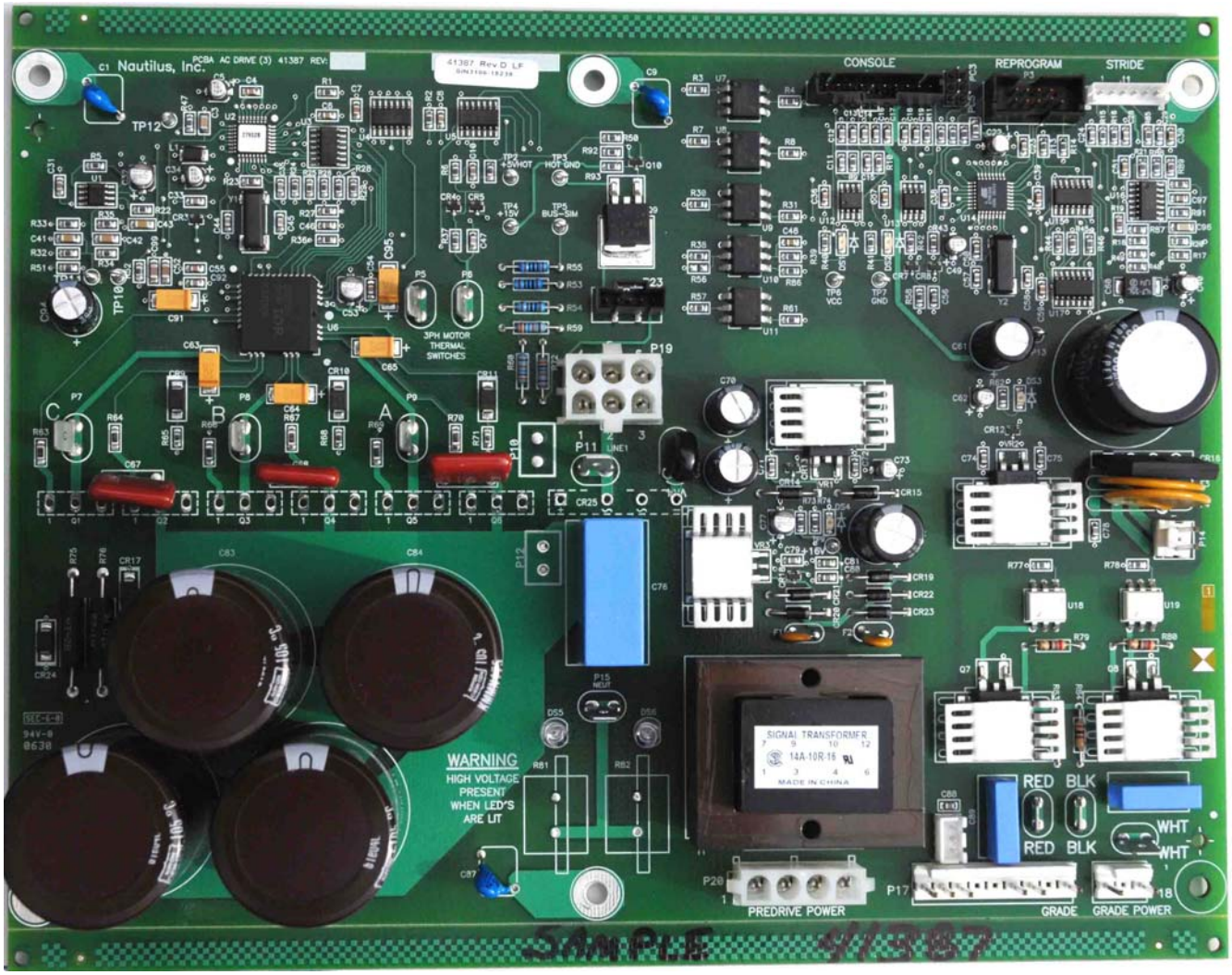
# K100LD Excellent Top-side Fillets; No Dullness, No Shrinkage



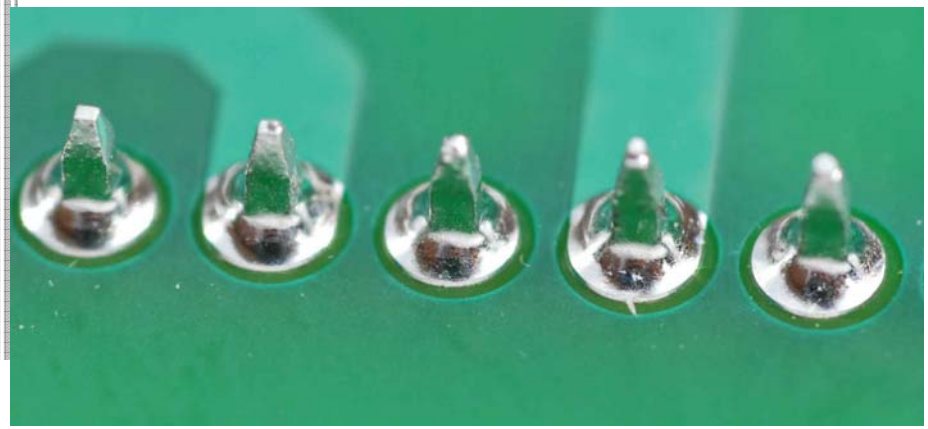
**SAC305 EM907 was used for top-side SMDs**

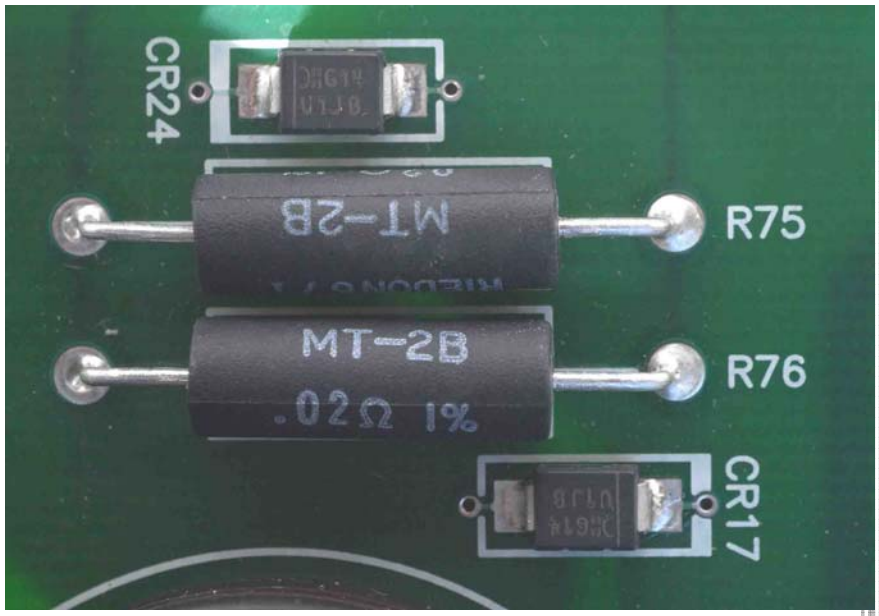
# K100 and 2235 Flux with SAC305 EM907 Top-side reflow,

# **0.093”** Thick SN100CL Finished

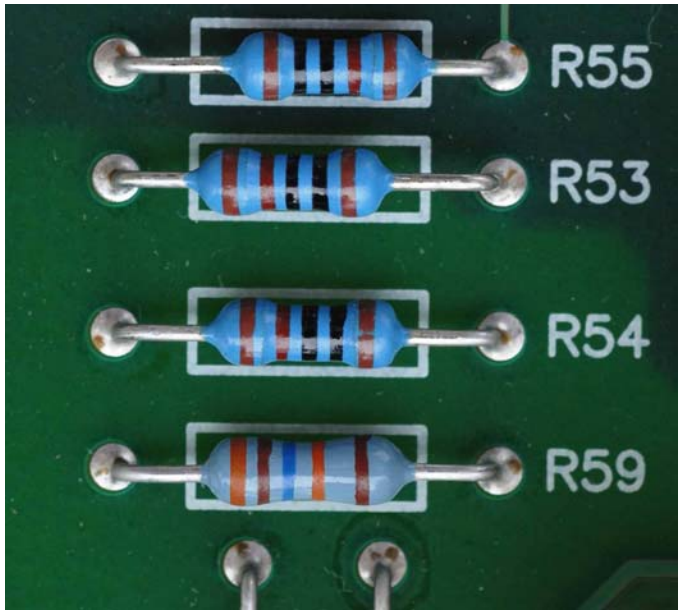


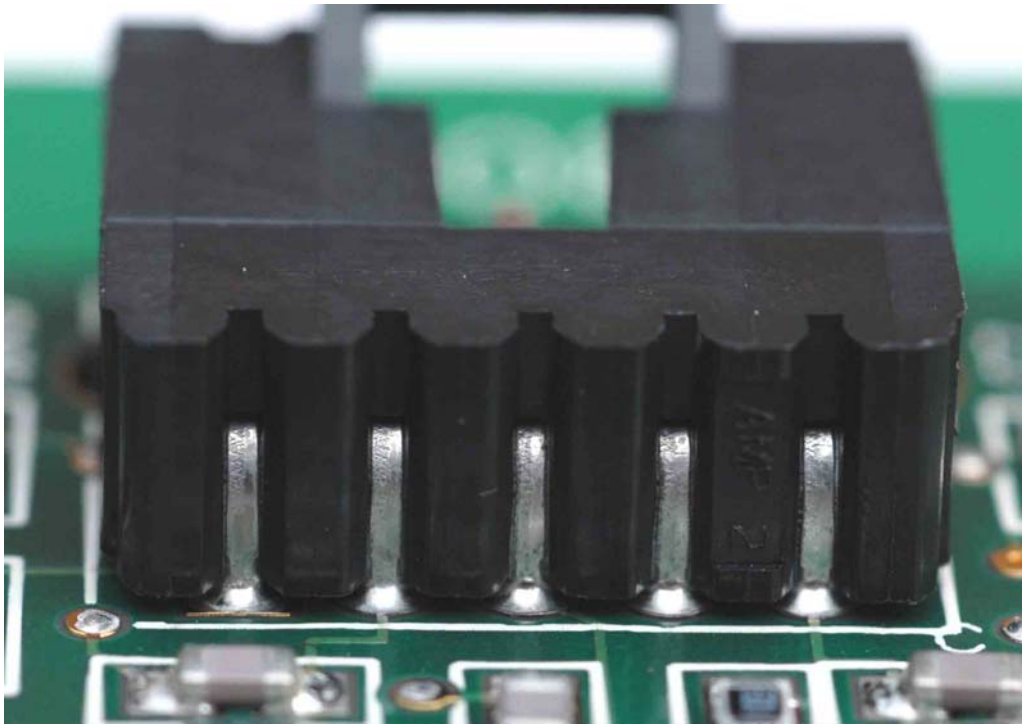
# K100LD excellent defect-free bottom-side and top hole-fill



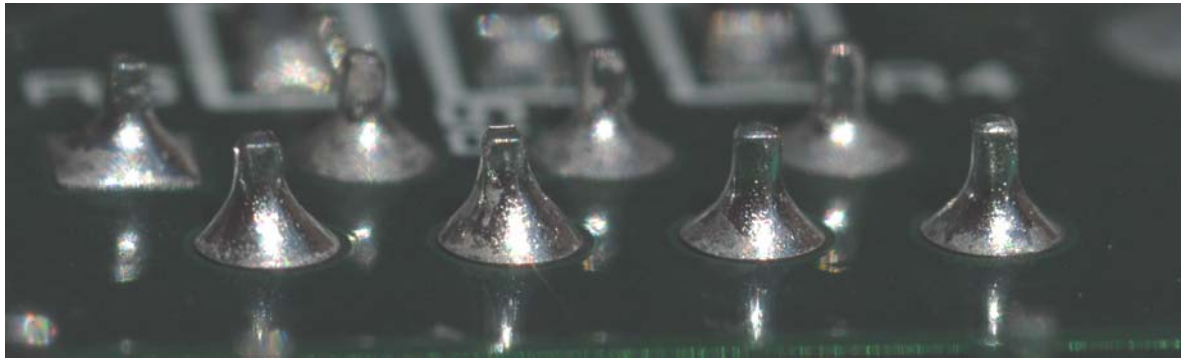


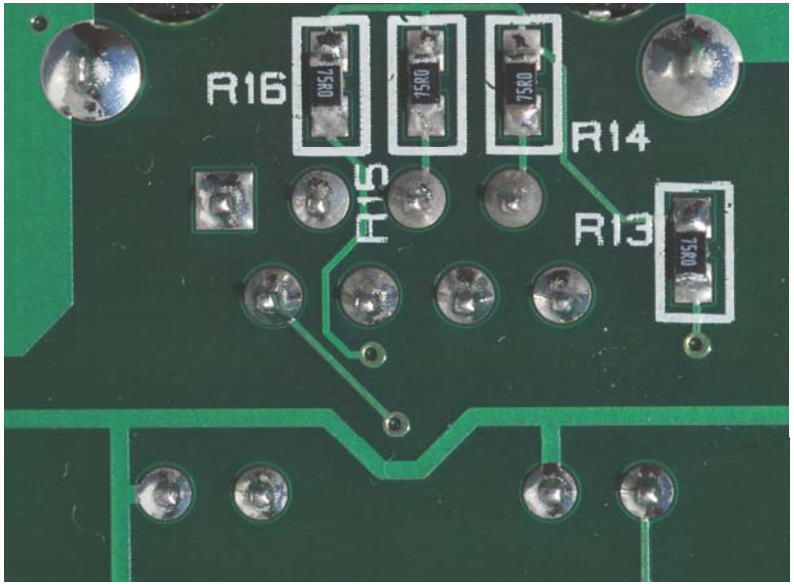
# K100LD on 0.093” thick board with excellent hole-fill

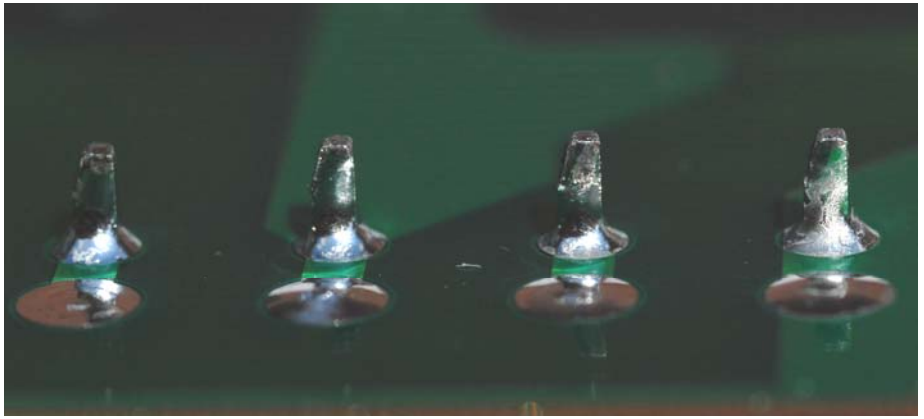


# SnCuNi +Bi (K100LD) Joints





# Optimized Wave Soldering Process for SnCu Enhanced Solders

- Wave pot temp. 260-265°C
- Conveyor speed 3.0-3.5 feet per minute
- Contact time 3-5 seconds
- Contact width 2 inches approx.
- Board to wave contact thickness ½ to ¾
- Board preheat 100 to 130 °C, flux dependant
- Flux was either sprayed or foamed

# Wave Defects - Cause and Effects

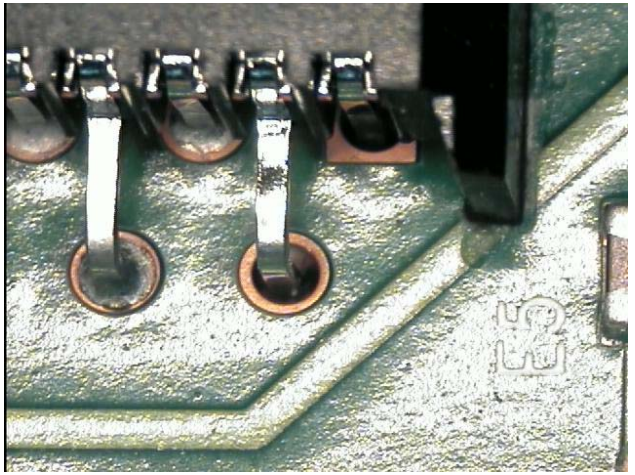
- Solderability of boards and components
- Lead-free solder alloy selected
- Flux selection
- Flux application and control
- Equipment process conditions
- Board & component design
- Solder mask type
- Cleaning process compatibility
- Conformal coating and flux compatibility

- **Non-wetting, skips**
- **Poor hole filling**
- **Bridging**
- **Fillet Lifting**
- **Solder balls**
- **Voids**
- **De-wetting**
- **Mask blistering**

# Skips, Non-Wetting, Poor-Hole Fill and De-Wetting

## No wetting; skips

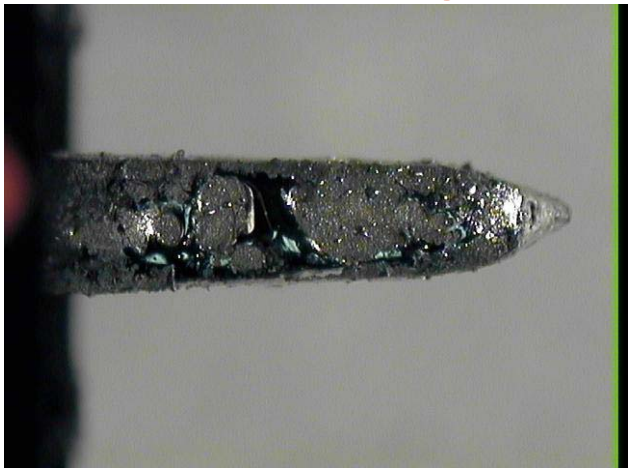
- Insufficient flux
- Lack of flux activity
- Solder wave low or uneven
- Conveyor too fast
- Board warp
- Lead-to-hole ratio too large
- Soldermask in hole
- Shadowing
- Pump too slow



Non-wetting

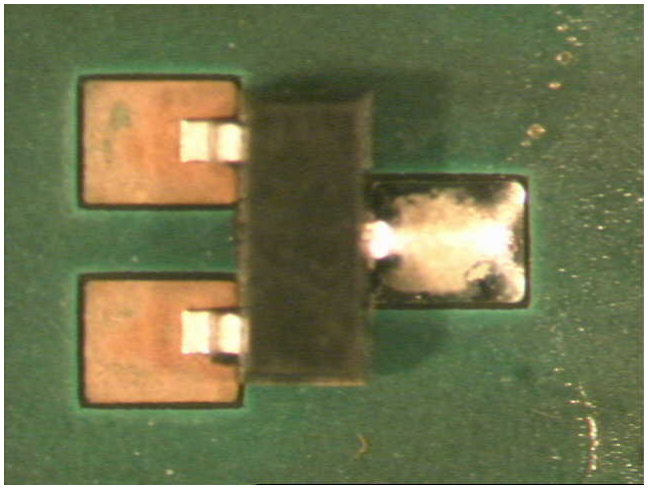
## De-wetting

- LF alloy dependent
- Pot temperature
- Contact time



De-wetting

# Shadowing Effects
# Surface tension differences

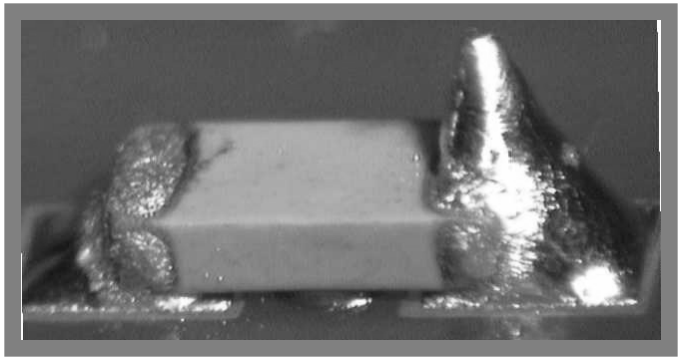


**SAC305 using no-clean flux, board OSP**

- Increases due to higher surface tension of lead-free solders
- Design issue
- Wave parameters, such as use of chip wave or higher impeller speeds

# Icicles or Flagging

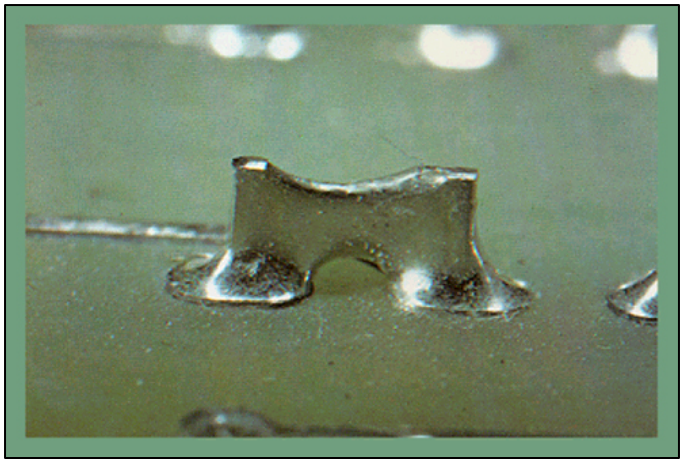
- Solder temperature low
- Solder contamination
- Preheat too low/high
- Solder wave height low
- Preheat temperature low
- Conveyor speed high
- Conveyor angle low
- Contact time
- Insufficient flux

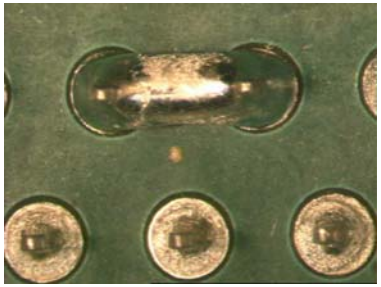


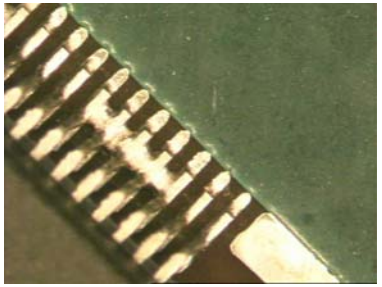
Fluxes for lead-free soldering with sustained activity reduces icicling. Higher solids percent and/or a higher acid number also helps.

# Bridging

- Solder temperature low
- Insufficient flux
- Preheat too low/high
- Flux not active enough
- Flux over thinned or old
- Leads too long
- Component/board design
- Orientation to wave
- Conveyor speed too slow/fast
- Contact time



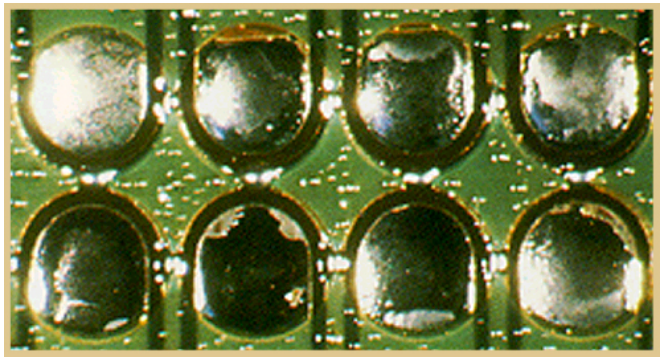




**Lead-free alloys wet surfaces at a slower rate and have slower peel back. Good sustained activity in the flux is needed.**

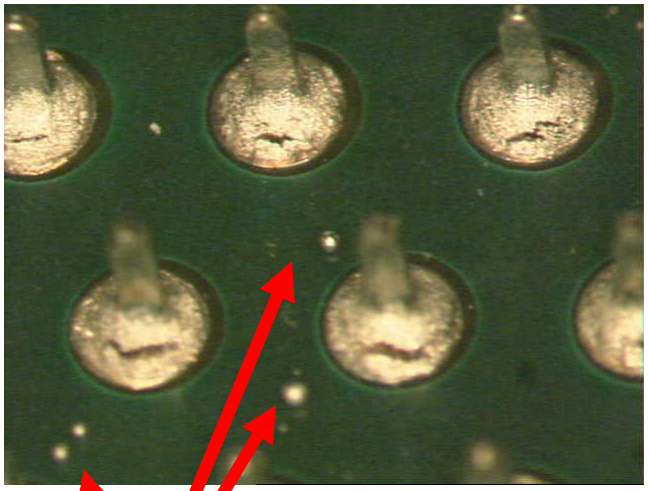
# Solder Balls

- Under-cured solder mask
- Solder temperature too high
- Insufficient flux
- Flux not evaporated before wave
- Incompatible flux and mask
- Correct flux for application
- Contact time



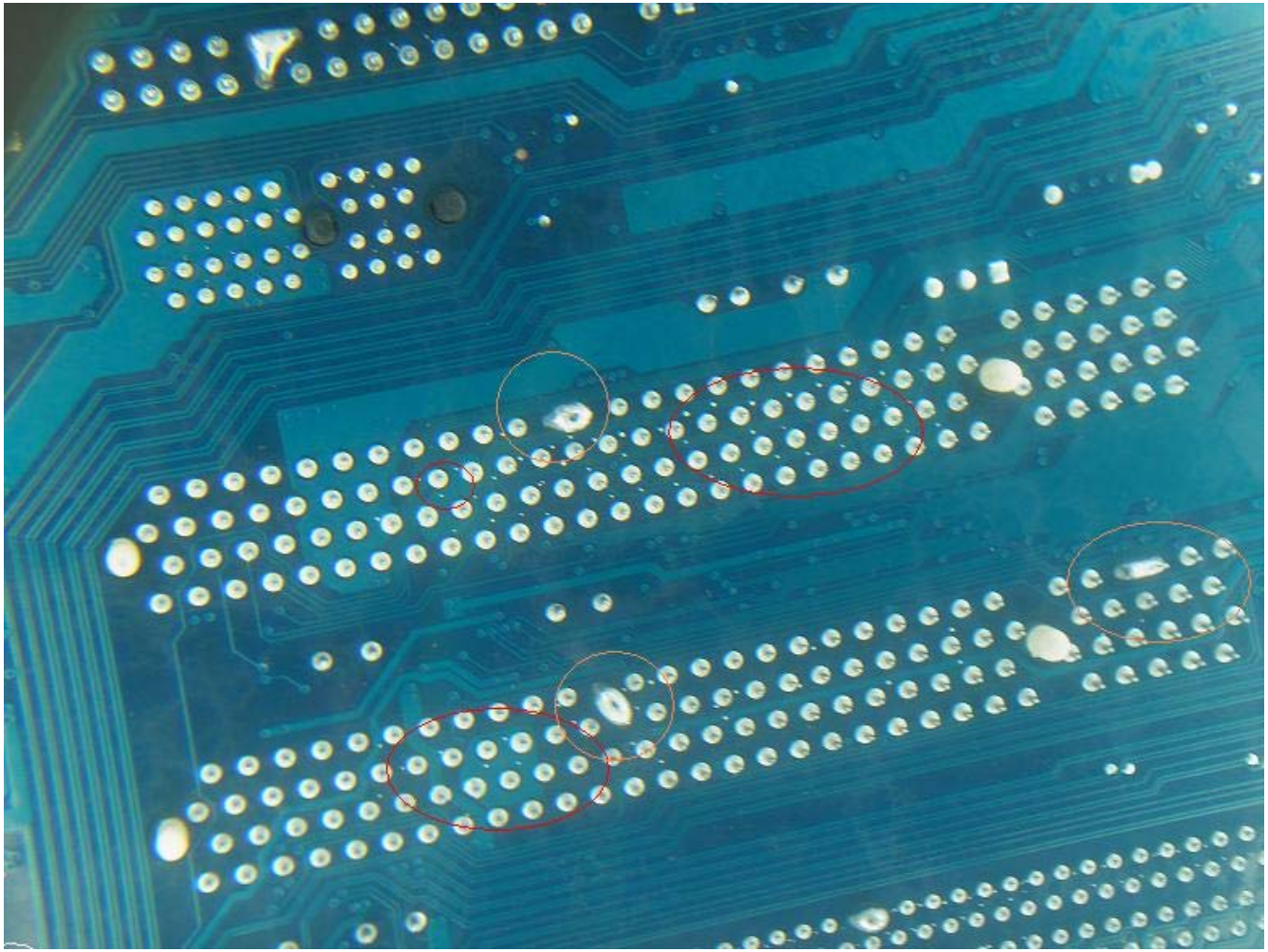
# SAC305 Solder Balls, No-clean flux

- **Flux can be cause**
- **Solder temperature**
- **Solder mask cure**
- **Contact time or dwell**



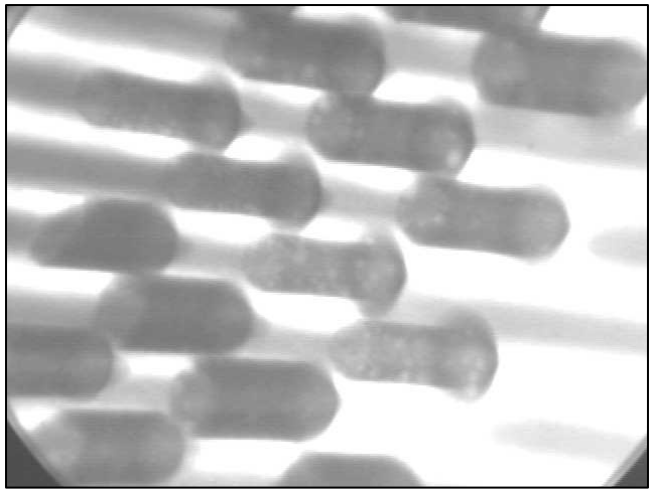
**Solder balls adhering to mask**

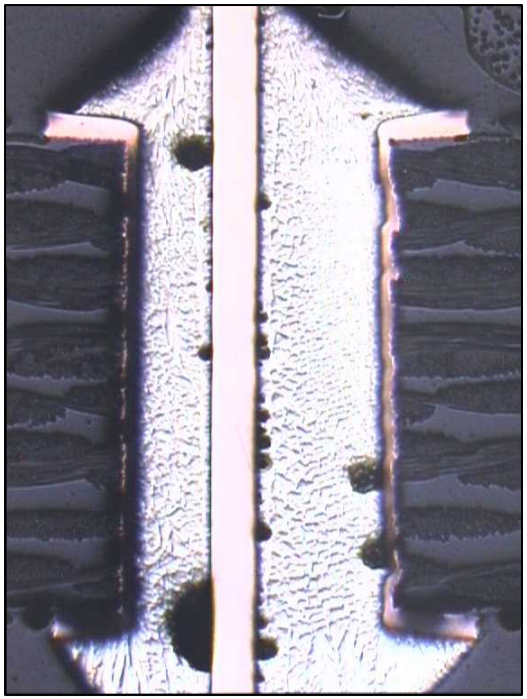
# Solder Balls using SAC305 and VOC-Free No-clean Flux



# Voids in Wave Soldering with Lead-Free alloys

- Higher surface tension impact
- Flux dependent
- Solder temperature dependent
- Contact time dependent
- Finish dependent, copper worst

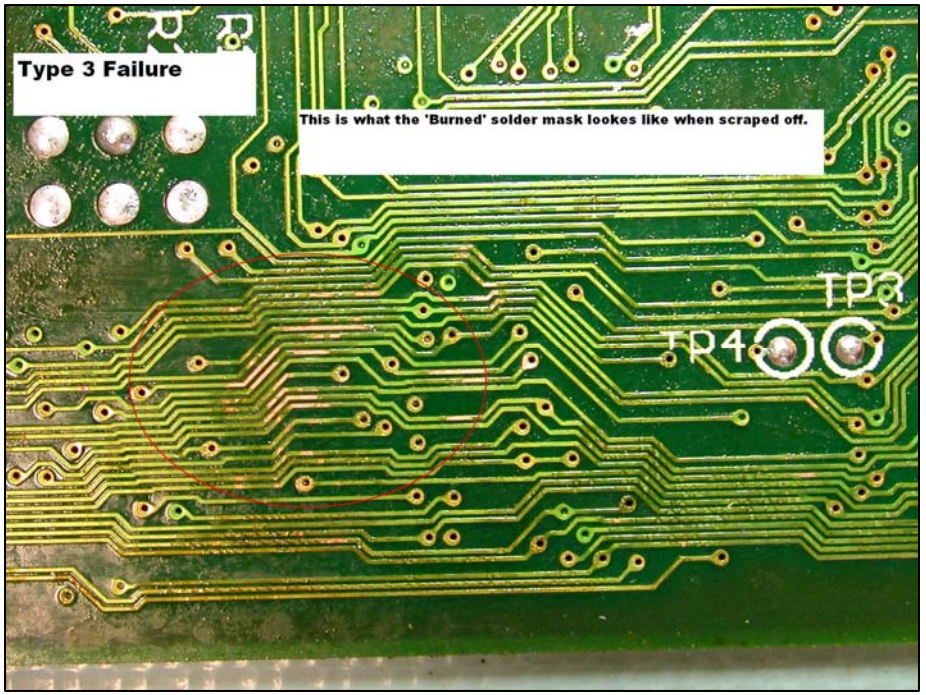




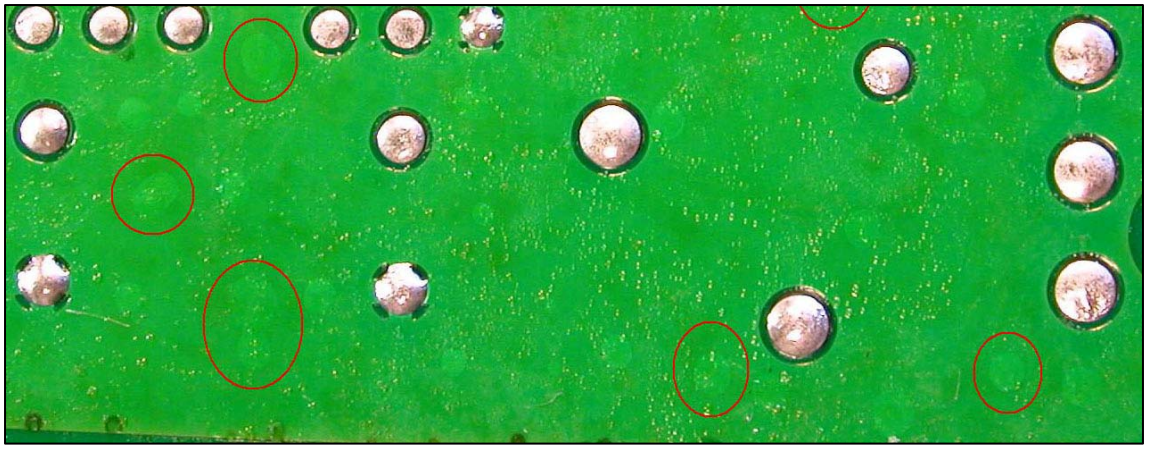
**Voids in DIP IC Socket, NiAu PCB, Tin plated leads, 1.4 meters/minute, Solder 260°C, in air, ROL1 Flux**

# Mask Blistering

- ❑ Excessive solder temperature
- ❑ Excessive solder contact
- ❑ Mask curing incomplete
- ❑ Flux incompatibility
- ❑ Moisture entrapment





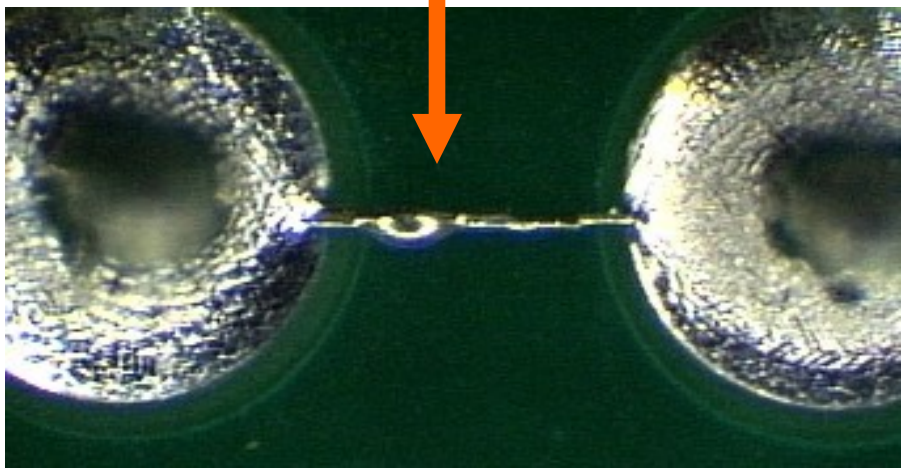


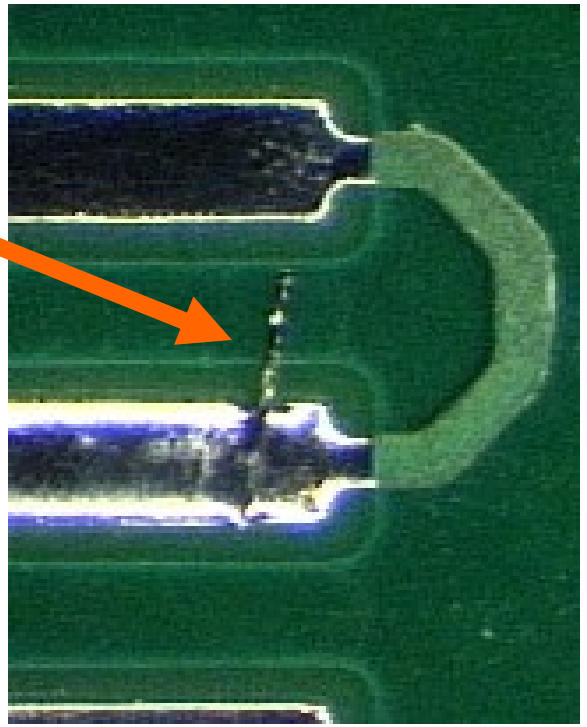
SAC305 solder was used in the above with a contact time of 5 seconds

# High Iron Contamination

- Formation of needles
- Surface tension effect

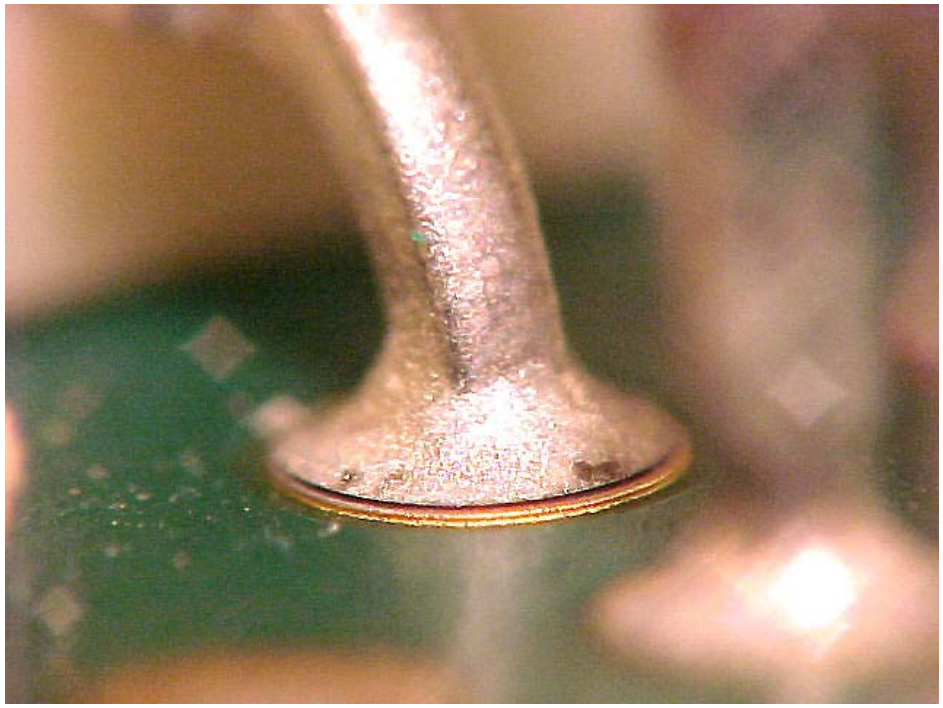
**Tin-Iron needles intermixed with solder**

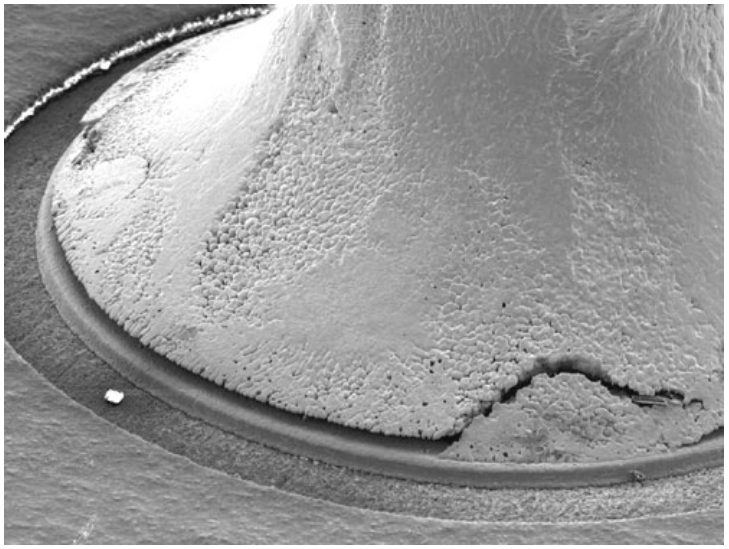


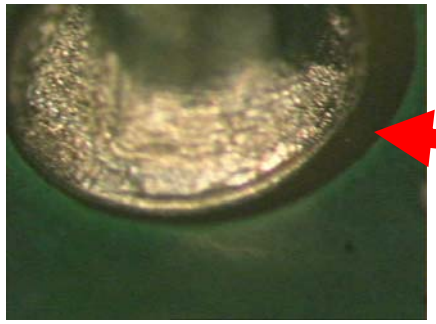


**Photos from Vitronics, 5 steps to Lead-free .**

# Fillet Lifting








- **Pad geometries**
- **Pb or Bi inclusions**
- **Not necessarily a defect as per IPC-610D**

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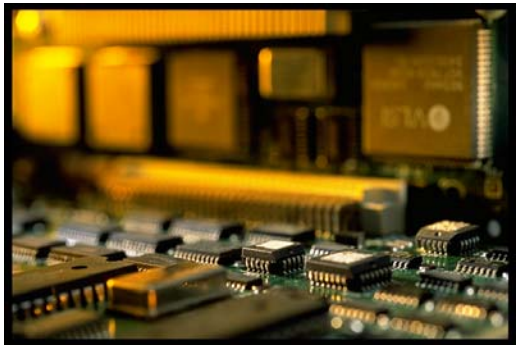


# Lead-free Hand Soldering and Rework

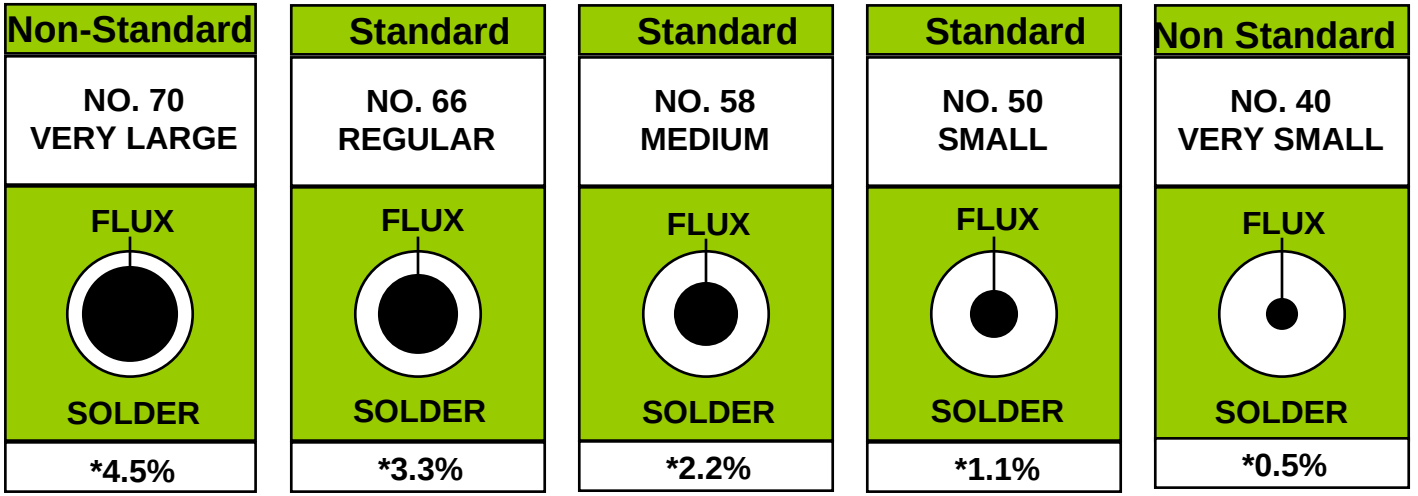
## Understanding the Process to Achieve Reliable Repeatable Results

# Hand-soldering Variables

- Alloy melting temperature
- **Soldering temperature requirements**
- Flux type - no clean, rosin, rosin free, water soluble
- Flux activation level
- **Flux percentage 2 or 3%**
- Flux volatility and flux spatter
- Cleanability of residues (if required)

# Standard Core Sizes

**Best Flux Percentages**




*Average weight percentage for LF and Sn60Pb40 alloy.
The average weight percentage will vary slightly depending on the density of the alloy.

# Standard Wire Diameters

| COMMONLY SPECIFIED DIAMETERS | | |
|---|---|---|
| INCH | ENGLISH WIRE GAUGE EQUIVALENT | APPROXIMATE MM EQUIVALENT |
| 0.125 | 11 | 3.17 |
| 0.093 | 13 | 2.36 |
| 0.062 | 16 | 1.57 |
| 0.050 | 18 | 1.26 |
| 0.040 | 19 | 1.02 |
| 0.031 | 21 | 0.78 |
| 0.025 | 23 | 0.63 |
| 0.020 | 25 | 0.50 |
| 0.015 | 28 | 0.40 |
| 0.010 | 31 | 0.25 |

# Connection Temperature

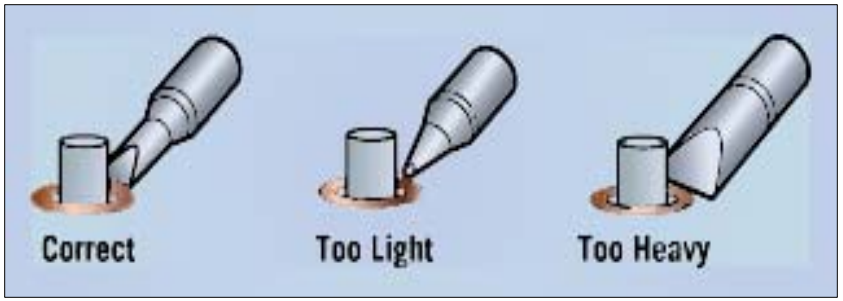
- High enough to melt solder & form inter-metallic.
- High enough to activate flux & cause wetting.
- Low enough to avoid damage to components/PCBs

**Too Low** → INCREASING TEMPERATURE → **Too high**

| Too Low | | Too high |
|---|---|---|
| ▪Cold solder joints | ▪Good wetting | ▪Component damage |
| ▪Poor wetting | ▪Good contact angles | ▪Board damage |
| ▪Little intermetallic | ▪Thin intermetallic layer | ▪Thick intermetallic |
| ▪Large contact angles | ▪Less oxidation | ▪Dewetting |
| ▪No reliability | ▪Reliable joints | ▪Reduced reliability |

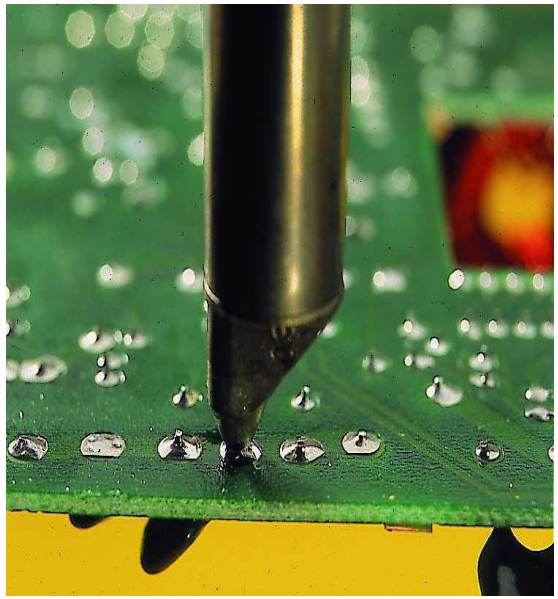
# Tip Care: Choosing a Tip

- Select the largest tip possible
- Use the lowest possible temperature

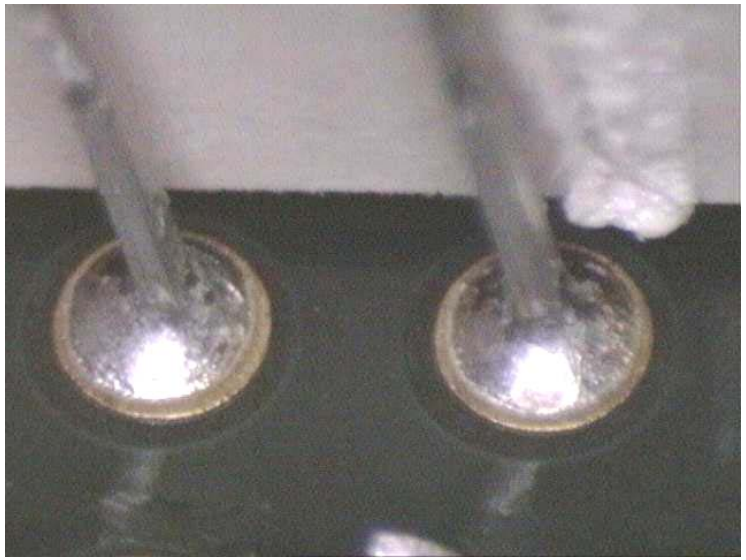


# Correct Tip Selection

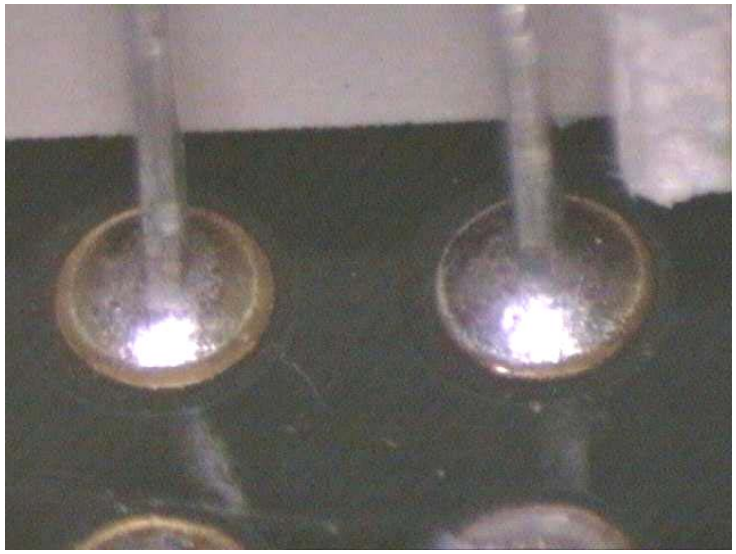
- Hole Size
- Pad Size
- No Pressure



# Hand-Soldered
# Top side connector fillet, SAC Alloy



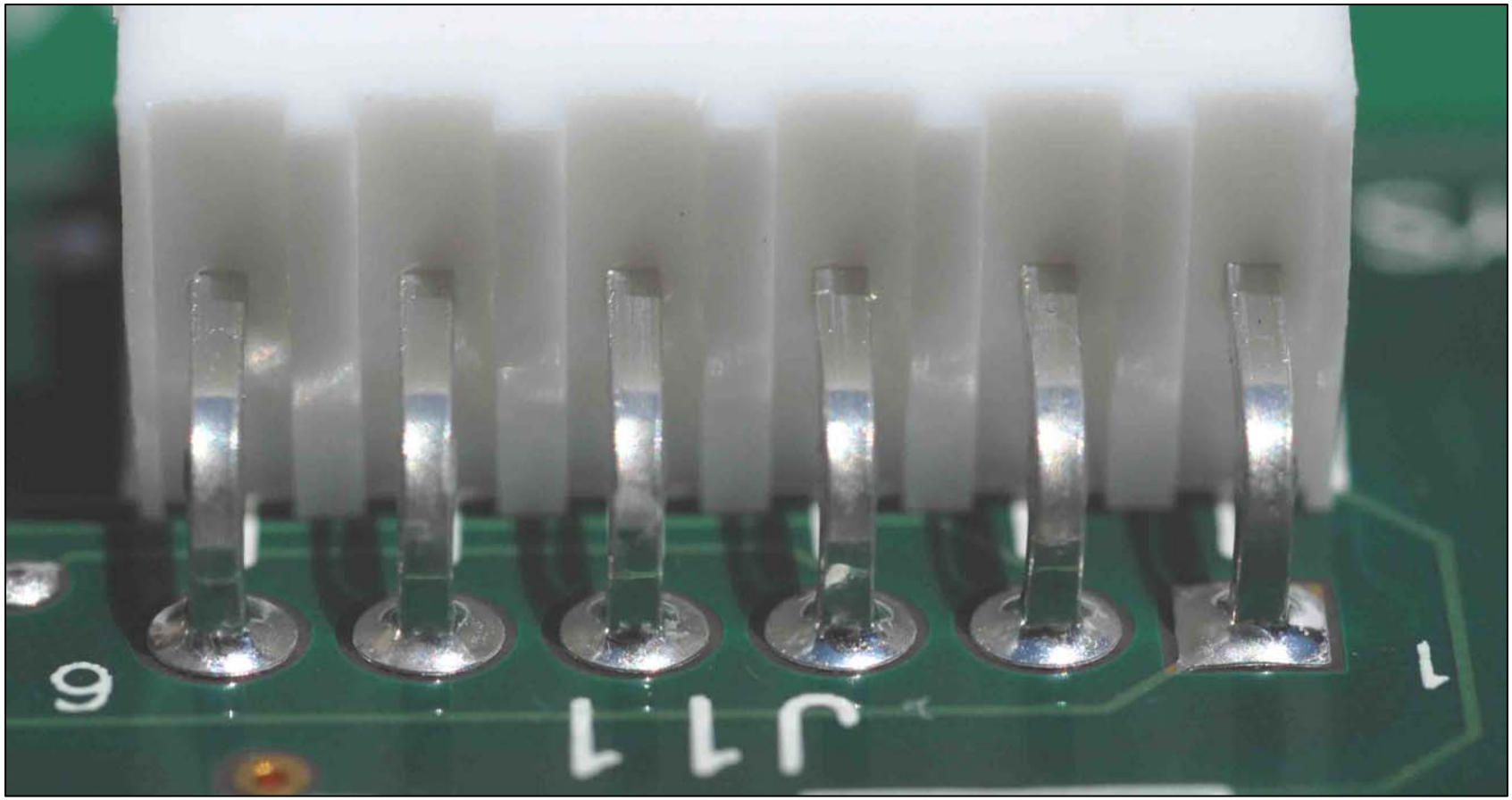
Lead finish SnCu



Lead finish Sn

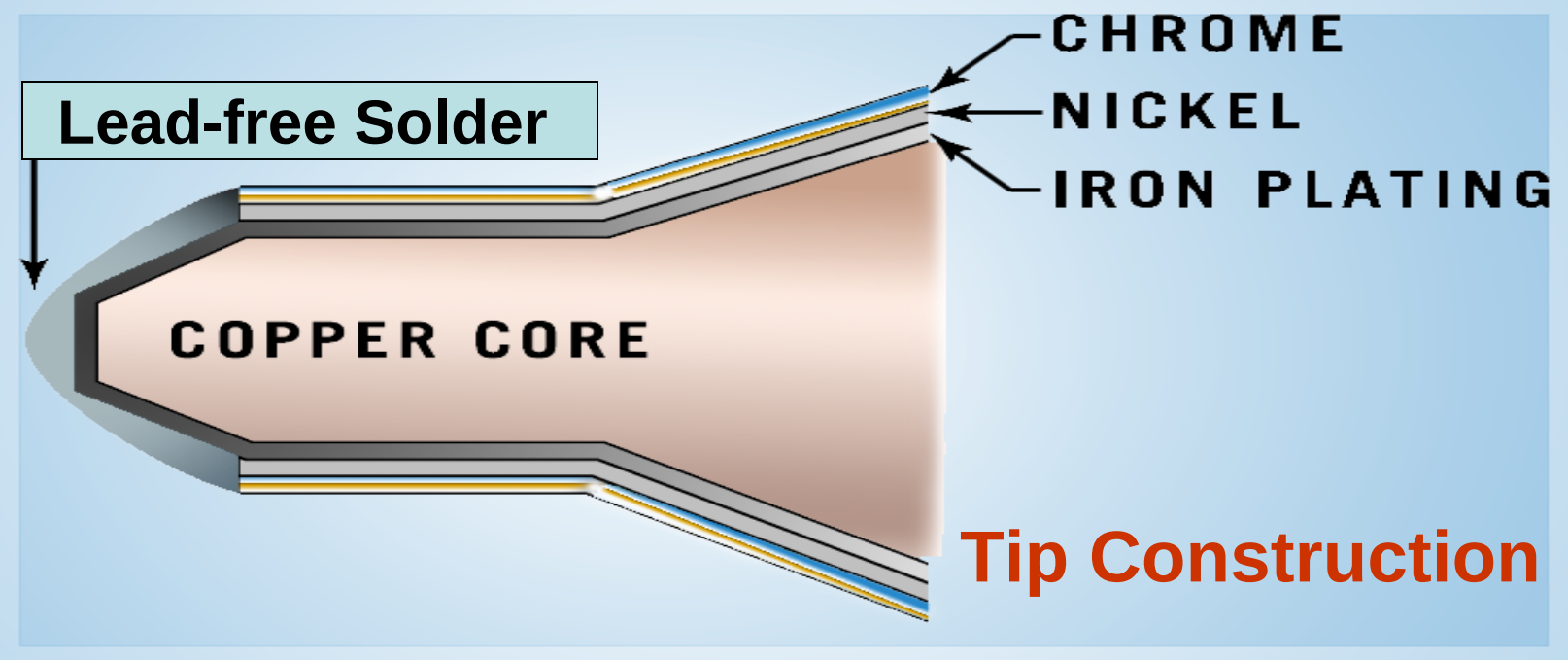
# K100 Solder Wire with 331 Flux,

# Hand-soldered Top-side J11 Connector



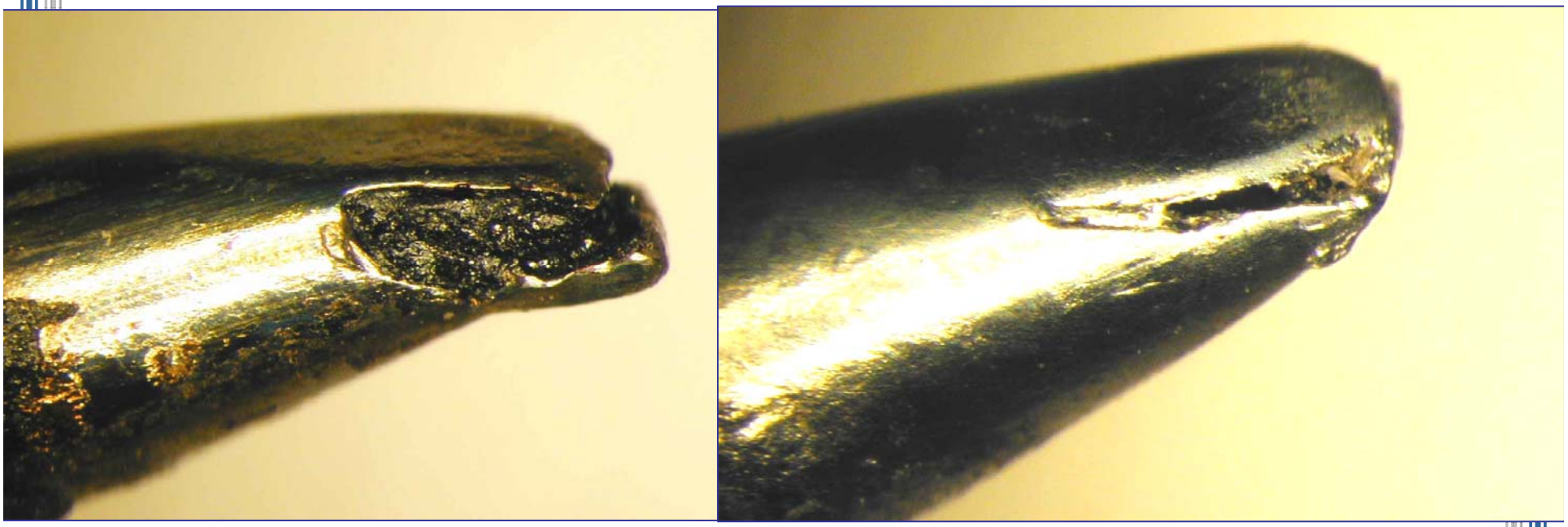

**Excellent flow and no dullness; no shrinkage effects**

# The Issue with Tip Plating




**For lead-free the tip is tinned with lead-free solder**

# Soldering Tip Erosion with Lead-free



**Failure after 3 weeks, 120 hours; typically was 3 months**

# What causes Tip Failures - Summary Apex Conference 2006

| FAILURE | CAUSE | EFFECTS | PREVENTION |
|---|---|---|---|
| **Stress/Crack** | Unnecessary Force Applied to Tip<br>Mishandling | Iron Plating Cracks<br>Solder Dissolves Exposed Solder Core | Select Proper Tip<br>Use Tip as Designed |
| **Abrasion**<br><br>**Normal Wear** | Scrubbing Tip with High Abrasives<br><br>Normal Use | Premature Wearing Away of Tip Plating<br>Solder Dissolves Exposed Solder Core | Use De-Ionized Water<br>Follow Proper Cleaning Procedures<br>Use Clean,Sulfur-Free Sponges |
| **Corrosion** | Tip Tinners Used incorrectly<br>Solder & Flux Interaction<br>**LEAD-FREE**<br>**MORE AGRESSIVE** | Iron Platting Stripped Away<br><br>**ISSUE**<br>**FLUX REQUIREMENT** | Use Lower Activity (RMA) Fluxes (Opposite w/LF)<br>Use Standard Solders for Tip Tinning<br>Use Clean,Sulfur-Free Sponges |
| **De-Wetting** | Oxidation of Iron Plating | Solder Doesn't Adhere to Tip<br>Reduced Heat Transfer | Clean & Tin Regularly<br>Solder @ Lower Temps |

# Solder Products Differentiation

- Material control
- Easily identifiable
- Increases awareness
- Simplifies training
- Avoids costly errors
- Insures reliability

# Thank-you

More info on any slide,
contact Peter Biocca at pbiocca@kester.com