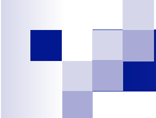


A Supplier's Perspective on the Development of Lead-free Soldering Materials

Keith Howell

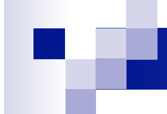
Nihon Superior

Silicon Valley Chapter

13 November 2012

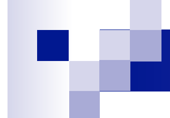
Agenda

- Solder Paste
- Flux Development
  - Voiding
  - Head-in-pillow
- Lead-free Alloys
- Q & A



Customer Wants

- Solder Assembly Materials
  - Wide process window
  - High first pass yield
  - High reliability in service
- Low Cost



Lead-free

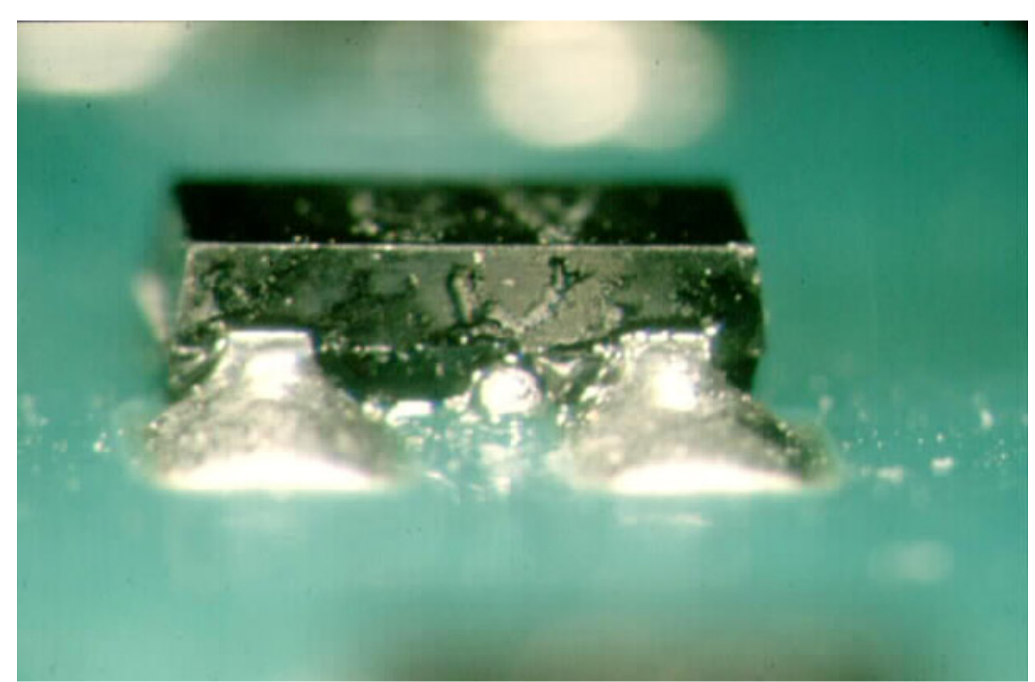
- Higher Processing Temperatures
- Slower Wetting
- Longer Profiles
  - Reflow
  - Wave
- More Demand on the Flux

Solder Paste

TEST RESULTS8

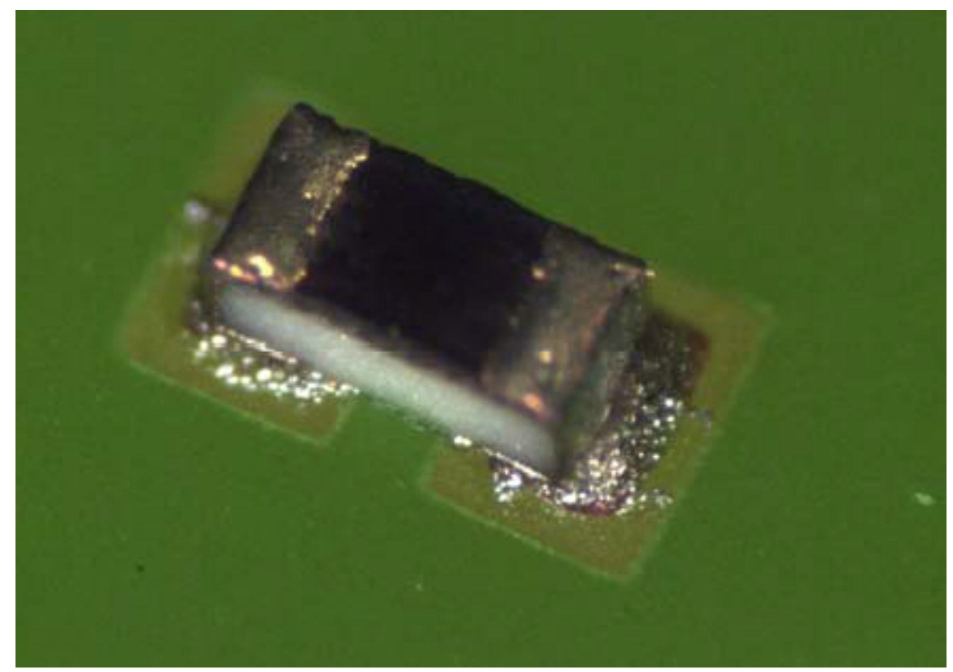
J-STD-004 (IPC Tm-650) Test	Result
Flux Type (per J-STD-004)	ROL0
Copper Mirror	Low
Halide test	0%
Silver Chromate	Pass
Fluoride test	Zero
Ion Chromatography	Zero
SIR-Surface Insulation Resistance	Pass
J-STD-005 (IPC-TM-650) Test	**Result**
Brookfield viscosity Type 3	680,000
Brookfield viscosity Type 4	720,000
Slump	Pass
Solder Ball	Pass
Wetting	Pass
Bellcore Test	**Result**
SIR-Surface Insulation Resistance	Pass
Electromigration	Pass

Solder Beading (Mid-Chip Balling)

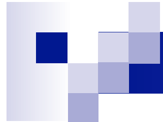


Courtesy: FCT Assembly

Graping



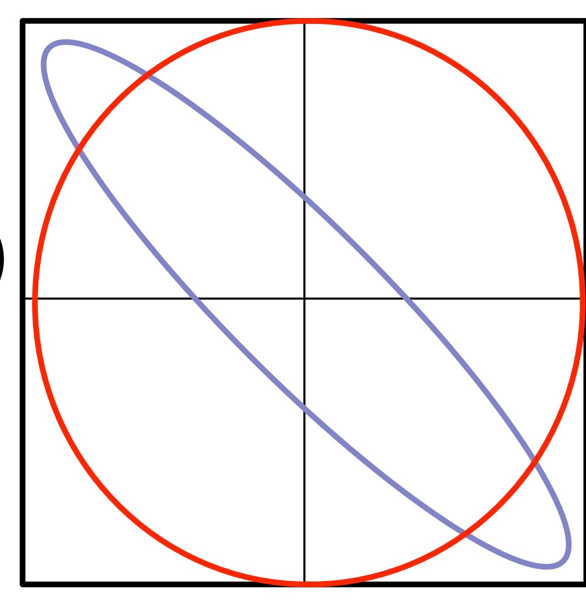
Ref: Neil Poole & Brian Toleno, Henkel Corporation



Solder Paste Attributes

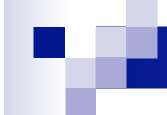
Printing

- Print Speed
- Stability (Repeatability)
- Stencil Release
- Transfer Efficiency
- Cold Slump
- Small Feature Printing
- Stencil Life
- Pause to Print
- Cleaning Cycle



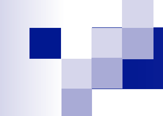
Reflow

- Wetting
- Reflow Window
- Hot Slump
- Bridging
- Solder Balling
- Graping
- Voiding
- Head-in-Pillow
- Residues



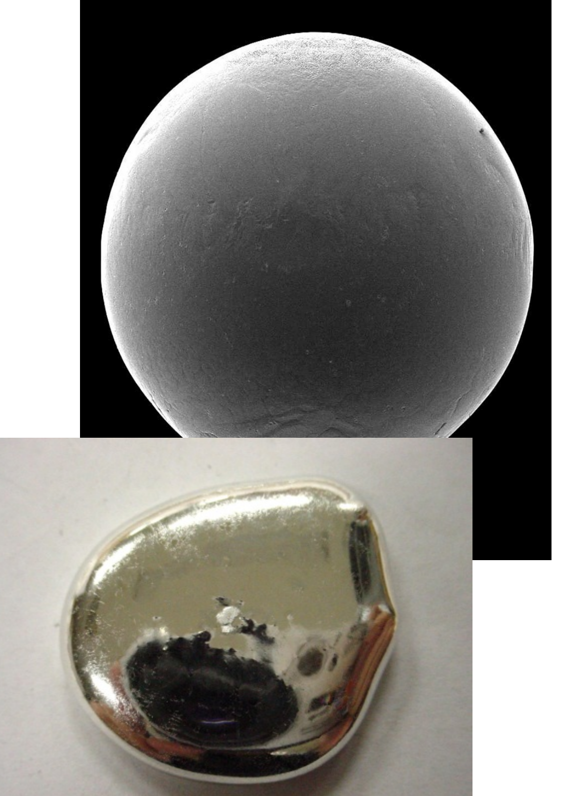
Solder Paste Print Performance

- Print performance is determined by the rheological
  - Metal percentage
  - Sphere size
  - Topography of the powder
  - Resin system
  - Solvents
  - Property modified additives

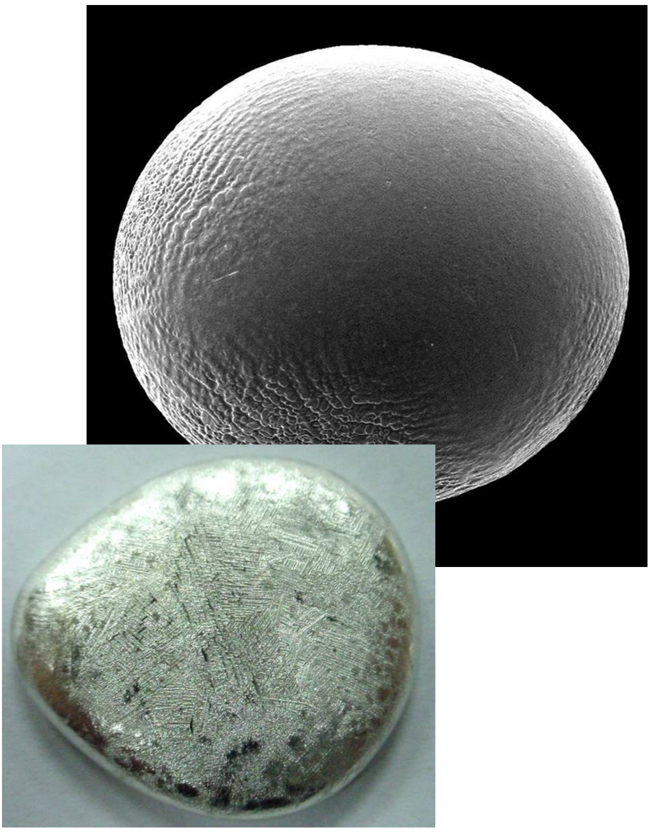


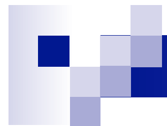
Alloy Surface Topography

SN100C



SAC305

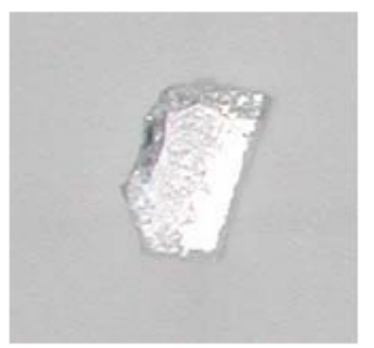


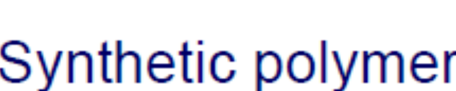


Resins

- Organic acids
- More advanced organic materials

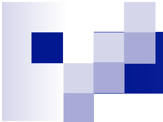
Modified wood resin





Synthetic polymer

Ref: Cobar Solder Products



Flux System

TGA - 5 minutes heating reflow profile

Temperature (°C) 250 230 210 190 170 150 130 110 90 70 50

Der. Weight (%/min) 2.5 2 1.5 1 0.5 0 -0.5

Time (min) 1.0 1.8 2.7 3.5 4.3 5.2 6.0 6.8 7.7 8.5

Temp

SN100C XF3

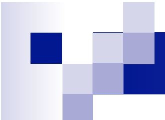
Typical LF Paste

Low evaporation rate results in longer stencil-life

Activation starts at 150°C. Remains during soak

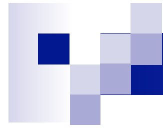
High activity at peak temperatures where oxidation becomes critical

Ref: Cobar Solder Products



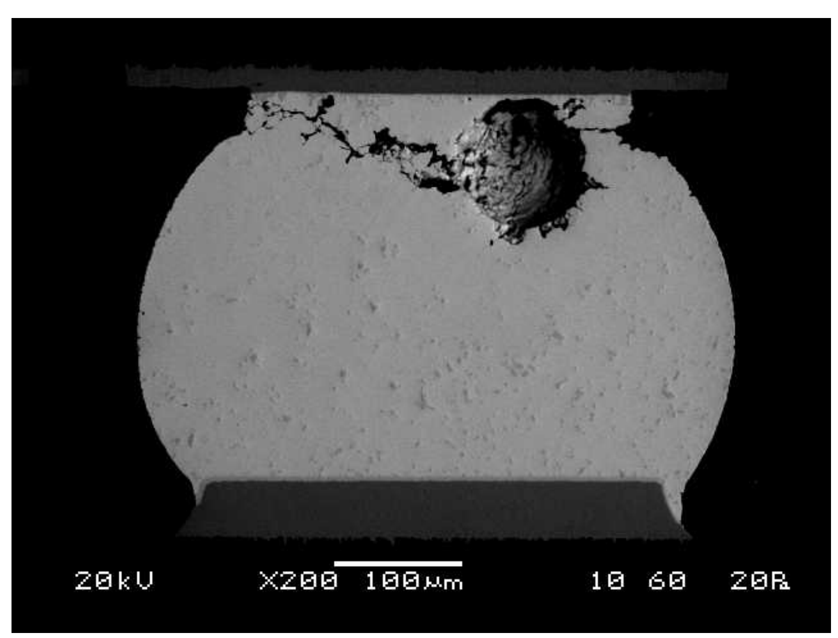
Voiding

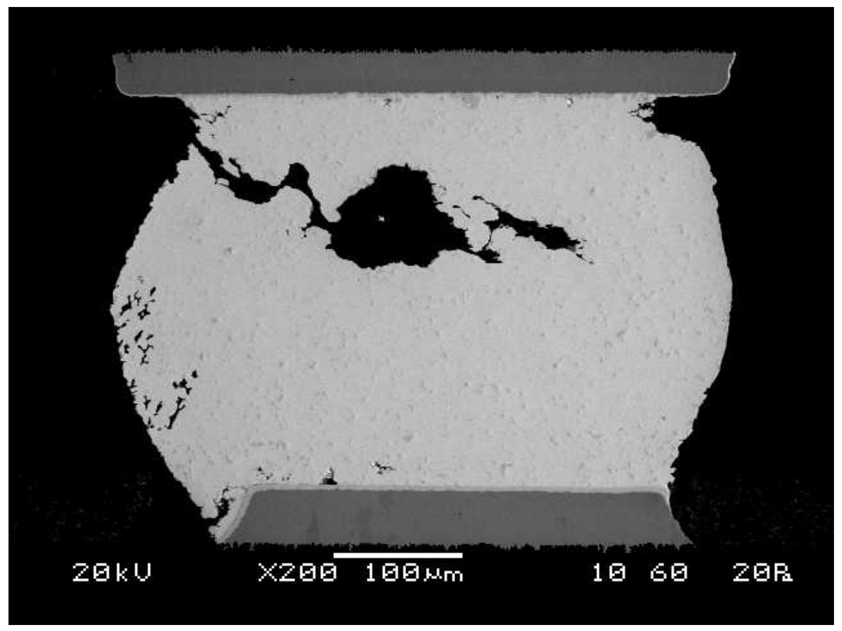
	Power semiconductor	BGA
IPC-A610 Acceptability Standards of Electronic Assemblies	-	≤25%
JIS-C61191-6 Evaluation Criteria and Methods of Measurement of Solder Joint Voids in BGA and LGA	-	<5%



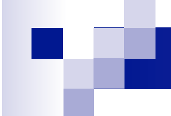
Voiding Issue?

- IPC-A-610 says voiding up to 25% of X-ray image of the joint area is acceptable in Surface Mount Area Array joints



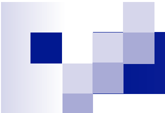


Association Between Void and Crack Path?



Gas Evolution from Flux Medium

Composition of Medium



Void Reduction Strategy

Reduce Volatiles Release in Reflow Stage of Profile

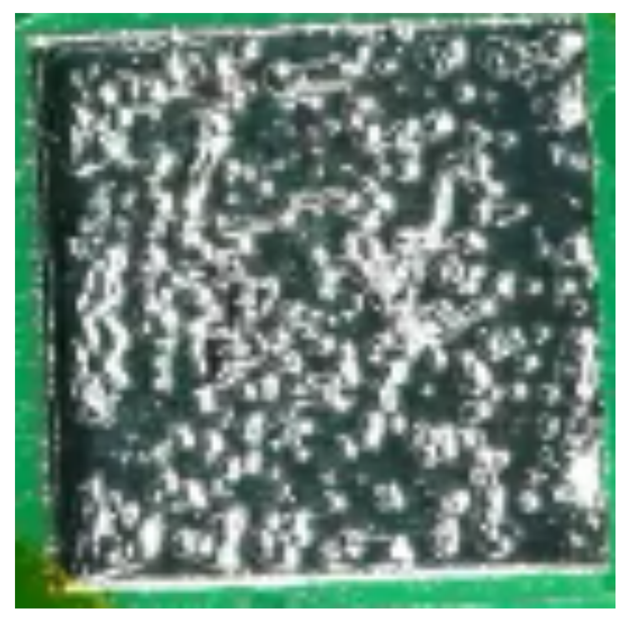
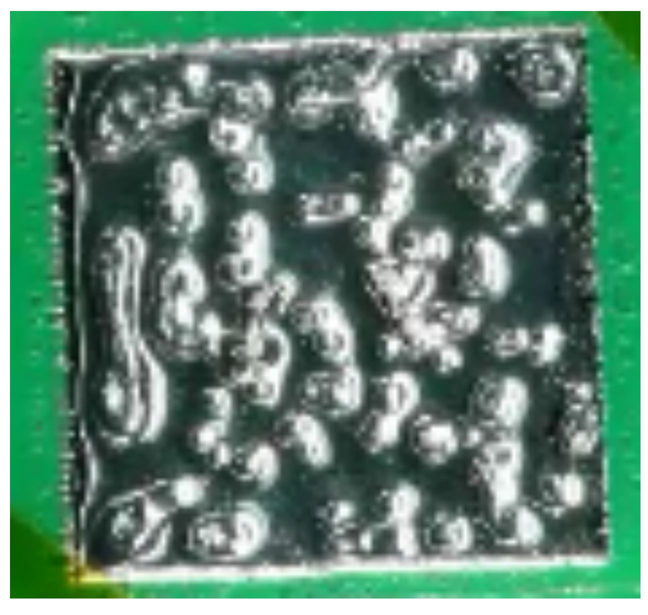
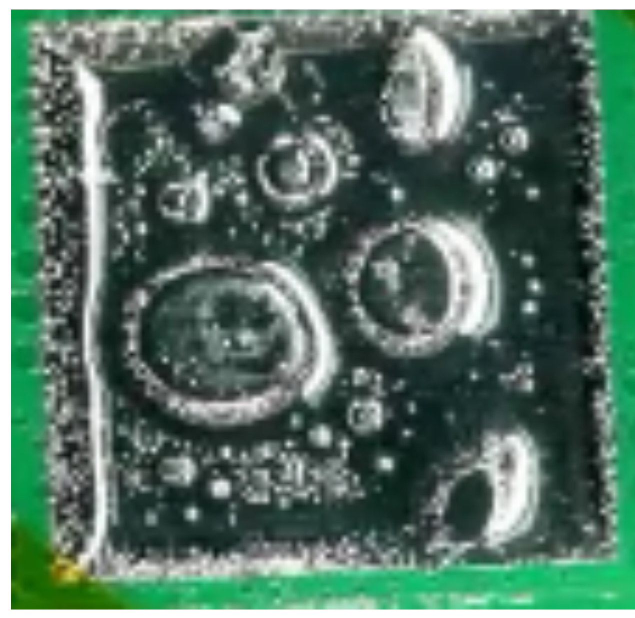
Use Solvent that Volatilizes During Preheat

Facilitate Escape of Volatiles

Reduce Surface Tension of Solder

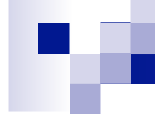
Improvement in Solder Paste Formulation

Bubbling in glass-covered solder paste during reflow

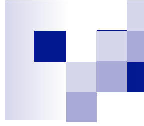




Voiding Results

	Air reflow	Nitrogen reflow	Vacuum reflow
General purpose paste			
Voiding	6.01%	5.72%	2.02%
Low voiding formulation			
Voiding	4.20%	2.83%	0.99%



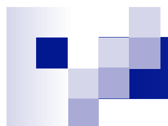
Head-in-Pillow



Head-in-Pillow

Figure 5.12 Assumed Mechanism for the Failure to Head-in-Pillow

Courtesy of Renesas



HIP Mitigation

Solder Paste

- Activity
- Slump Resistance
- Oxidation Barrier
- Tackiness

Component

- Warp and Planarity
- Ball Oxidation
- Ball Alloy
- Flux Residues

Inspection

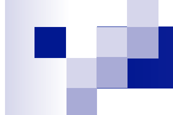
- Planarity
- Transfer Efficiency
- X-ray or Visual
- PCB Design and Layout

Process and Environment

- Reflow Profile
- Printer Optimization
- Component Storage
- Nitrogen use

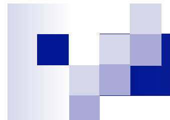
No Head-in-Pillow Defects

© Indium Corporation 2012



Head-in-Pillow Solutions

- Component Warpage
- Temperature Profile
- Solder Paste
  - Oxidation
  - Flux Activity
  - Improved Wetting
- Lower Process Temperature



Formulating a Lead-Free Solder

Melting Point (°C)

230

Sn

SnCu

220

SnAg series (+Cu) (+Sb)

SnAg series with a little Bi (+Cu)

210

200

SnAg series with more Bi (+Cu)

+ In

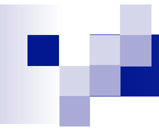
190

SnZn series with Bi

Sn-37Pb

180

SnBi



Where Did It All Start?

S.2637
Latest Title: Lead Exposure Reduction Act of 1990
Sponsor: Sen Reid, Harry [NV] (introduced 5/16/1990) Cosponsors (13)
Latest Major Action: 10/18/1990 Placed on Senate Legislative Calendar under General Orders. Calendar No. 1002.

S.2637

Lead Exposure Reduction Act of 1990 (Introduced in Senate - IS)

`SEC. 402. RESTRICTIONS ON CONTINUING USES OF CERTAIN LEAD-CONTAINING PRODUCTS.

`(a) GENERAL RESTRICTIONS- Except as provided under subsections (b), (c), and (d) of this section, beginning on the date that is 1 year after the date of the enactment of the Lead Exposure Reduction Act of 1990, no person may manufacture, process, or distribute in commerce any of the following product categories:

`(1) Paint containing more than 0.06 percent lead by dry weight.
`(2) Solder containing more than 0.1 percent lead by dry weight.
`(3) Plastic additives, printing inks, or pigments containing more than 0.06 percent lead by dry weight.
`(4) Plumbing fittings containing more than 2 percent lead by dry weight.

But…

"After intense lobbying by the electronics industry and the Lead Industries Association, electronics solders were deleted from subsequent revisions to the bill."

103D CONGRESS

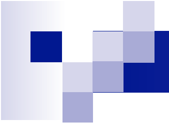
1ST SESSION **S. 729**

To amend the Toxic Substances Control Act to reduce the levels of lead
in the environment, and for other purposes.

IN THE SENATE OF THE UNITED STATES

APRIL 1 (legislative day, MARCH 3), 1993

1 "(1) IN GENERAL.—Not later than 2 years 2 after the date of enactment of this section, the Administrator shall promulgate regulations to ban the manufacture, importation, processing, sale, and distribution in commerce of lead solders commonly used in plumbing systems, including lead solder that contains 50 percent tin and 50 percent lead (50–50 tin lead solder) and lead solder that contains 85 percent tin and 15 percent lead (85–15 tin-lead solder).



In the meantime …

Q4 1998 the European Union issued a second draft of a directive on eliminating lead from electronics

1998 Japanese Diet enacted
Home Appliance Recycling Law

Initially applies to Televisions, Air Conditioners, Refrigerators, Washing Machines

Scheduled for Implemented April 1, 2001

The Japanese electronics industry realised that the economics of recycling would force them to eliminate lead

And then…

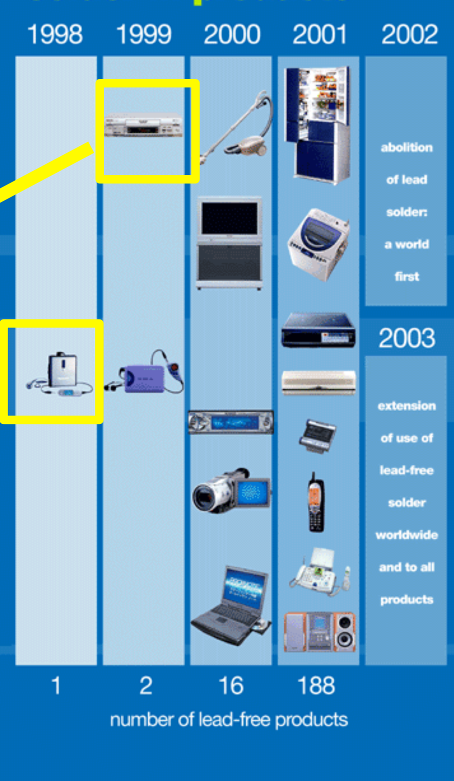
The Japanese electronics industry declared its intention of switching to Pb-free technologies

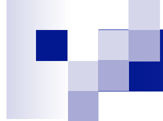
March 2009 VCR

Wave solder with SN100C

October 1998 Minidisk Player

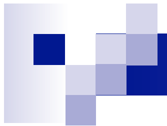
Reflow with Sn-Ag-Bi-In





DIRECTIVE 2002/95/EC
of THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
of 27 January 2003

1. Member States shall ensure that, from 1 July 2006, new electrical and electronic equipment put on the market does not contain lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE).



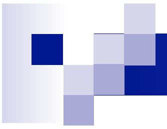
Why SAC305?

Round Robin Testing and Analysis of Lead Free Solder Pastes with Alloys of Tin, Silver and Copper

Final Report

A Research Report by the Lead Free Technical Subcommittee

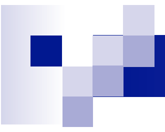
IPC SOLDER PRODUCTS VALUE COUNCIL



Why SAC305?

"In conclusion, based on the results of this study, it is the recommendation of the IPC SPVC that, due to lower cost and equivalent performance, the 96.5/3.0/0.5 SAC alloy be the lead free alloy of choice for the electronics industry."

But what was the basis for that recommendation?



Why SAC305?

The three SAC alloys were compared on the basis of:

- **Melting Point**
- **Wetting Rate**
- **Spread**
- **Reflow soldering**
- **Joint microstructure**
- **Thermal cycling of reflowed test assembly (0-100°C, 10 minute dwells)**
- **Thermal shock of reflowed test assembly (-40-125°C, 5 minute dwells)**
- **Cross-sectioning after thermal cycling**

Why SAC305?

The three SAC alloys were NOT evaluated in:

- **Wave soldering**
- **Selective solder**
- **Hand soldering**
- **Rework**

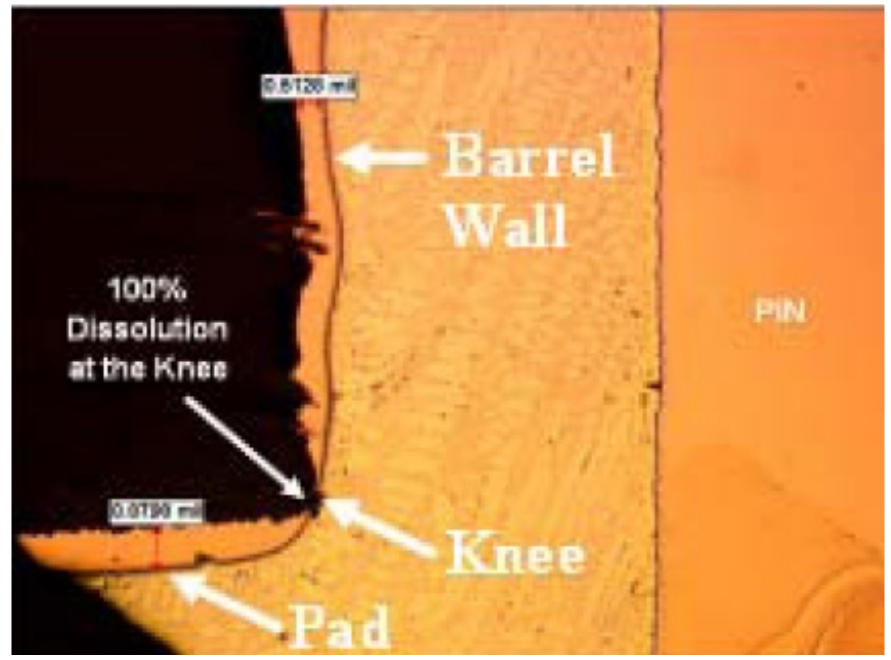
Why SAC305?

The three SAC alloys were NOT evaluated for:

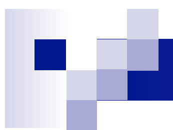
- **Aggressiveness towards copper (Copper Erosion)**
- **Aggressiveness towards stainless steel (Solder Pot Erosion)**
- **Reliability in high strain situations (e.g. Vibration)**
- **Reliability in shock loading (e.g. Drop test)**

Cu Erosion

- Example of Cu dissolution
  - Typically occurs at the knee



Ref: Celestica/IBM Study



Cu Erosion

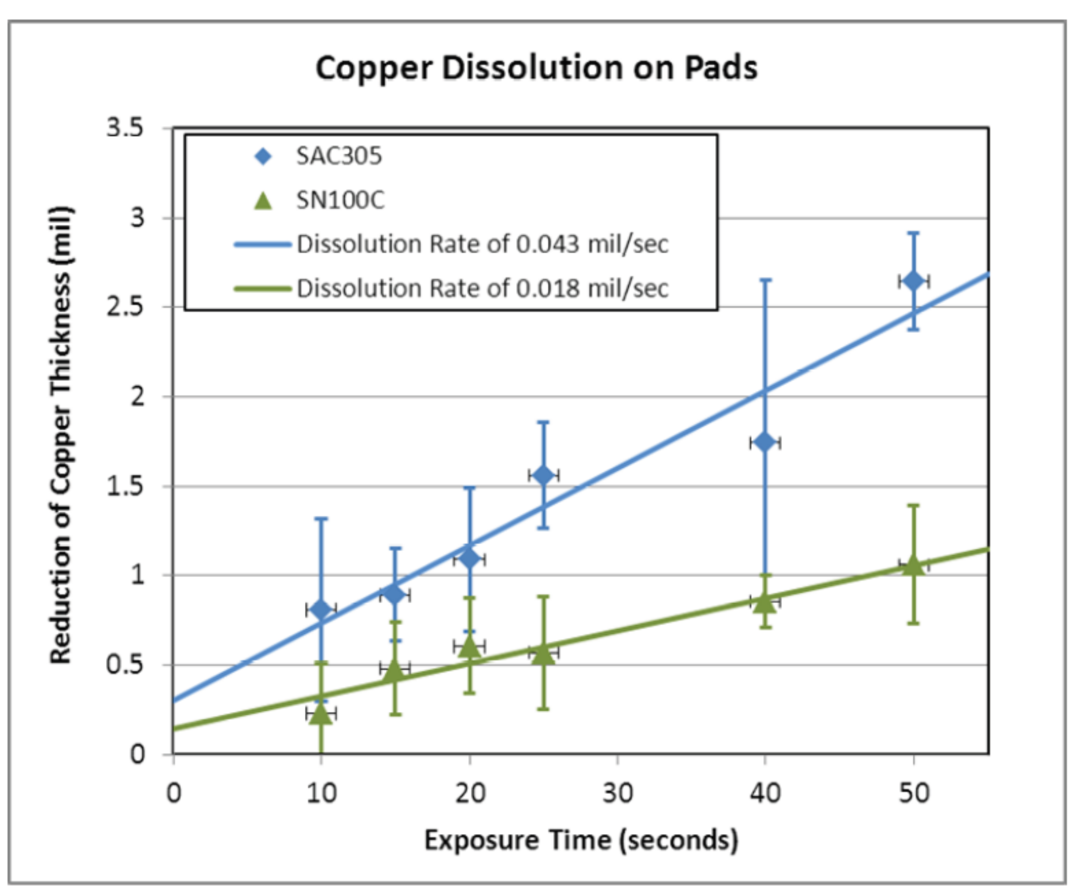
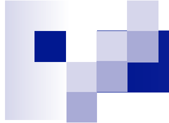


Figure 9: SAC305 and SN100C Copper Dissolution Results for SMT QFP

Ref: Jeff Kennedy, Dave Hillman, Ross Wilcoxon – TEERM NASA DoD Phase 2



Where Are We Now?

Reflow

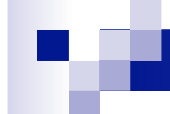
- Predominantly SAC305
- Increasing LowSAC and NoSAC where they can be a drop-in replacement for HiSAC

Wave & Selective

- A strong trend away from SAC305/405 to LowSAC or NoSAC

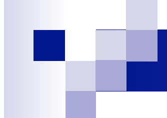
Hand Soldering & Wave Rework

- LowSAC and NoSAC replacing SAC305



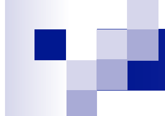
Legislation

- RoHS
- REACH
- Canada – Rosin Ban
- California Prop 65
- Chemicals of Concern
- Conflict Minerals
- EPA



Summary

- Most defects and reliability issues are caused by the assembly materials
  - Not true
  - Materials are one component in the assembly process
- Solder suppliers must work with component and process equipment suppliers to meet customers' demands



Summary (continued)

- Solder material suppliers must continue to innovate and development materials to address new issues
- “Horses for Courses”
  - Application specific materials
  - Chemists’ and metallurgists’ playground

k.howell@nihonsuperior.co.jp