Assembly of Large PWBs in a RoHS Environment

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EXECUTIVE SUMMARY
As early as 2001, leading cellular phone manufacturers had established stable assembly processes that were RoHS compliant for their cellular phone products. Since this time, the products manufactured on these lines have demonstrated equal or better quality and reliability as compared to cellular phones assembled with tin-lead solder and non-RoHS compliant components. This success may have created the belief that there are few issues remaining in RoHS compliant assembly. This belief is far from the truth. Organizations that need to assemble a wide range of large, thick printed wiring boards (PWBs) continue to have considerable process challenges. These difficulties – combined with the need to assemble RoHS 5 (tin-lead solder paste and components with tin-lead finished leads, the remaining hardware being RoHS compliant), RoHS 5.5 (RoHS 5 with BGAs that have SAC or SACX solder balls) and RoHS 6 (fully compliant RoHS assembly) in one facility – create not only assembly technical challenges, but considerable material handling and logistics issues.

This paper is a review of the work done at one facility, to address these challenges. An overview of the process development work in stencil printing, component placement and reflow soldering that was required to develop optimized assembly processes for PWBs with dimensions exceeding 56 cm and thicknesses approaching 0.3 cm will be discussed. The methods developed to handle the logistics issues of having RoHS 5, RoHS 5.5 and RoHS 6 assembly in one facility will also be presented.

The paper will conclude with a review of several of the products currently being assembled with these processes and logistics.

Large Board Assembly in a RoHS 5, 5.5 and 6 Environment

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Reminder: RoHS is to Make Recycling Easier

- "RoHS has been enacted for nearly two years and I don't feel safer"
- Objective: To assist recycling efforts set forth by WEEE

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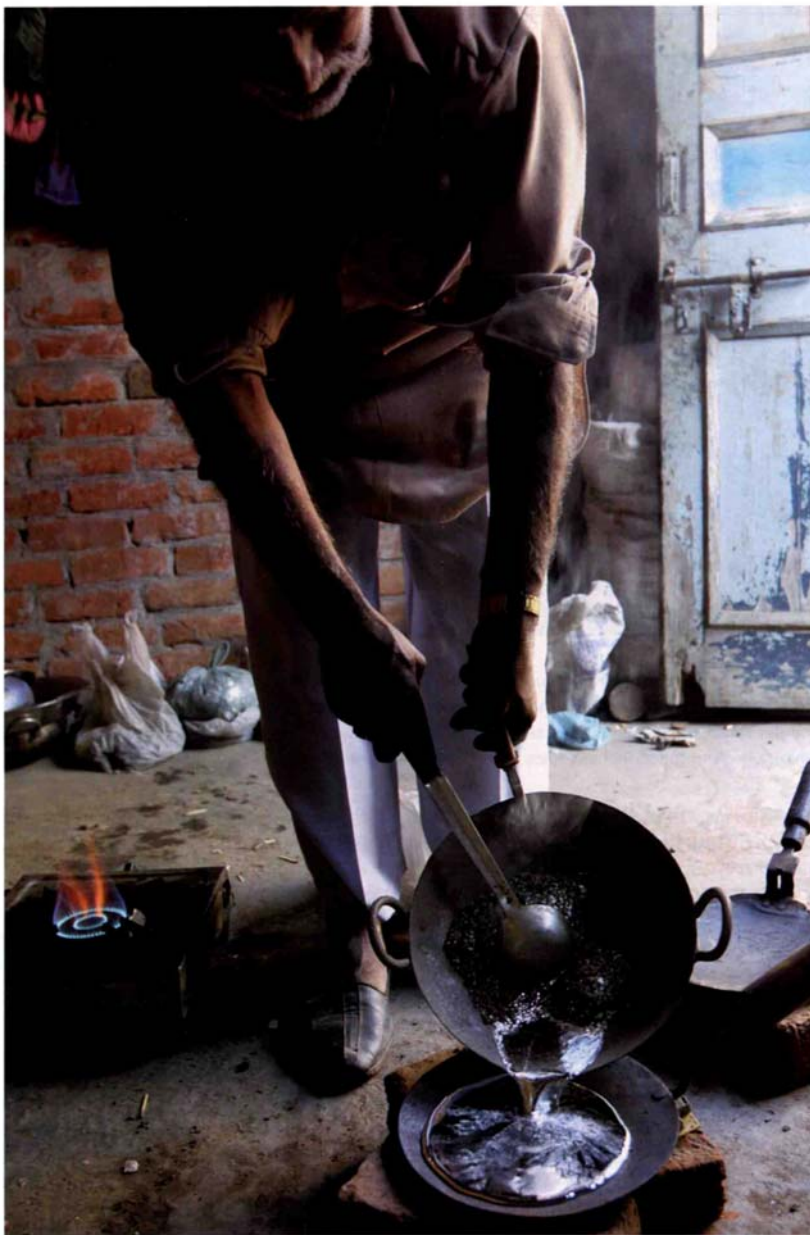
REUSE Workers strip picture tubes from thousands of used computer monitors piled at Monitex, a Grand Prairie, Texas, recycler. Tubes that work will be exported to a factory in Thailand, where they'll be used in low-cost TVs. Broken ones are recycled domestically.



TOXIC MELT In a poor suburb of New Delhi, India, where informal e-waste processing is a common household business, a man pours molten lead smelted from circuit boards. His family uses the same pots for cooking–a potentially deadly practice.

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DUMPED A farmer in rural Taizhou, China, readies sweet potatoes for market beside circuit boards burned so metals could be extracted. The region has long been a major dump site for e-waste, but a crackdown by authorities has reduced illegal trade.

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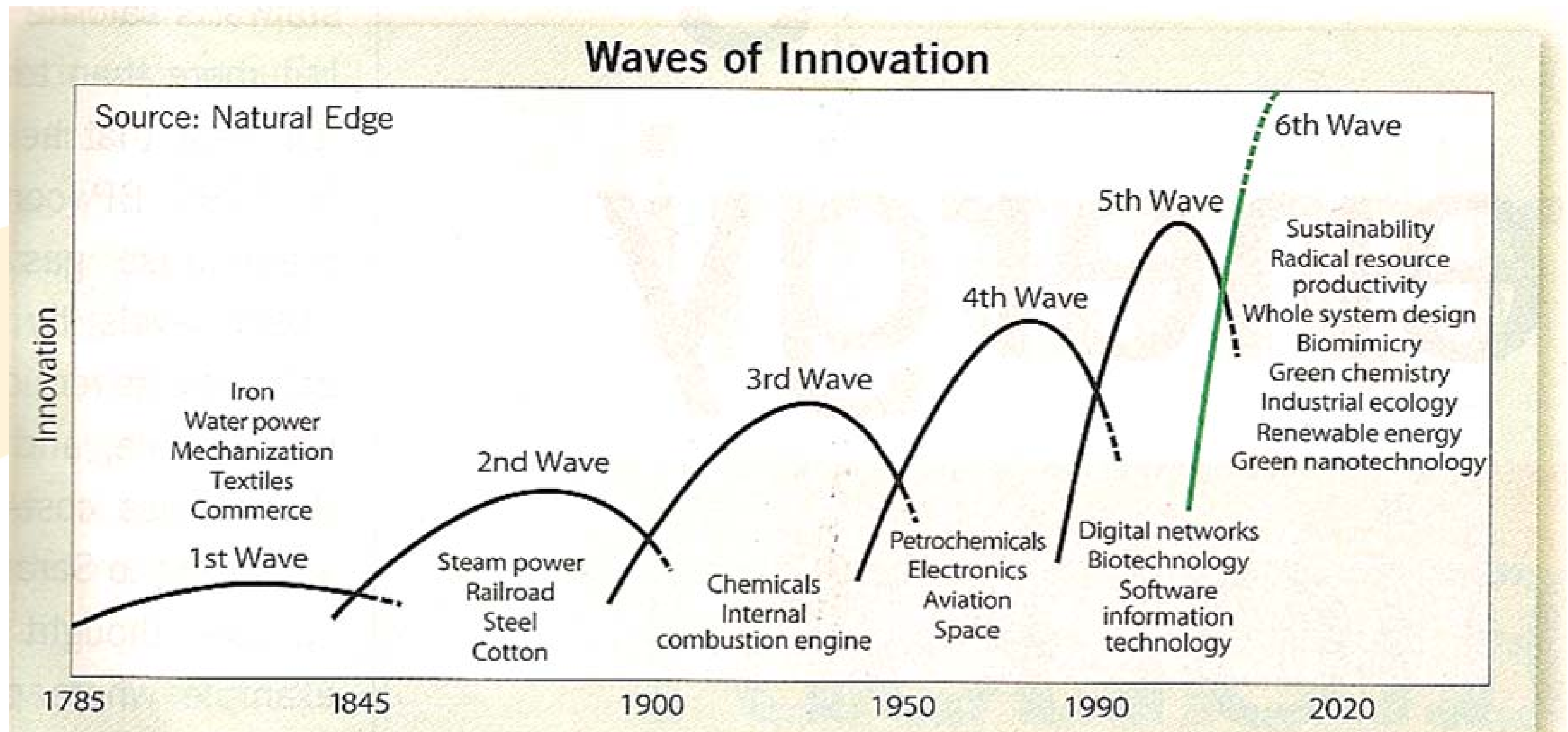
The Green Generation



Global Foundation, Business Week 02/04/08

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Lead-Free Reliability Thought

- "Everyone knows there is no data on LF reliability right?"
- Wrong
  - $500 B of products made, some since 2001
    - No "sky is falling" reliability issues
  - $100M of R&D
- Long term (>5 years) data still sketchy

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Jabil Billerica

- Medium to Large Facility
- Medium to Large size customers
- Broad Product Mix
- Special Expertise in large board assembly

RoHS 5, 5.5, 6

- RoHS 5 (tin-lead solder paste and components with tin-lead finished leads, the remaining hardware being RoHS compliant),
- RoHS 5.5 (RoHS 5 with BGAs that have SAC or SACX solder balls)
- RoHS 6 (fully compliant RoHS assembly)

Close Customer Relationship is Vital

- Education/Training both ways
- Agree on Deliverables
  - Technical Tasks
  - Materials Management
  - Documentation
- Designate an Owner/Watchdog to establish and track all deliverables/ concerns

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Jabil Billerica

- Developed RoHS 5, 5.5, 6:
  - In one facility
  - For PWBs up to 56cm long and 0.3 cm thick
- Color coding established:
  - RoHS 6 is green
  - RoHS 5 is yellow
  - Used for all equipment, benches, racks, components, procedures, assembly space

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Logistics Continued

- Even paperless documents are color coded and linked to latest waivers, deviations etc.
- Critical Issue: Reflow Temp Difference
  - RoHS 5: $T_m = 183^o$ C
  - RoHS 6: $T_m = 217^o$ C
  - Tolerance control tighter on RoHS 6

Component Concerns

- High Temperature Performance
- Engineering Change Orders (ECOs)
- Material Change Orders (MCOs)
- Color coding mandatory

Reflow Profile Challenges

- RoHS 6 Can Require a 5°C process window
- RoHS 5.5 must be hot enough to completely melt the solder balls
- SAC305 is standard alloy: T_m =217°C
- SAC105 creates more of a challenge
- T_m =227°C

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Sn/Pb Paste; SAC Ball

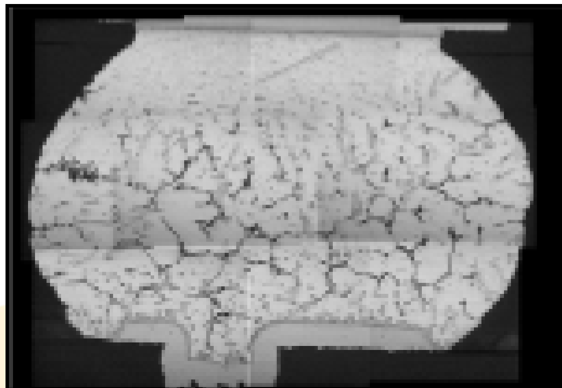


Figure 9a: Pb diffused along the grain boundary with reflow profile below the lead free solder ball melting point. Black/Grey – Pb Rich, Rod shape – Ag_3Sn, Grey Particles – Cu_6Sn_5.

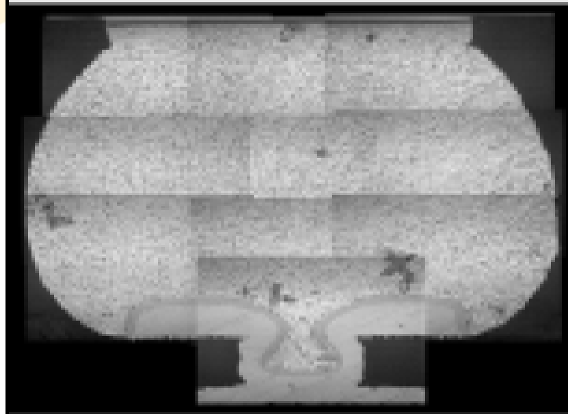
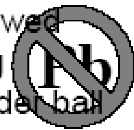


Figure 9c: The refined solder microstructure obtained when the peak reflow temperature is higher than (217°C) the melting point of 95Sn4.5Ag0.5Cu

Backward Compatibility solder joints showed severe grain growth if the peak soldering temperature was below the lead free solder ball melting point.



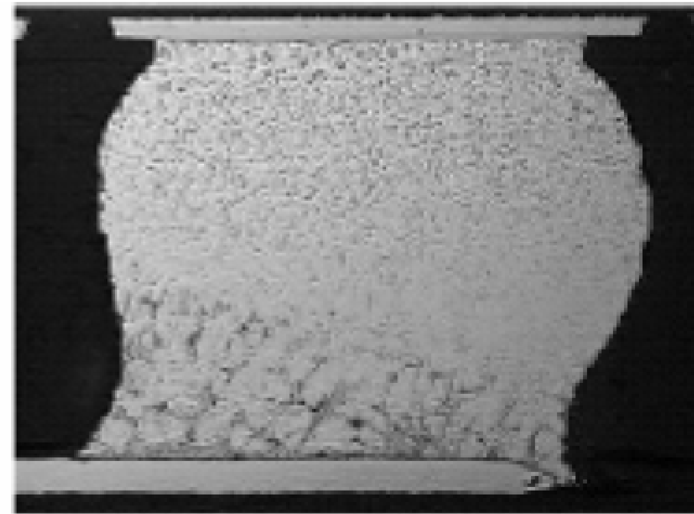


Figure 10: Solder ball was not completely collapsed after cooling and this led to abnormal joint shape (showing necking). Pb was not diffused throughout the whole solder joint.

C. Key Chung, Raiyo Aspandiar, K. Foo Leong, Cheng Siew Tay, "The Interactions of Lead (Pb) in Lead Free Solder (Sn/Ag/Cu) System", 52nd ECTC, S04-P7, San Diego, CA, May 28-31, 2002

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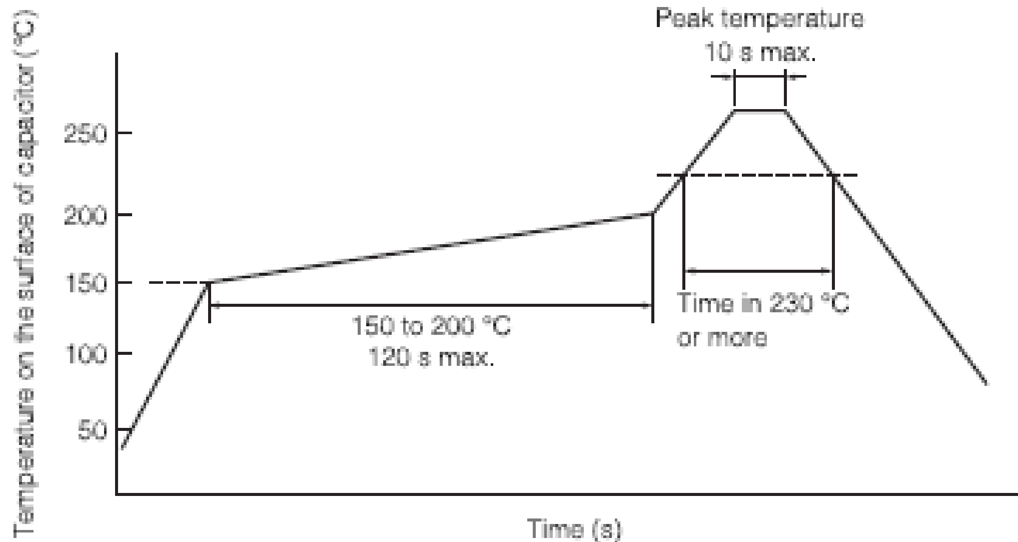
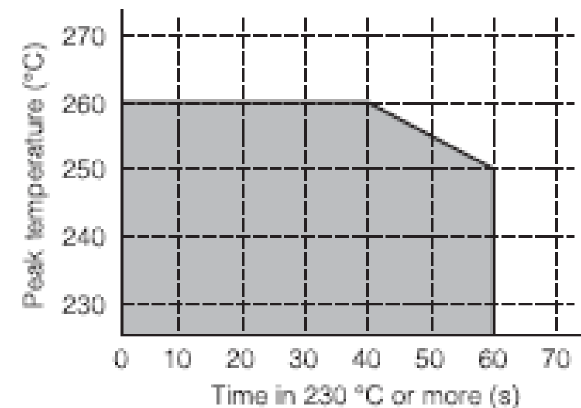
SAC RoHS 6 Reflow Process Window



EX.)

Peak temperature	Time in 230°C or more
260°C, 10s max.	40s max.
250°C, 10s max.	60s max.



Large Board Challenges

- Goes Beyond IPC-9850 when PWB > 50 cm
- PWB dimensional stability and equipment tolerances are issues

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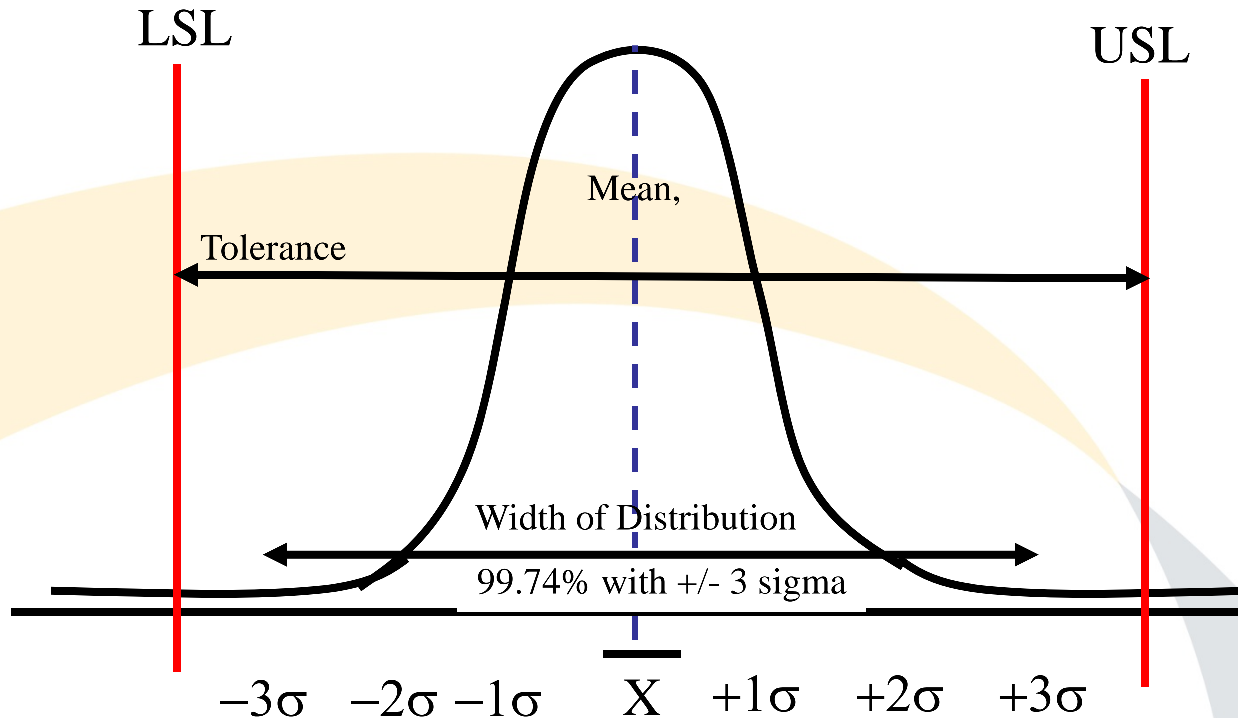
Good C_p and C_{pk}



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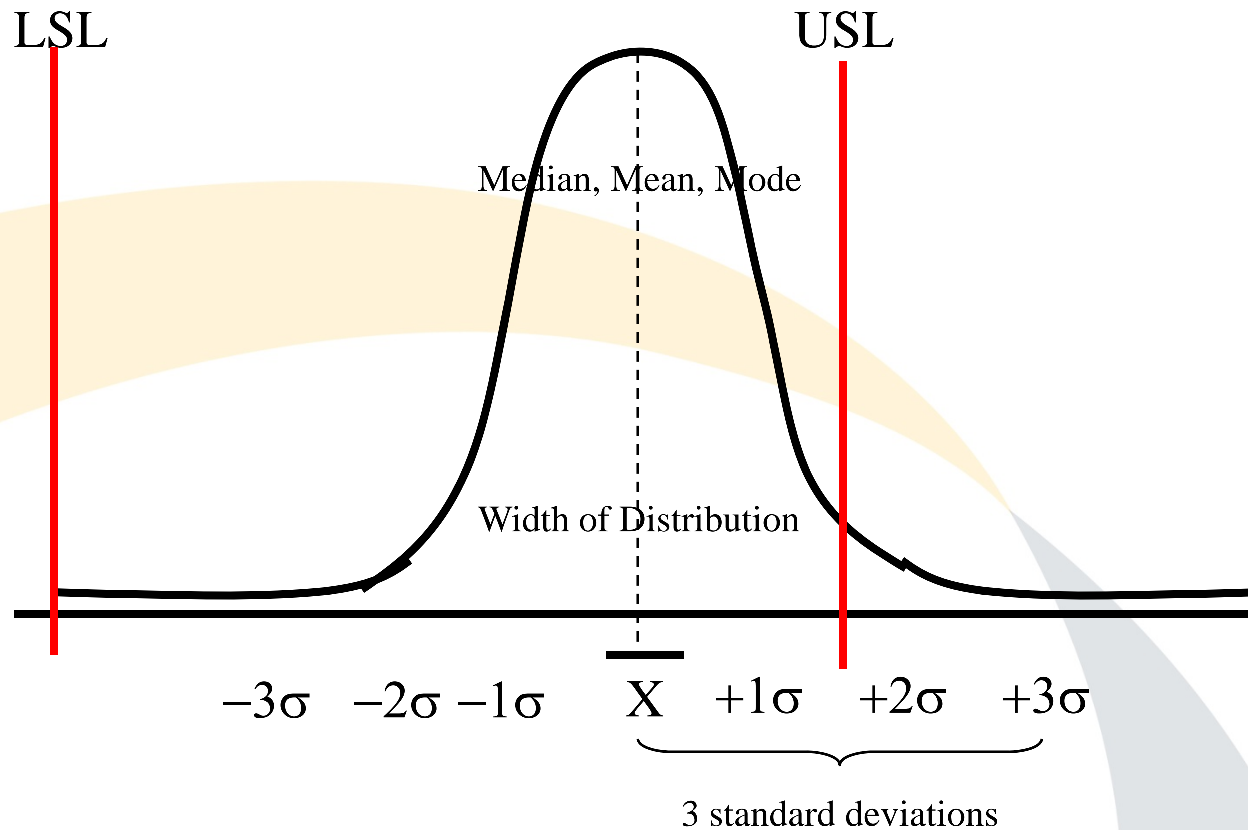
Good C_p, Poor C_{pk}



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C_p and C_{pk}

- $C_p = \dfrac{USL - LSL}{6\sigma}$
- $C_{pu} = \dfrac{USL - Xbar}{3\sigma}$
- $C_{pl} = \dfrac{Xbar - LSL}{3\sigma}$
- $C_{pk} = \min(C_{pu}, C_{pl})$

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Stencil Printer Evaluation

- Two Cameras
  - Load PWB and align 50 times
  - Fiducials 53.3 cm apart
  - Tolerance +/- 0.025 cm
  - 75 cm capable
- Results
  - $C_p X_1 = 8.28$
  - $C_p Y_1 = 2.23$
  - $C_p X_2 = 3.58$
  - $C_p Y_2 = 3.28$

Component Placement

- 16 aluminum boards run
  - 2 fiducials
  - 0402 passives
  - 100 pin QFP Glass Slugs
  - Success Criteria C_{pk} >1.67
- Placement capable to 66x25 cm

Accuracy & repeatability data for QFP

Dimension	Mean	StDev	Spec	Cpk
XDev	26.57	5.35	75	3.02
YDev	24.08	8.17	75	2.08

Accuracy & repeatability data for 0402

Dimension	Mean	StDev	Spec	Cpk
XDev	20.48	11.63	100	2.28
YDev	2.95	12.97	100	2.49

Data in microns

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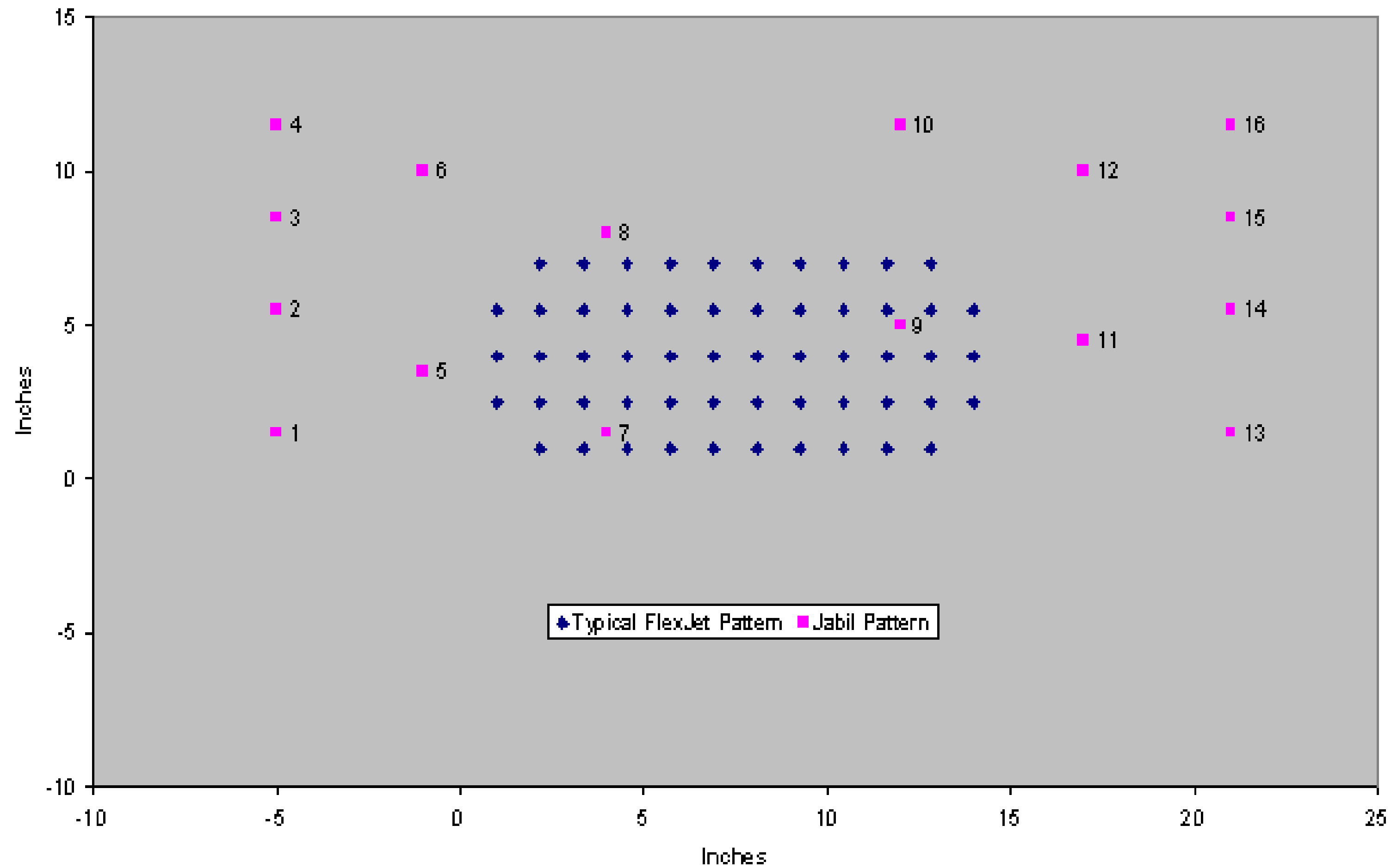

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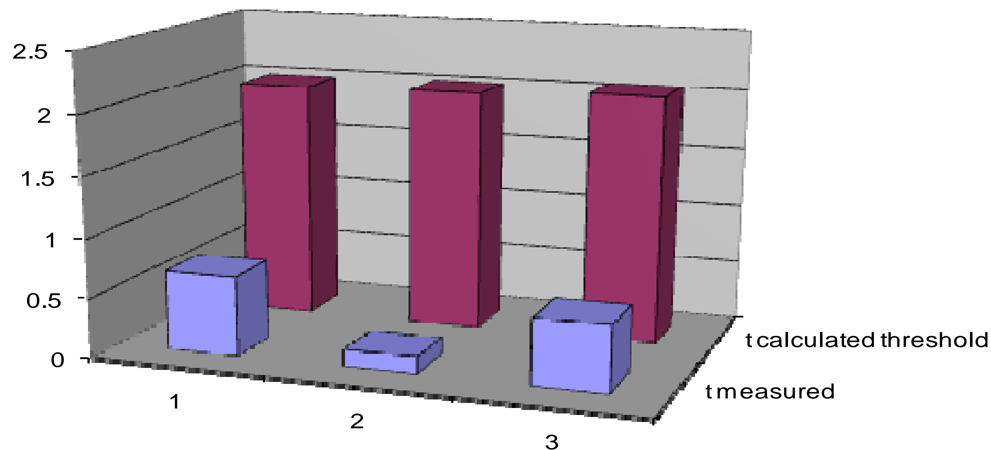
Solder Paste Consistency

- Volume Analysis with SVS 8100
  - 1 = Leaded Standard 0402 to Homeplate
  - 2 = Leaded to Lead-free Homeplate
  - 3 = Lead-free to leaded BGA
- Compare with t test



$$t_0 = \frac{\bar{x}_1 - \bar{x}_2}{s / \sqrt{n}}$$

< 2, values considered equal

Reflow Objectives

- A high & long preheating cycle which can minimize temperature distribution above liquidus
- Very low ramp rate at the liquidus crossing, this feature along with slow preheating can mitigate tombstoning
- Stable slump characteristics to minimize solder beading failure modes for optimized land pattern design with reduced space between pads
- “Flat top” profiling shape (see Figure) above liquidus to suppress temperature spread and minimize temperature load on components and the PWB (recent studies of RoHS 6 PWB materials suggest that some PWBs are susceptible to high thermal load)
- Reasonable flux activity above liquidus for a temperature range starting as low as 235C with known / confirmed environmental reliability

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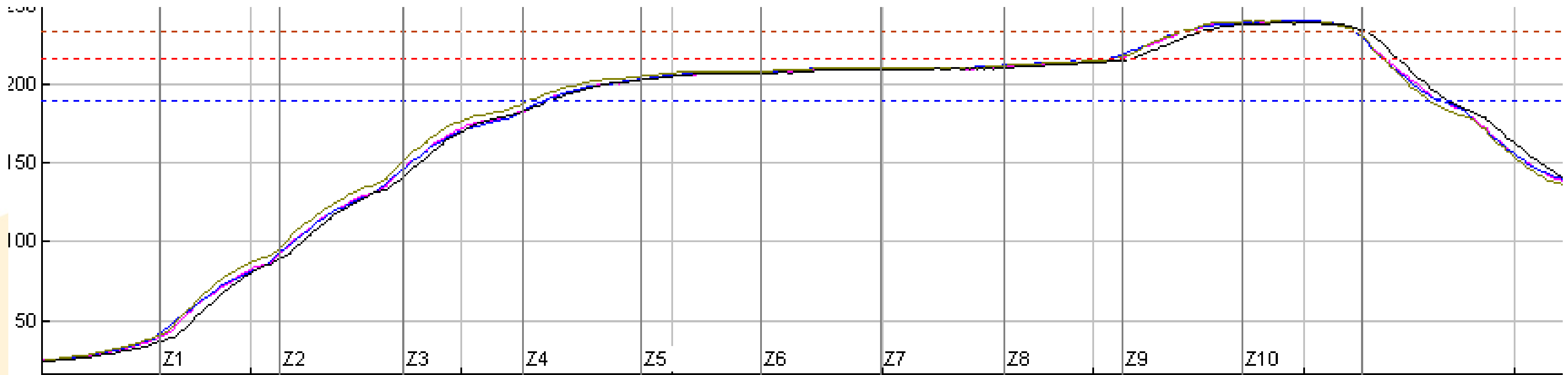
Preferred RoHS 6 Profile



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Profile Adjustments to Fit Product

Product size	Component spread	RoHS level	T max spread	TAL spread
59x42x0.3 cm	BGA 1936 - cap 0402	RoHS 6	236.1-246C	72.2-105.4 sec
38x38x0.29 cm	BGA 1521, 1517, 1508 - cap 0402	RoHS 6	234.9-241.8C	66.8-78.5 sec
38x38x0.29 cm	BGA 1521, 1517, 1508 - cap 0402	RoHS 5.5	223.7-231.5C	140.1-159 sec

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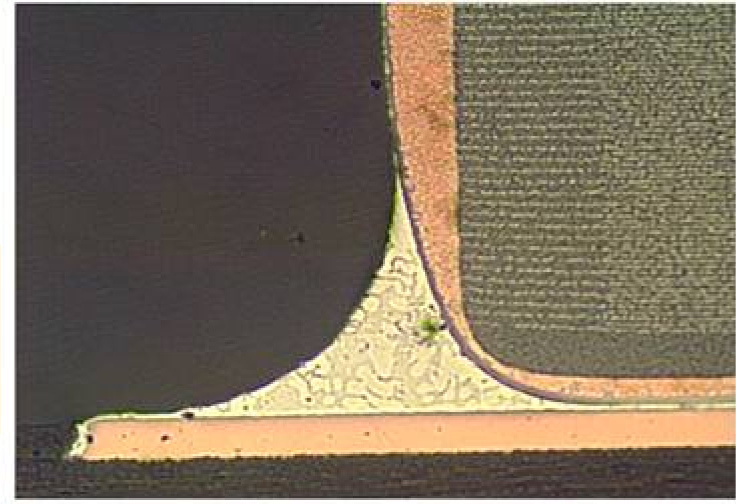
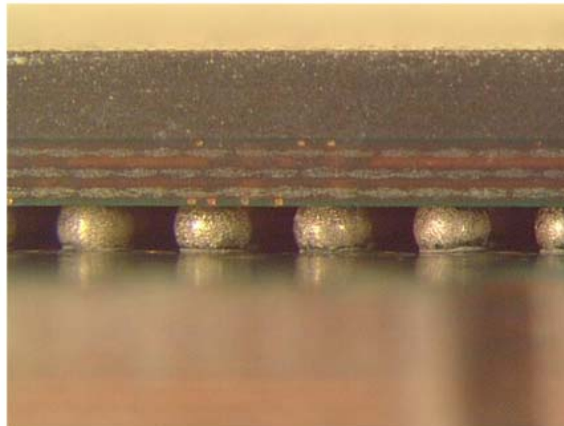
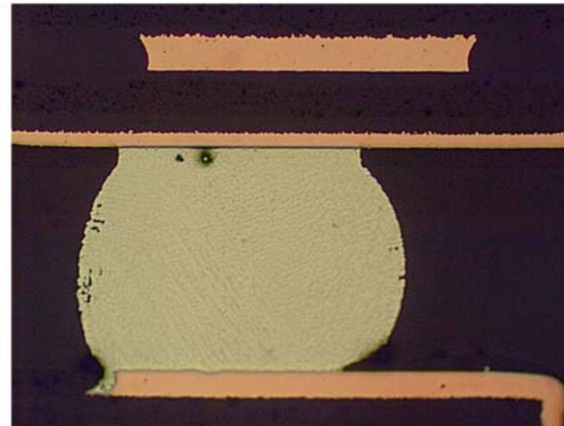
The Results: RoHS 6 Solder Joints







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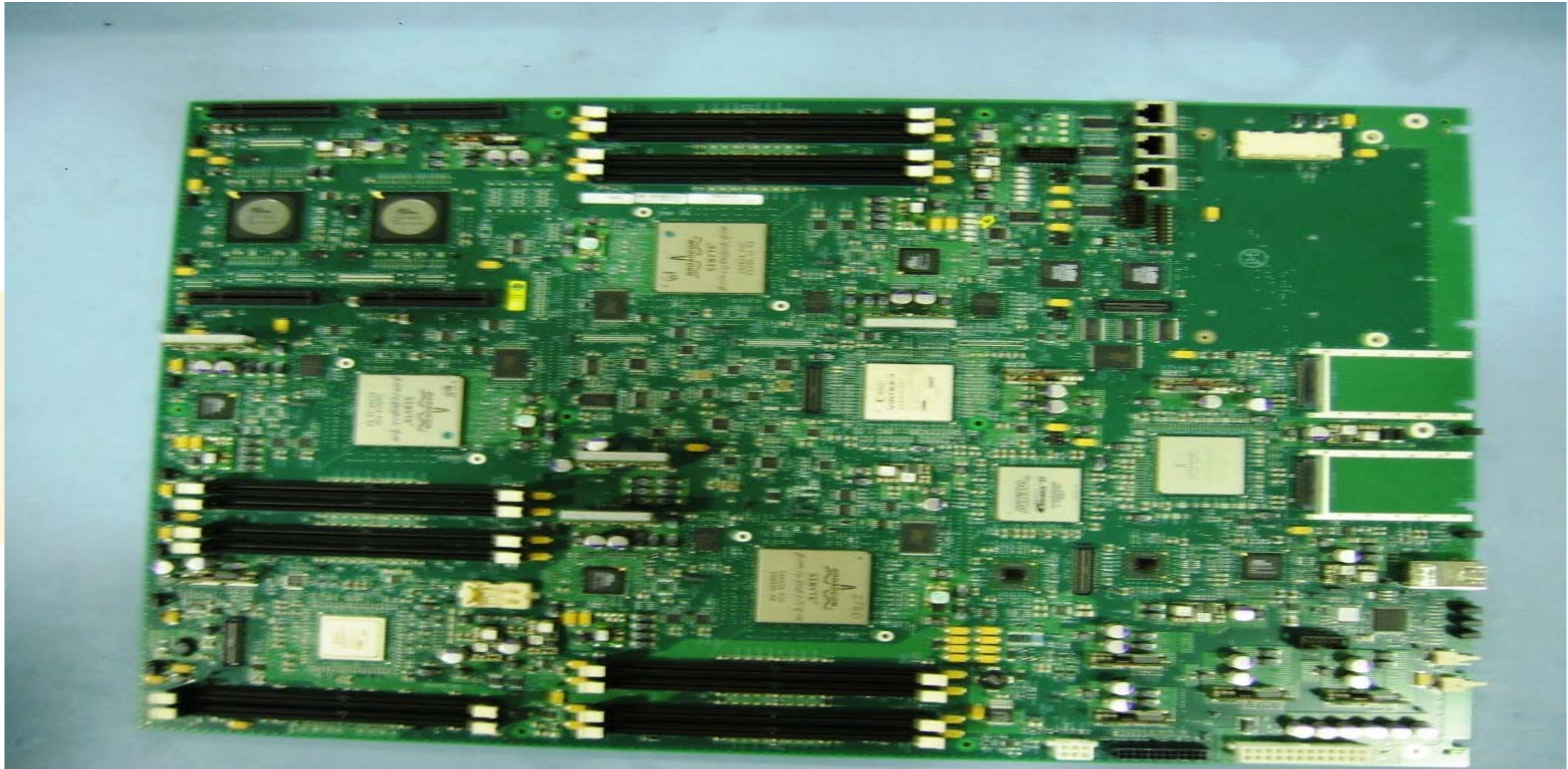
Up to 0.3cm thick, 22 layers, 56 cm



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Conclusions

- RoHS 5, 5.5, 6 Large Board assembly can be achieved with
  - Careful attention to logistics
    - Color coding and a product owner
    - Effective ECO and MCO control
  - Meticulous process development
    - Effective Printing and Placement Cp, Cpk
    - Careful Product Specific Reflow Profile Development