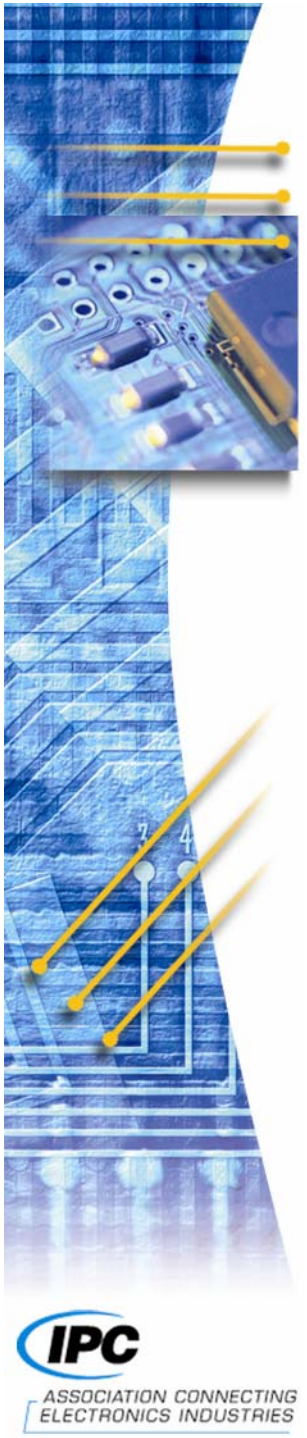

IPC 6-10 Product Reliability

Pb-Free Activities

IPC/iNEMI Reliability Summit

by

Reza Ghaffarian, Ph.D.

Co-Chair IPC 6-10 Committee

JPL/Caltech/NASA

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Outline

- Reliability
  - Reliability definition
  - IPC 6-10 Product Reliability
- IPC 6-10d SMT Attachment Rel
  - IPC 9701A Pb-Free
  - IPC 9706/TM 2.6.27
- IPC 9701
  - Pb-Sn
  - Pb-Free
  - Cross-over on TC failures!
- What is next?

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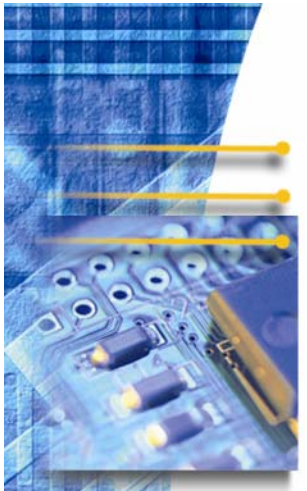

What is Reliability

"Reliability is the ability to function as expected
under the expected operating conditions
for an expected time period
without exceeding expected failure levels"

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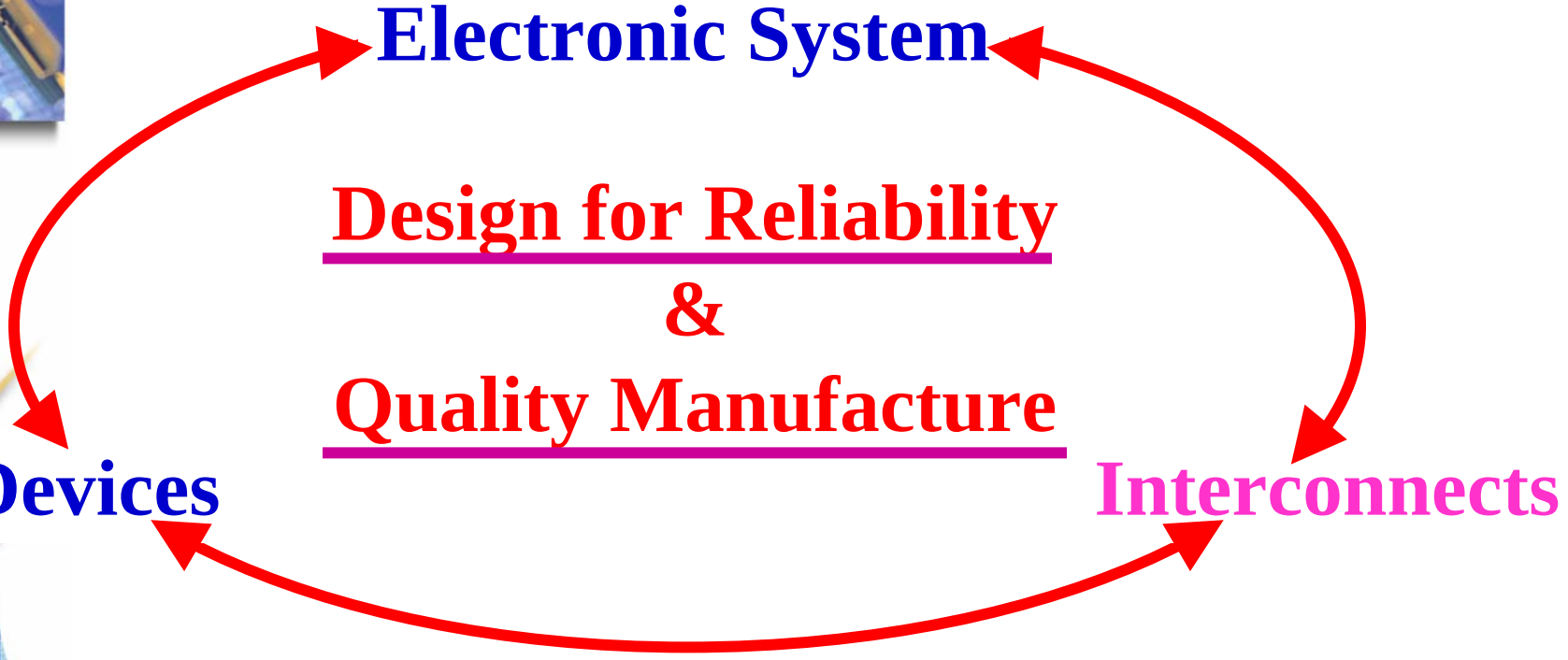
Reliability Threats



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6-10 b/c LF Reliability Activities

6-10b

IPC-D-279 “Design Guidelines for Reliable Surface Mount Technology Printed Board Assemblies”

6-10c

Plated Through Hole/Via Design Reliability- Accelerated Test Methods

- Round Robin in progress on “Standard” vs. “Lead-Free” Soldering Impact
- Determine the Correlation/Comparison of “Standard” vs. “Lead-Free” Soldering Impact
  - Piggy-pack onto current IPC-PCQR2 study
  - Highly Accelerated Thermal Shock (HATS™) test method

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6-10d SMT Attachment- Reliability Test

- IPC 9701, Released Jan 2002
- IPC 9701A, Lead free, Released 2006

"Performance Test Methods and Qual Requirements for SMT"

- Details on thermal cycle test and acceptance

- IPC-JEDEC 9702- Released July 2004

"Monotonic Bend Characterization of Board-Level Interconnects"

- Details on bend test to detect failure due handling, probe test, etc.

- IPC 9703, Draft August 2004- Draft End of Oct 2006

"Mechanical Shock Test Methods and Qual Req for SMT"

- Many telecons and two meetings at Intel during 2006
  - Details on mechanical shock and drop tests
  - Increase load/drop levels to failure
  - Use specific requirement

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6-10d SMT Attachment- Reliability Test

- IPC 9704, Final Draft Feb-Released July 2005

"PWB Strain Gage Test Guidelines"

  - Solder joint failure due to mechanical loading during probe test
  - Limited to static load, dynamic will be covered later

- IPC 9705, Initial Draft Feb 2005- Update 2006

"Area Array Connector Testing and Reliability"

  - IPC 9701 and additional specific requirement for connectors

- IPC 9706, Initiated Oct 2004- Approved-Draft 2006

"Guidelines on Lead-free Implementation for High Reliability Applications"

  - Data being generated by NASA-DOD-Industry on lead-free
  - Reliability data by industry
  - Plots removed from IPC 9701A-lead-free spec

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6-10d SMT Attachment- Reliability Test

New Activities:

IPC-TM-650 Method 2.6.27
"Characterization of Printed Board Pad Crater Following Mechanical Shock Data"

- New phenomenon for Pb-free solder assembly
- Methodology developed will define best test practice based on test data

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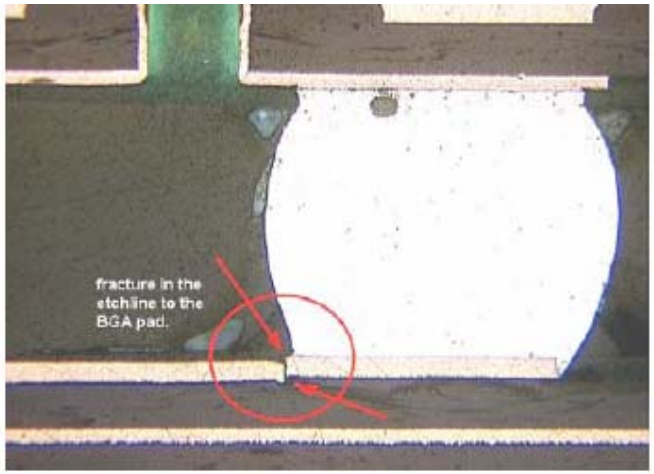
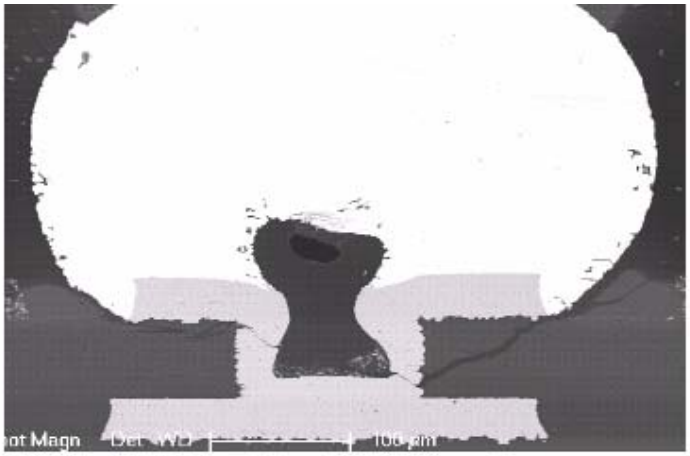
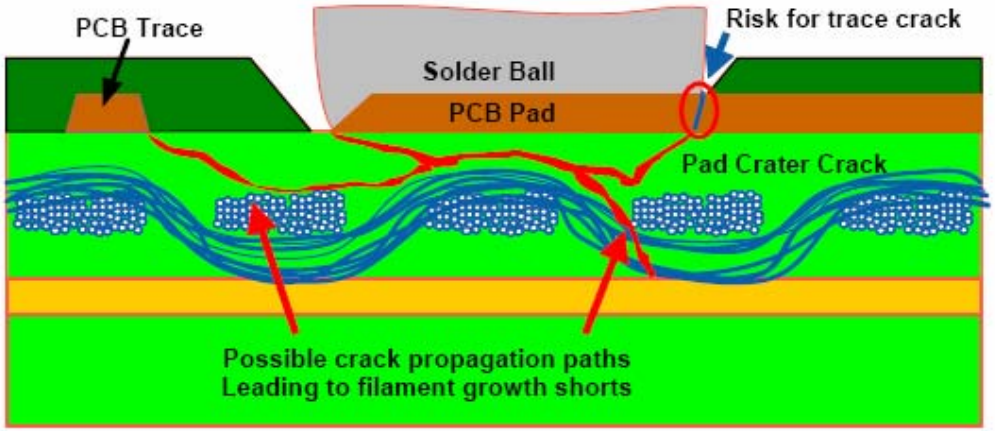
Crater Failure





Figures 1A and 1B – Open failures resulting from Pad crater circuit fractures.



Lead Free Assembly Impacts on Laminate Material Properties and "Pad Crater Failures

Gary Long, Todd Embree, Muffadal Mukadam, Satish Parupalli, and Vasu Vasudevan
Intel Corporation

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Qualification- IPC 9701

- IPC 9701, Released Jan 2002
  - IPC SM785- Guideline
    - No answer to the question of data for product application
    - Data comparison
  - IPC 9701
    - Details on thermal cycle test and acceptance
- Key Controls
  - Surface finish (OSP, HASL), thickness, 93 mil, NSMD, continuous monitoring, etc.
- Five Cycle Conditions
  - Preference 0/100°C
- Five number of thermal cycles
  - Preference 6,000 cycles

IPC 9701- "Performance Test Methods and Qualification Requirements for Surface Mount Solder Attachments"

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IPC 9701 Temp Cycle Req

Table 1 Temperature cycling requirements specified in Table 4.1 of IPC 9701

Test Condition	Mandated Condition
Temperature Cycle (TC) Condition: ***TC1***	***0°C ↔ +100°C (Preferred Reference)***
TC2	–25°C ↔ +100°C
TC3	–40°C ↔ +125°C
TC4	–55°C ↔ +125°C
TC 5	-55 °C<-> 100°C
Test Duration	Whichever condition occurs FIRST: 50% ***(preferred 63.2%)*** cumulative failure (Preferred Reference Test Duration) or
Number of Thermal Cycle (NTC) Requirement: NTC-A	200 cycles
NTC-B	500 cycles
NTC-C	1,000 cycles (Preferred for TC2, TC3,and TC4)
NTC-D	3,000 cycles
NTC-E	***6,000 cycles (Preferred Reference TC1***)
Low Temperature Dwell	10 minutes
Temp. tolerance (preferred)	+0/–10°C (+0/–5°C) [+0/–18°F (+0/–9°F)]
High Temperature Dwell	10 minutes
Temp. tolerance (preferred)	+10/–0°C (+5/–0°C) [+18/–0°F(+9/–0°F)]

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Lead-free Guideline- IPC 9701A-Appendix B

- IPC 9701A, 2nd draft to team July 2005, Oct final draft
- Appendix B, "Guideline for Thermal Cycle Requirements for Lead-free Solder Joints"
  - Moisture sensitivity, use J-STD-020
  - Reference to several models
    - Details covered in IPC 9706
- Release delayed due to lack of data on dwell- 2 dwells
  - D10 (10 minute dwell)
    - Most efficient
    - Use as "stand-alone", only when modeling understood could be theoretically compared to tin-lead
  - D30+ (30 minutes or higher)- To experimentally induce damage somewhat comparable to tin-lead
- Surface finish
  - Only OSP, IAg
- Requalification is required when
  - Solder paste change
  - Lead terminal change

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Lead-free Guideline- IPC 9701A-Appendix B

Effect of Area Array Package Types on Assembly Reliability and Comments on IPC-9701A

Reza Ghaffarian, Ph.D.
Jet Propulsion Laboratory, California Institute of Technology
Pasadena, CA

Back-up information for IPC-9701A
Discussion on Key Thermal Cycle Parameters and Projection for Lead-Free Vs Lead-Based Solder Joints

The appendix B of IPC-9701A establishes guidelines for modifications required to IPC-9701 for lead-free solder joints. Currently, there are only limited data and insight to determine acceleration factors and acceleration models for lead-free solders [1-13]. Data on the impact of various thermal cycle profiles on the results of accelerated testing in comparison to eutectic tin-lead solder are still being gathered by industry.

Acceleration thermal cycle test results especially when are compared to lead-free solder alloys are sometimes inaccurately assumed to be the same as product reliability. Correlations between acceleration test and product reliability for tin-lead are somewhat have been established during many years of investigation and product use whereas that is not true for less understood lead-free solder attachment. Reliability is the ability of a product, here surface mount solder attachments, to function under given conditions and for a specified period of time without exceeding acceptable failure levels. Therefore, comments such as a lead-free solder joint is more or less reliable than standard tin-lead solder joint based on only laboratory test results are unsubstantiated. Such general statements are incomplete when the lead-free alloy composition or/and when product information and use conditions are not specified. Product reliability needs to be estimated for solder joint under relevant use conditions.

Ref: APEX 2006

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Effect of Dwell Time

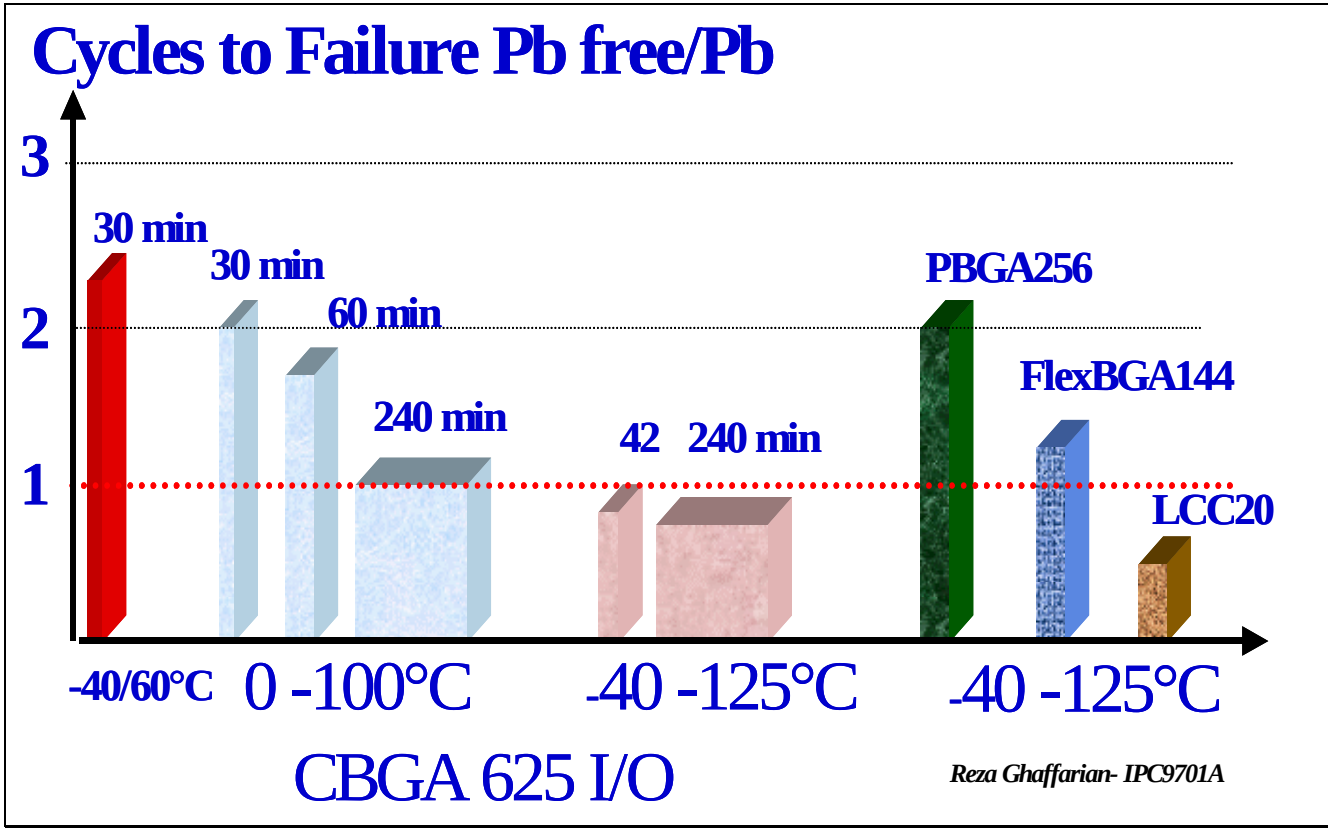

Figure B1 Cycles-to-failures for SAC (Sn-Ag-Cu) solder attachment depend on thermal cycle range and state of stress/strain (Courtesy Reza Ghaffarian, NASA-JPL, CIT), different source of data including [11].

Note: When comparing cycles-to-failure data for lead-free and lead-based solders, it should be noted that such comparison may not be valid since failures depend not only on the temperature cycle profile but also on the type of package and assembly configuration.

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SAC/SnPb & Package/Delta Temp

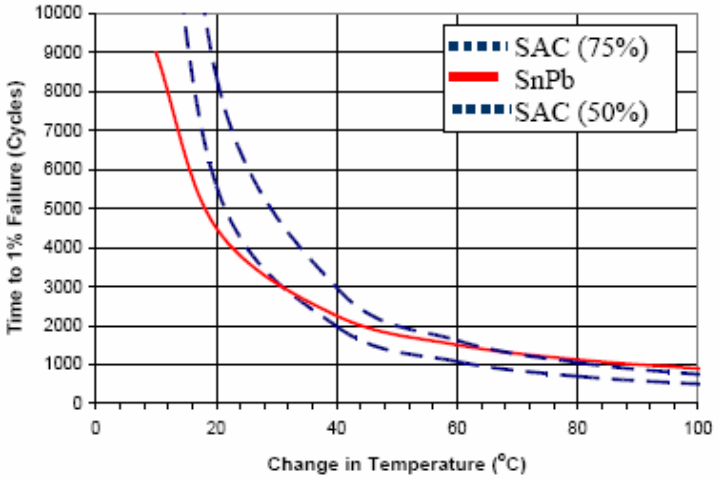

Figure 11: Time to 1% failure for 2512 resistors attached with SAC or SnPb solder and subjected to long dwells (~8 hours).

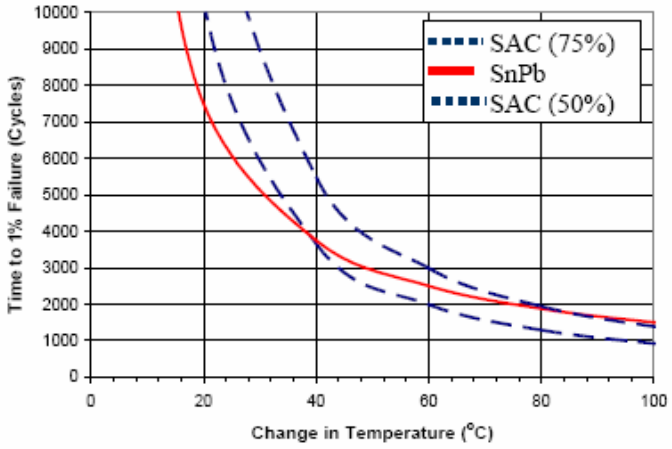

Figure 12: Time to 1% failure for Alloy42 TSOPs attached with SAC or SnPb solder and subjected to long dwells (~8 hours).

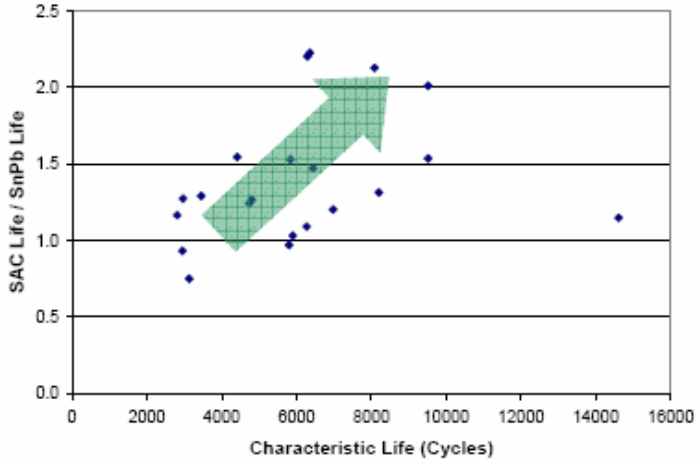

Figure 14: Ratio of SAC/SnPb reliability for area array devices as a function of characteristic lifetime of the SAC component.

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SAC/SnPb Cross Over-Thermal Cycle

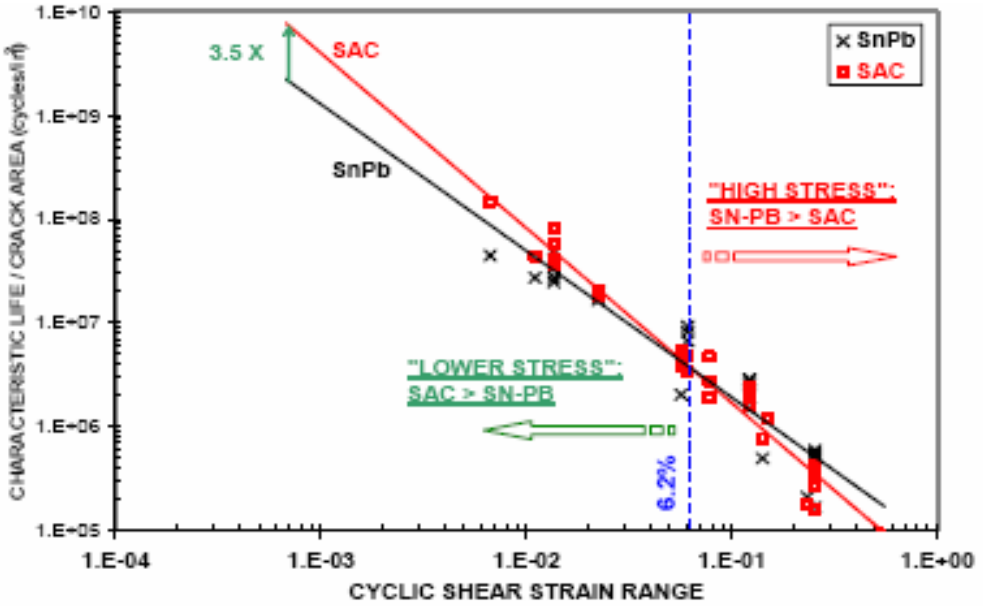

Figure 3 - Correlations of Joint Characteristic Life Scaled for Solder Joint Crack Area versus Average Cyclic Shear Strain Range in Temperature Cycling for Standard SnPb and for 100% Lead-Free SAC Assemblies

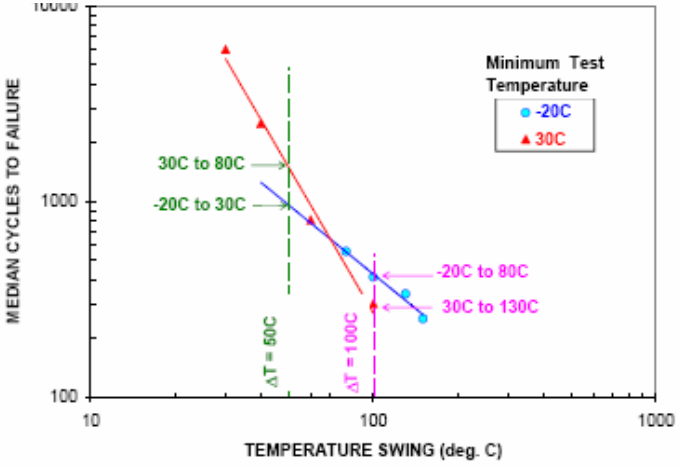

Figure 18: LCCC mean solder joint life vs. temperature swing (ΔT) for cold temperatures of -20°C and 30°C (data points from Figure 15 in [27]).

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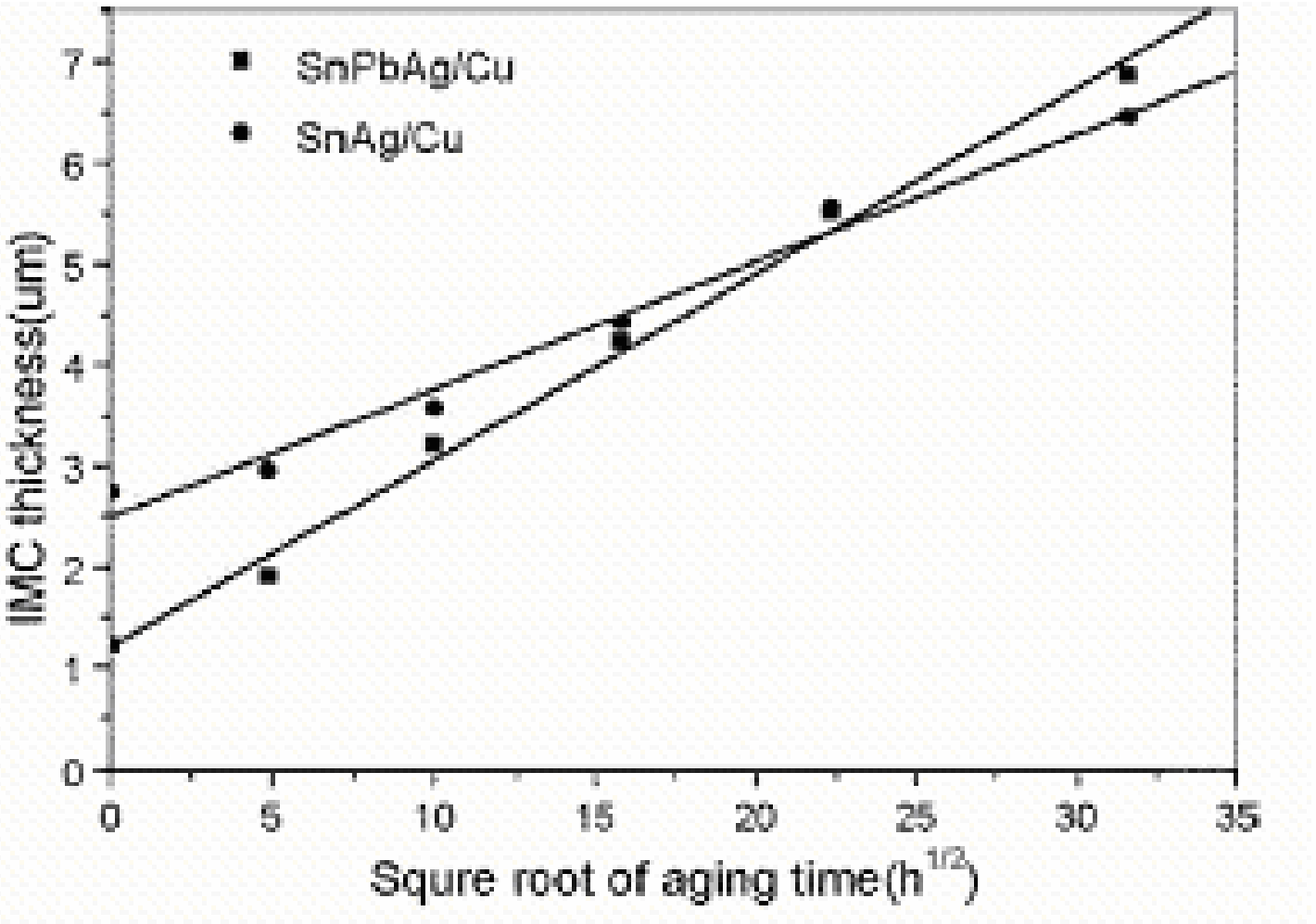
SAC/SnPb Cross Over-IMC Growth



Shawkret Ahat, Mei Sheng, and Le Luo, "Microstructure and Shear Strength Evolution of SnAg/Cu Surface Mount Solder Joint During Aging", Journal of ELECTRONIC MATERIALS, Vol. 30, No. 10, 2001

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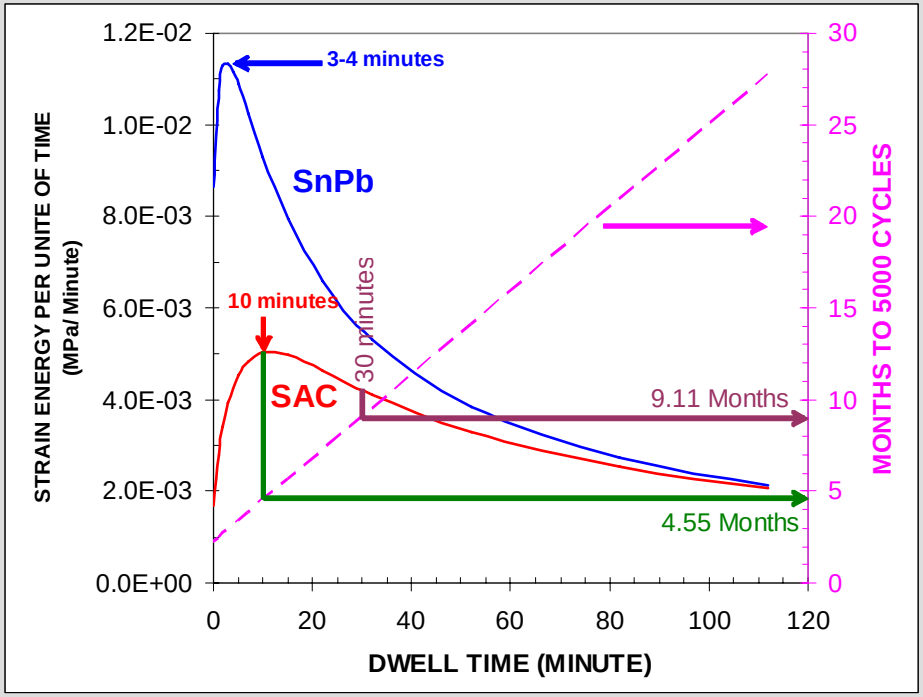
Effect of Dwell Time

Effect of Dwell Time on Test Efficiency

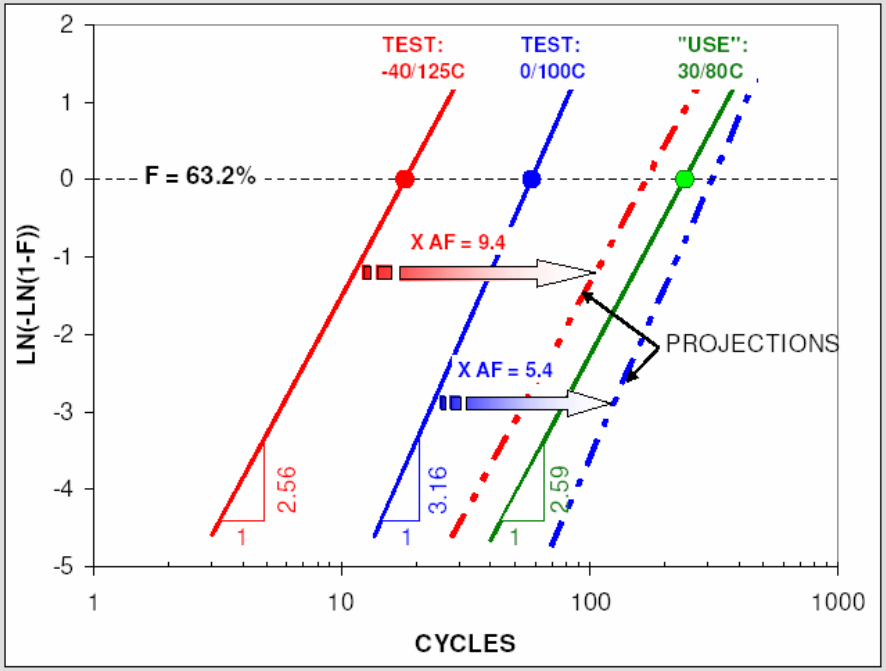


- Simulations are for CBGA assemblies and equal dwell times at 0°C and 100°C (~ 10°C/min. ramps)
- Max. test efficiency (strain energy per minute) is at dwell times of:
  - 3-4 minutes for SnPb; 10 minutes for SAC

EPSI Inc, 2005

Effect of Dwell Time

Weibull Plots & Extrapolation of Test Results



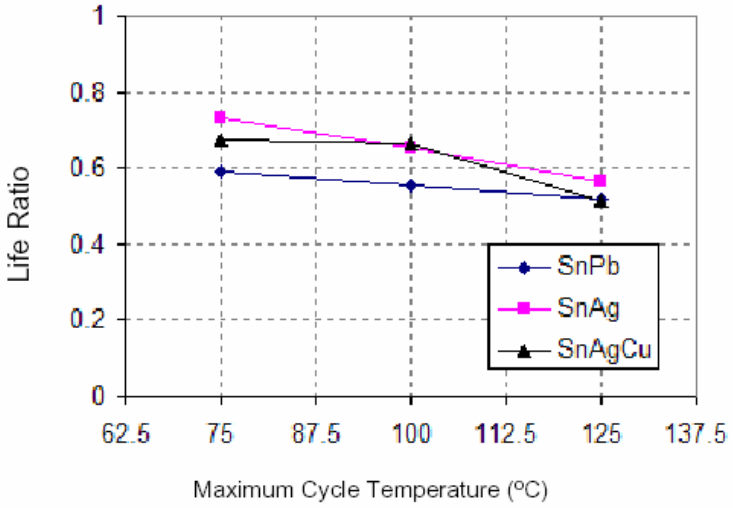
- Extrapolation of -40/125C and 0/100C data to 30/80C "use" conditions brackets the actual 30/80C test results and would probably overlap with 30/80C confidence bands (which were not available in Salmela et al.'s paper).

Effect of Dwell Time

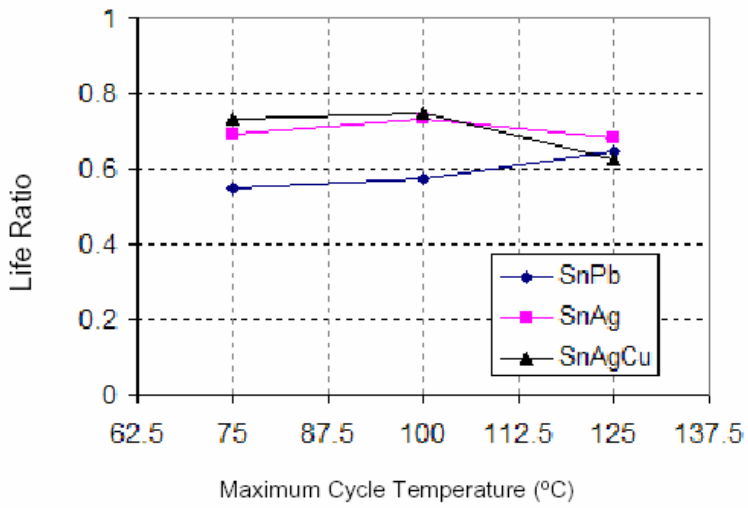
Effect of Package Size

Life Ratio = Life of LCCC84/ Life of LCCC68

$$\frac{\Delta\gamma_{68IOs}}{\Delta\gamma_{84IOs}} \approx 0.8$$



Dwell time of 15 min



Dwell time of 75 min

- Life reduction caused by the package size (i.e., larger $\Delta\gamma$) becomes larger as the maximum temperature increase: this effect is slightly larger in the SnPb solder.
- The life ratio of Pb-free solders approaches to that of SnPb solder as the temperature increases.
- Longer dwells generally the reduce the effect of temperature on life ratio.

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Effect of Mean Temp

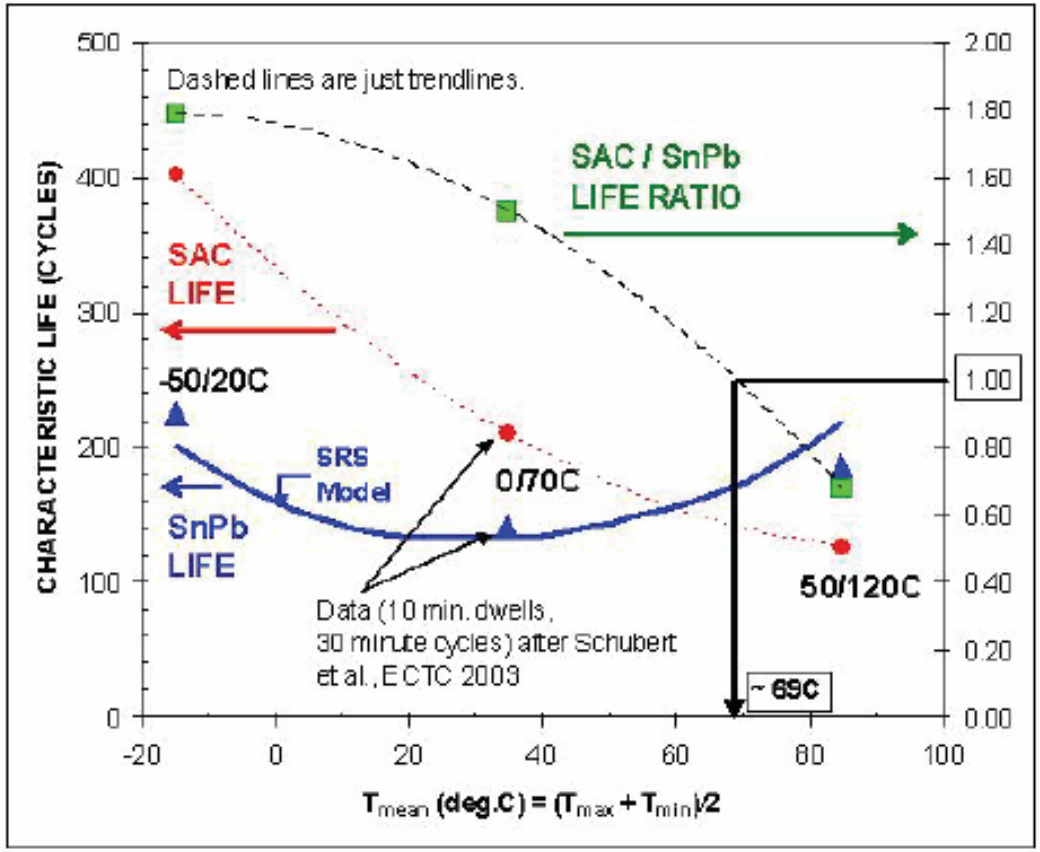
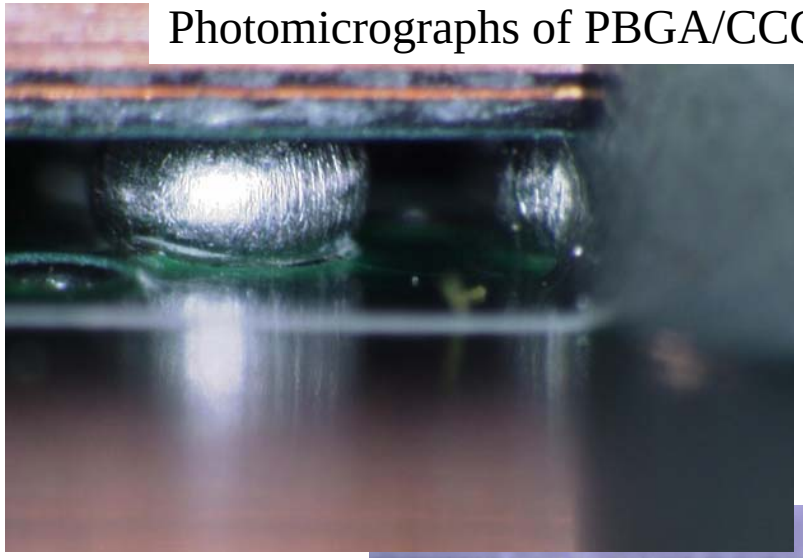
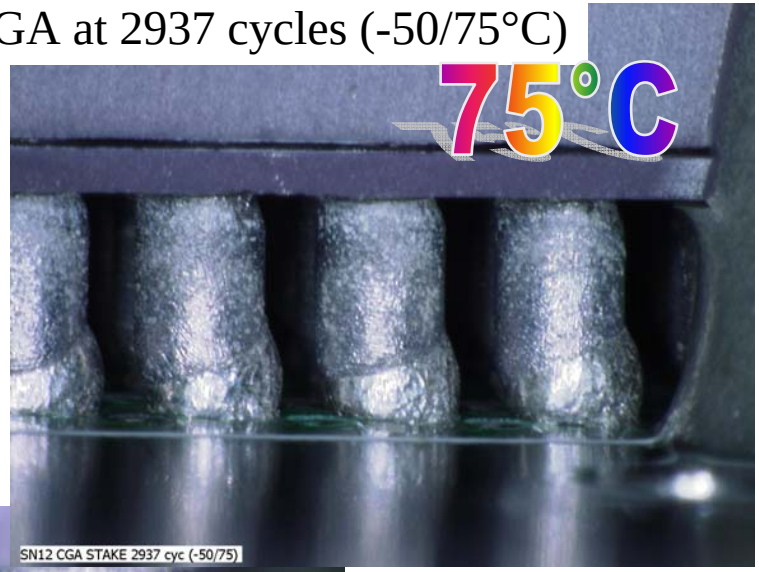


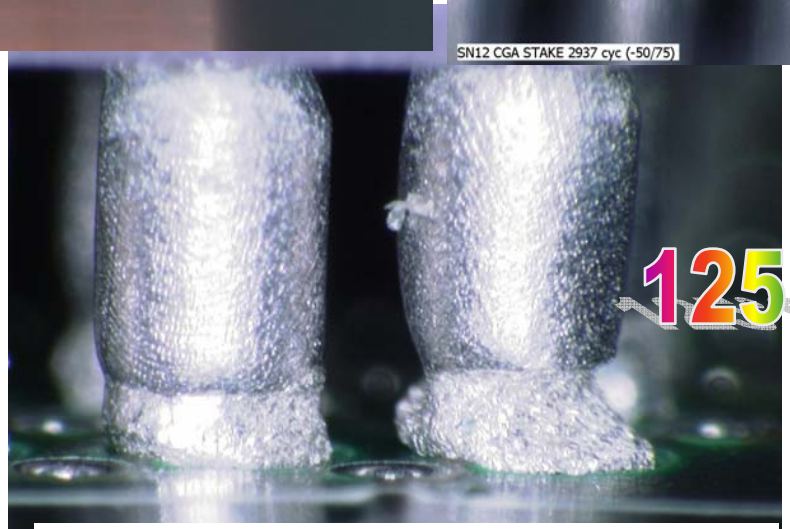
Figure A6 - Characteristic Life Projection versus Mean Thermal Cycle Temperature for Lead-Free and Lead-Based Solders (Courtesy of Jean-Paul Clech)

Effect of Max Temp On Pb-Sn

Photomicrographs of PBGA/CCGA at 2937 cycles (-50/75°C)







CCGA, after 478 cycles (-55/125°C)

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Needs Different Cause Different Ranking? Different

	Part Finish	Solder Paste	Ranked by Importance					
Before Rework	SnPb	SnPb						
			TW	MW	JB	RG	LC	MS
After Rework	SnPb	SnPb	1 - needed as a control	1	2	3	2 (control)	1
After Rework	SnPb	Pb-free	3 - unlikely scenario	3	4	4	4	3
After Rework	Pb-free	SnPb	2 - if SnPb part finish not available	2	1	1	1	2
After Rework	Pb-free	Pb-free	4 - covered by first JG-PP test	4	3	2	3	4

What to Evaluate Before Rework

	Part Finish	Solder Paste	Ranked by Importance					
Before Rework	Pb-free	Pb-free						
			TW	MW	JB	RG	LC	MS
After Rework	SnPb	SnPb	2 - a likely scenario	4	1	3	3	3
After Rework	SnPb	Pb-free	4 - unlikely scenario	2	4	4	4	4
After Rework	Pb-free	SnPb	3 - possible scenario	3	2	1	1	1
After Rework	Pb-free	Pb-free	1 - most likely scenario	1	3	2	2	2

What to Evaluate After Rework

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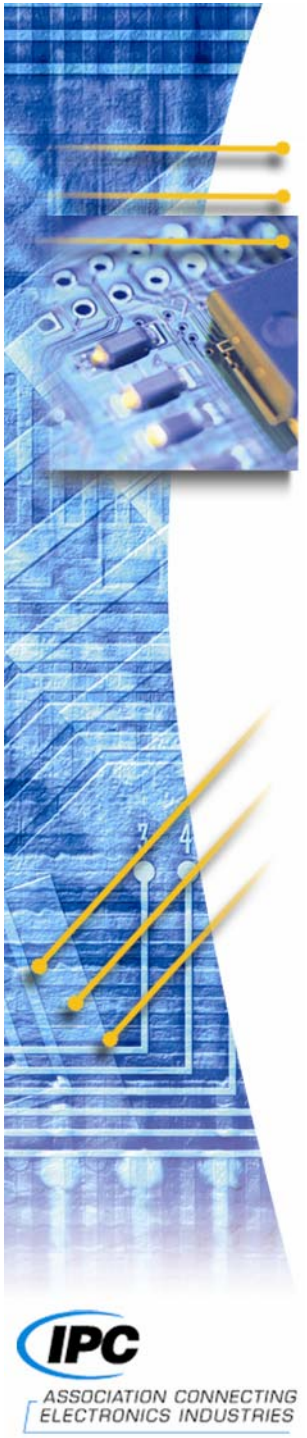

What Is Next?

- More Pb-Free Alloys
  - Less Reliability Data
  - More Confusion on Rework
- More Pkg Types
  - Damage @ higher Temp for Pb-Free
  - Mix Pkg/Board issues
- PCB Issues
  - Higher temp/Surface finish/Cu dissolution
- Specifications
  - Better, as more data become available
  - Collaboration needed
- High Reliability Sector is Next?

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