

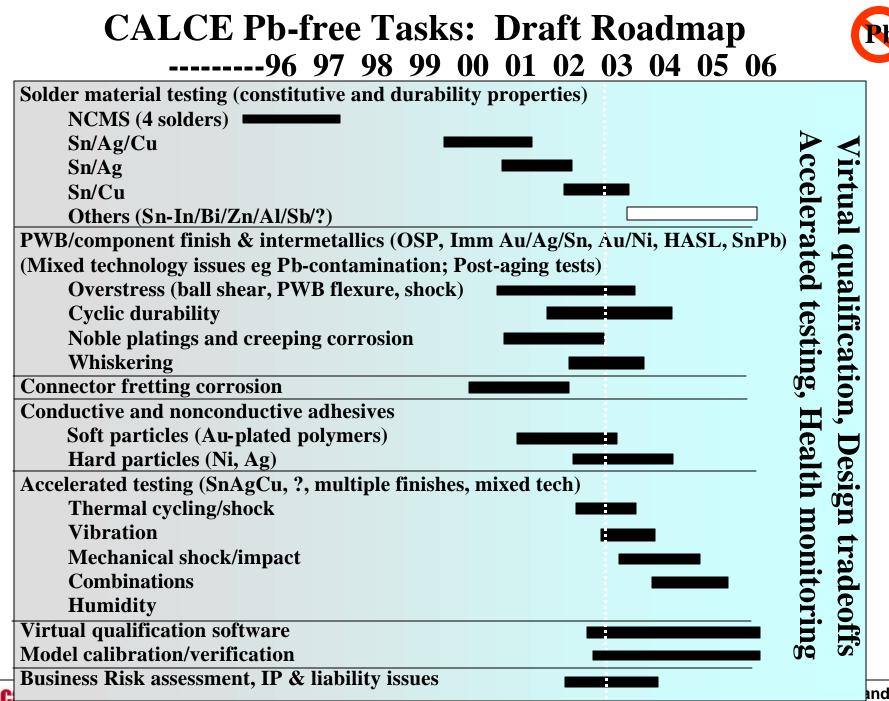
### Overview of Risk Assessment, Mitigation, and Management Research for Pb-free Electronics



### Electronic Products and Systems Center University of Maryland College Park, MD 20742 (301) 405-5323 http://www.calce.umd.edu

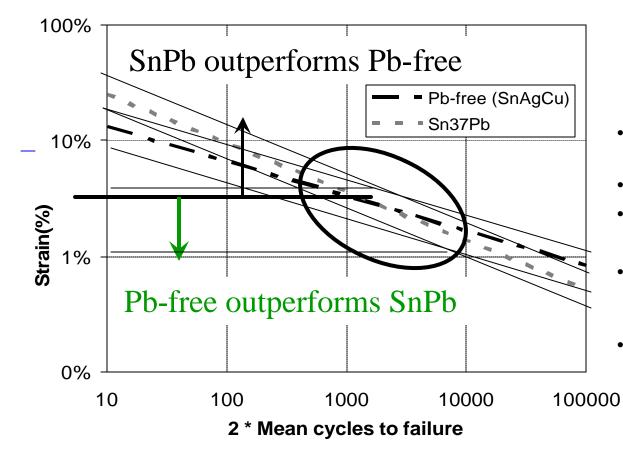
Formed 1987

ISO 9001 Certified, 1999



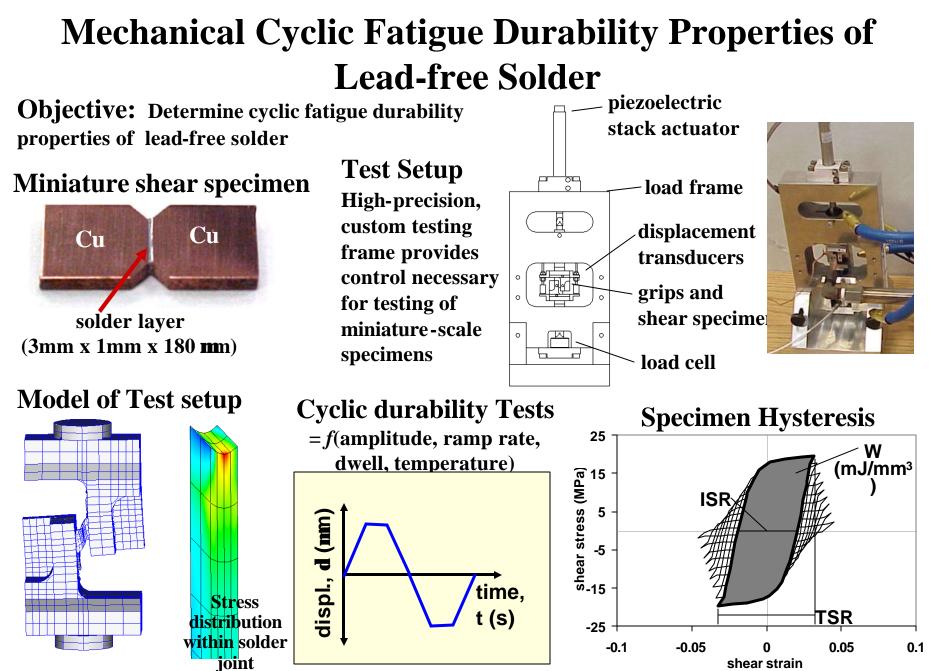
# **Durability of Solder under a Temperature Cycle**

Collected experimental data has resulted in a preliminary rapid assessment model for Sn4.0-3.8Ag0.7Cu solder, released in the calcePWA software. Data consists mostly of standard test conditions (i.e. -40 to 125°C, -55 to 125°C, and 0 to 100°C) with little variation in dwell or mean temperature.



$$N_f = \frac{1}{2} \left( \frac{\Delta \boldsymbol{g}}{2\boldsymbol{e}_f} \right)^{\frac{1}{c}}$$

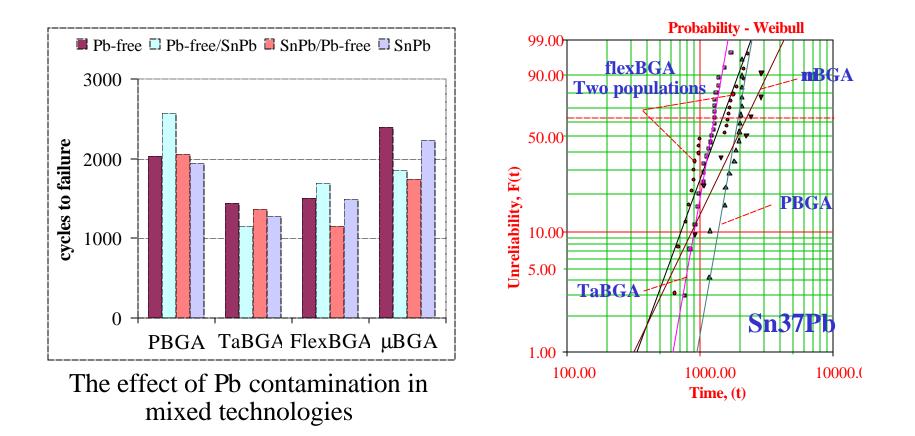
- N<sub>f</sub>: mean number of cycles to failure
- $\Delta \gamma_{\rm p}$  : inelastic strain range
- $\varepsilon_{f}$ , c : material constants
- Qualitative graph represents CalcePWA model predictions for SnPb and SnAgCu solders.
- Crossing point likely to shift due to temperature cycle parameters
   (i.e. mean temperature, temperature range, dwell time, and ramp rate)



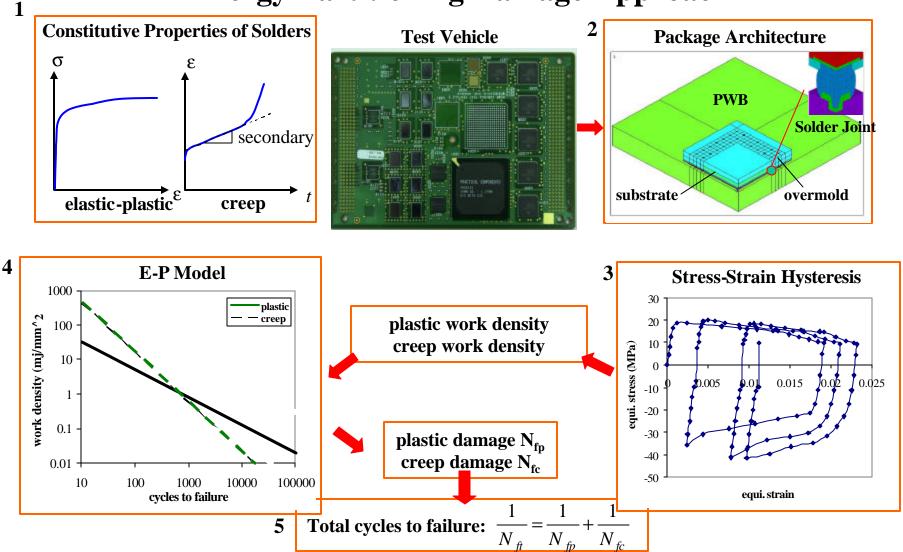
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### **Accelerated Thermal Cycling**



### **Detailed Modeling** Energy-Partitioning Damage Approach



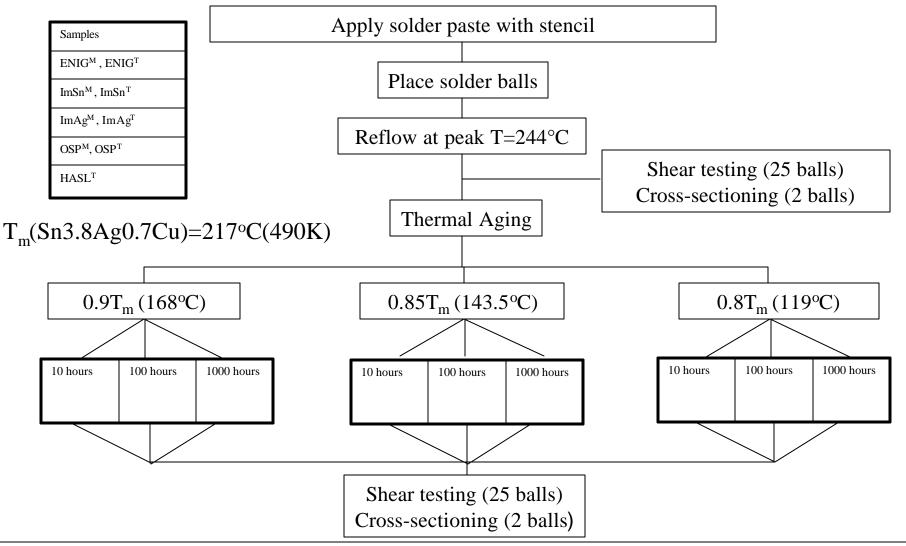
### **Rapid Failure Assessment Software for Pb-free**

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			U15	2.0 3.0 4.0	U3-solder-open U5-solder-open PTH-barret-open	20 30 20	1ST_TF_JLEAD 1ST_TF_PBGA CALCE_PTH	4.22 years (DR:1.42) 4.43 years (DR:1.36) 4.53 years (DR:1.33)	View View View
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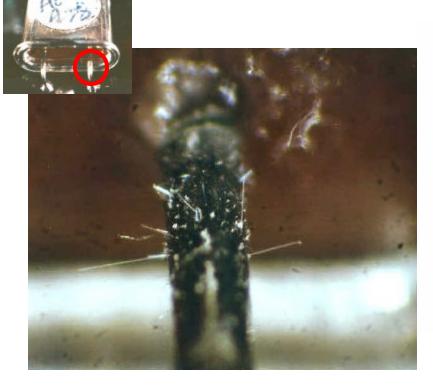
On-going efforts in rapid assessment of printed wiring assemblies has resulted in a preliminary model for assessing failure of Pb-free (SnAgCu) solder package to board interconnects.

### **PWB Plating Study**

Five different platings from two manufacturers were reflow soldered with Sn3.8Ag0.7Cu to determine the intermetallic formation and shear strength.



# **CALCE Tin Whisker Study**



#### Tin Whisker Information

Tin Whisker Alert (Whitepaper) A candid discussion of the concern over failures in electronics related to "tin-whiskers" and its potential re-emergence due to the move lead-free solders.

**Tin Whisker Risks** (Whitepaper) A technical discussion of the "tin-whiskers" phenomenon, current knowledge and remaining questions.

**Tin Whisker Experiences** (Whitepaper) A collection of experiences where "tin-whiskers" have been observed.

**Tin Whisker Mitigation Guide** (Whitepaper) A guide for mitigating the risk of tin-whiskers as a failure source in electronic hardware.

In addition to conducting multiple research projects on lead free solder issues this past year, CALCE joined with a number of companies to author an alert regarding the use of pure tin as a surface finish.

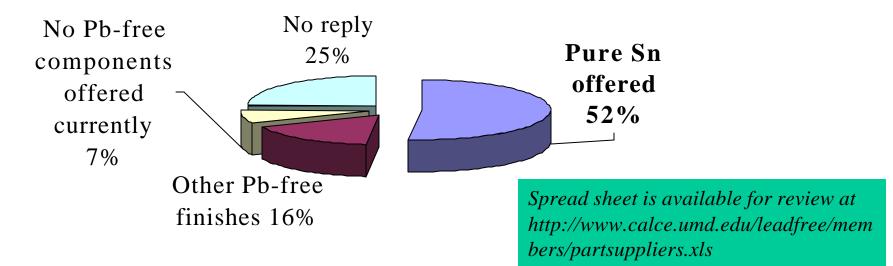
This alert was followed closely by a mitigation guide authored by CALCE with inputs from companies participating in the Tin Whisker Alert Working Group.

### http://www.calce.umd.edu/lead-free/tin-whiskers

## **CALCE Tin Whisker Team Studies (Roadmap)**

2002	Tin V	CALCE W	Whisker Team		
2003	T	in Whisker Mitigation Gu			
Sold	er Dip	Heat treatments	Confor	mal Coating	
-No whisker was found at solder-dipped portion -Sample size was too small		-Initiated experiments with bright and matte tin over brass, Cu, and alloy 42.	-Initiated experiments to investigate the environmental conditions for tin whisker growth		Supplier survey
TMTIStProjecteff-SolderbeDipping-dip	004 Eudy on fect of ending, older pping, and urrent	-Initial results showed heat treatments may not be effective to mitigate the risks caused by tin whiskers -Whiskers grow more on bright tin plated specimens than matte tin	-Testing was done at Boeing/Raytheon -Whisker can grown through some types of conformal coating		Observation of pure-tin plated components Examination of plating and grain size of
		Update of tin whisker n	ounde	pure-tin plated components	

### **Component Manufacturers' Survey** - Pb-free Component Finishes -



- Since October 2003, an additional 10 % of companies selected pure tin (matte) as a Pbfree option. Survey was conducted among 104 leading component manufacturers.
- Even though a list of Pb-free components offerings is showed in the companies' websites (i.e., those components have been qualified and can be manufactured), availability of Pb-free component is still limited in the actual supply chain.
- Due to insufficient traceability of components, mistaken delivery of Sn-Pb components instead of Pb-free components has occurred.

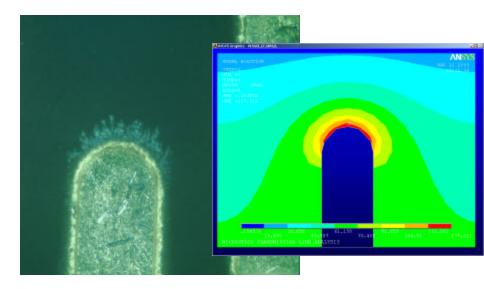
### **CALCE Pb-free Alloy Patent Finder** - D X

🌺 CALCE Pb-Free Patent Finder

-ile					and where an
CA	LCE Pb-free a	alloy paten	t finder	alloy is p	atented
	high wt.% low wt.9	% high wt.	% low wt.%		
Sn	100 0	<b>Bi</b> 100	0	Compare	patented
In	100 0	Ag 100	0	alloys	1
Cu	100 0	<b>Sb</b> 100	0	<u> </u>	
Zn	100 0	Ni 100	0		
	(h	0-1			Restrict
	Choose Algorithm	Select issuir			search by Select issuing body
	within range	All Countrie	s •		All Countries
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AU2560400	▼ AU256040	) 🔻	Part Comp	methods	Korea 🗾

### **Electrochemical Migration in the Age of Pb-Free**

- What does Pb-Free mean to electrochemical migration (ECM)?
  - New plating materials
  - New interconnect materials
  - New flux chemistries
- ECM and alternative platings
  - ENIG and ImSn dependent upon plating quality
  - ImAg dependent upon electric field
- Sn-Based Alloys
  - Use environment likely to be acidic with the presence of oxygen and halides
  - Potential for order of magnitude increase in corrosion rate



Major flux manufacturers have stated that the poor solderability of Pb-free solders and Pbfree platings and the higher reflow temperatures will require much more <u>aggressive</u> flux formulations.

### **2004 CALCE Consortium Research**

#### http://www.calce.umd.edu/general/projects/current.htm

- C04-01 Logistics and Cost Analysis for Lead-Free Implementation
- C04-02 Risk Assessment & Accelerated Qualification of Pb-free Electronics
- C04-03 Durability Characterization of Pb-free Solders
- C04-04 Effect of Temperature Cycle on the Durability Pb-Free Inteconnects (Sn-Ag-Cu and Sn-Ag)
- C04-05 Determination of Fatigue Constants of Lead-free Solder for calcePWA
- C04-06 Intermetallic-Related Embrittlement of Lead-free Solder Die Attach
- C04-07 Investigation of Issues on Lead-free Plating (Pure Sn)
- C04-08 Reliability of Pb-free Interconnect Solutions
- C04-09 Hermeticity of Wafer Level Packaging
- C04-10 Qualification and Reliability Assessment of New Capacitor Technology
- C04-11 Cracking of BME Ceramic Chip Capacitors in High Humidity
- C04-12 Reliability Assessment of High Density IC sockets and Tests for the Causes of Failure
- C04-13 Effects of Conformal Coating of Solder Spreading Phenomenon
- C04-14 Dendritic Growth and the Effect of Conformal Coating
- C04-15 Environmental Degradation of Polymer Waveguides
- C04-16 Backplane Databuses for Modular Avionics
- C04-17 Long-Term DMSMS Management and Planning
- C04-18 Life Consumption Monitoring/Prognostic Application Space (ROI for Maintenance Planning)
- C04-19 Integrated Health and Usage Monitoring System
- C04-20 Methodology for Equipment Manufacturer Intervention in their Supply Chain

- C04-21 Reliability Capability Assessment for Contractors and Vendors
- C04-22 Advanced Micro-Structured Surfaces for Heat Sinks/Heat Spreaders
- C04-23 Advanced Liquid Cooled Module for Cooling of High Flux Electronics
- C04-24 Spot Cooling of High Flux Electronics with Thin Film Evaporation
- C04-25 Thermal Characterization of Die Attach Adhesives
- C04-26 Development of Hybrid-Level Screening Methodology
- C04-27 Analysis of Intermittent Failures in Electronic Assemblies
- C04-28 Failure Analysis of the Main Board in LCD Laptop Computer
- C04-29 Dynamic Behavior of Plastics under Impact Loading
- C04-30 Reliability Assessment of Electronic Assemblies Under High-G (Artillery Launch) Loads
- C04-31 Improved Failure Simulation of Vibration Induced Failures - continued
- C04-32 New Analysis and Modeling Capabilities for calcePWA
- C04-33 Solder Joint Reliability with FBGA
- C04-34 Reliability Assessment of Surface Mounted Chip Varistor Subjected to Thermal Shock
- C04-35 Development of PoF Based Virtual Qualification Methodology for COF Packages (Phase II)
- C04-37 PoF-Based Wire Lift-off Models for Aluminum Wedge Bonds
- C04-38 Virtual Qualification of Subsystems at High Temperatures

# **CALCE Lead Free Forum Web Site**

#### Current Issues

- Projects
- Services
- Training
- Articles
- Related Research Groups
- Contact Us

Lead Free and Green Electronics Forum

The CALCE Electronic Products and Systems Center's Lead Free Forum is dedicated to the collection, generation, organization, and dissemination of information related in the manufacture, assembly, and fielding of lead free and "green" electronic products and systems.

#### Current Issues and Events:

Lead-free Electronics - 2004 Edition A new reference book for Pb-free electronics is now available from CALCE EPSC Press.

CALCE Pb-Free Patent Finder Software (Members' Only) A software tool for examining existing international patents for Pb-Free Solders. This software was developed in part under C03-01. (Updated Version 1.0.1 posted 2/17/04) Tin Whisker Studies Information related to the tin whisker as a potential source of failure in electronic hardware.

CALCE Lead Free Forum Workshop (CALCE Members Only) On October 10th 2002 CALCE hosted a Lead-Free Workshop.

Failures in Microeletronics Attributed to Phosphorus An update to the warning of a potential reliability risks attributed to molding compounds that use phosphorus as a flame-retardant.

Lead Free Forum Point of Contact: M. Osterman

Please Mail Inquires to - leadfree@calce.umd.edu

### http://www.calce.umd.edu/lead-free/

### **Pb-Free Resources**

http://www.calce.umd.edu/general/published/books/books.html

#### Lead-free Electronics 2004 Edition



Edited by Sanka Ganesan Michael Pecht Chapter 1 Lead-free Electronics: Overview Chapter 2 Lead-free Alloys: Overview Chapter 3 Constitutive Properties and Durability of Lead-free Solders Chapter 4 Interfacial Reactions and Performance of Lead-free Joints Chapter 5 Lead-free Manufacturing Chapter 6 Component-level Issues in Lead-free Electronics Chapter 7 Conductive Adhesives Chapter 8 Lead-free Separable Contacts and Connectors **Chapter 9 Intellectual Property** Chapter 10 Costs to Lead-free Migration Chapter 11 Lead-free Technologies in the Japanese **Electronics Industry**