Global Transition to Pb-free/Green Electronics

calce

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

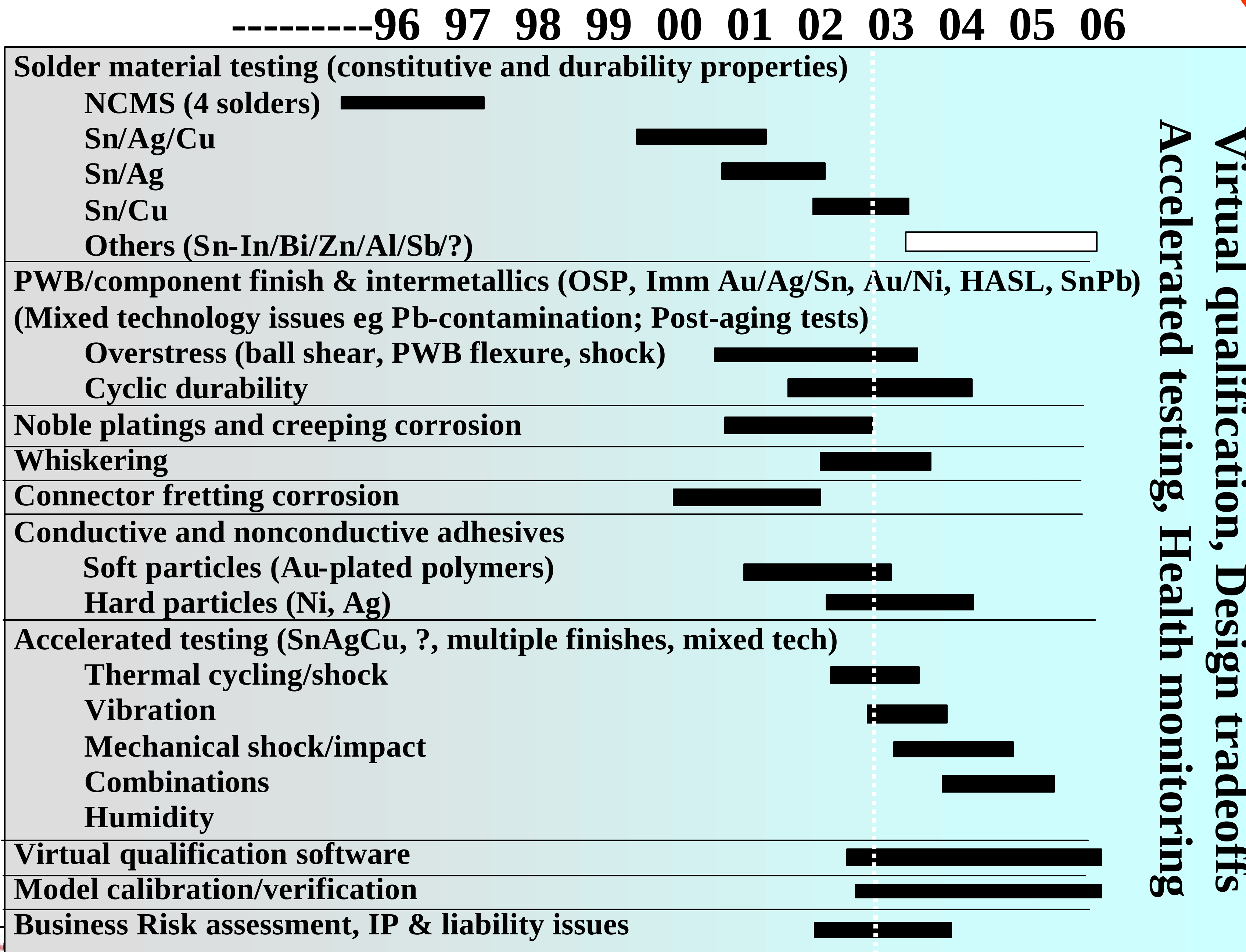
Formed 1987

ISO 9001 Certified, 1999

Abbreviations

- CALCE: Computer Aided Life Cycle Engineering
- EU: European Union
- EC: European Commission
- RoHS: Restrictions of Hazardous Substances
- WEEE: Waste Electrical and Electronic Equipment
- ELV: End-of-Life Vehicle Directive
- EICTA: European Information and Communication Technology Industry Association
- EIA: Electronic Industries Alliances
- JEDEC: Joint Electron Device Engineering Council
- JGPSSI: Japan Green Procurement Survey Standardization Initiative
- JEITA: Japanese Electronics and Information Technology Industries Association
- NEMI: National Electronics Manufacturing Initiative
- EPO: European Patent Office
- IPC: formally Institute of Interconnecting and Packaging Electronic Circuits
- WIPO: World Intellectual Property Organization
- HDPUG: High Density Packaging User Group

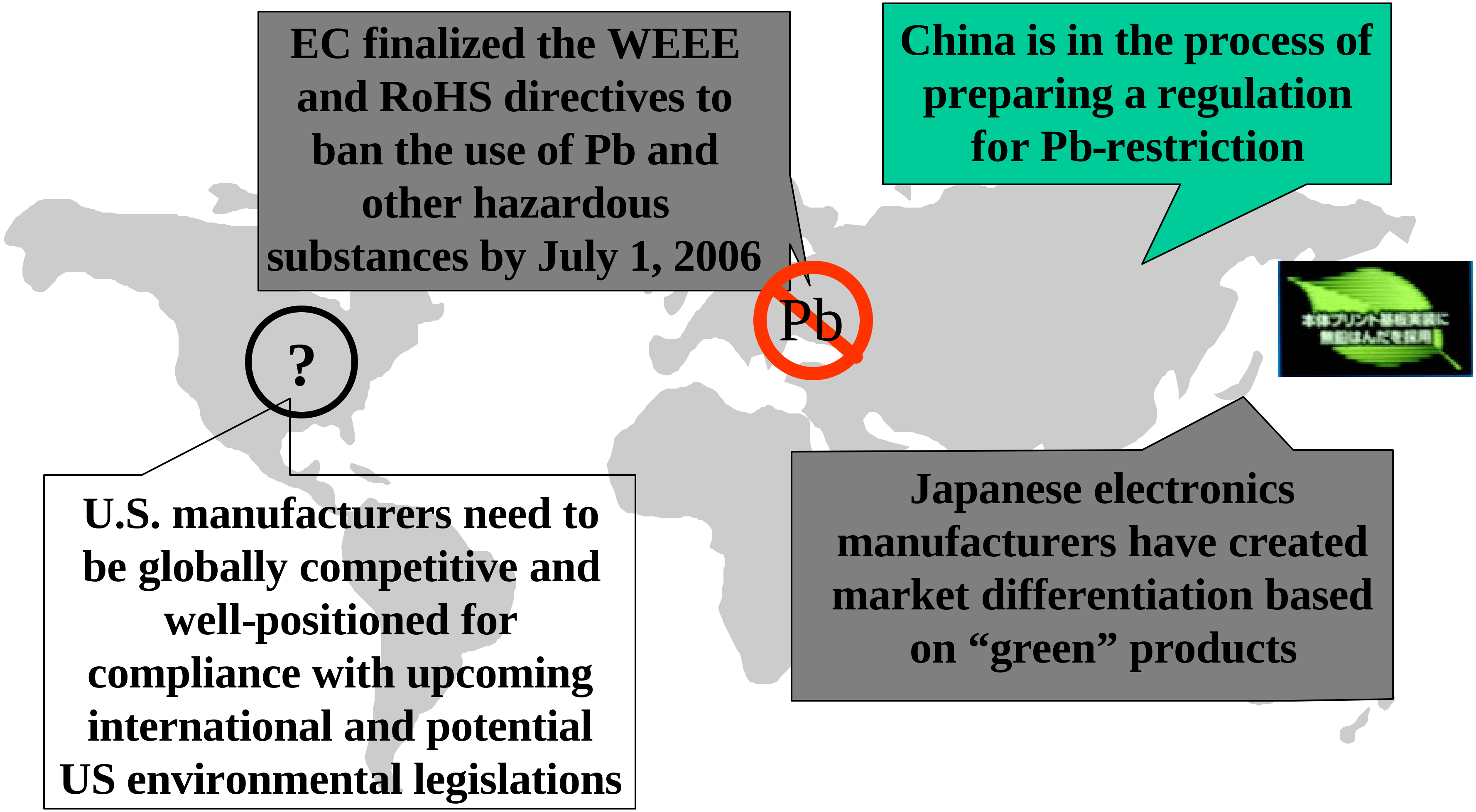
CALCE Pb-free Tasks: Draft Roadmap



Socio-Political Situation

- In most developed countries, environmental responsibility is driven by public opinion.
- Regulations:
  – US: low population density at 31 people/km^2. No ban on lead in electronics, but reporting requirements were made stricter for lead consumption.
  – Europe: high population density between 80 and 474 people/km^2. Lead in electronics, except mission-critical applications, will be banned in 2006.
  – Japan: high population density at 339 people/km^2. Japan endorsed take-back legislation for recycling of household electronic appliances and mandated reclamation of lead used by 2001. The Ministry of International Trade and Industry also set a lead reduction timeline.
- Pb in solder represents less than .5% total lead consumption.
- Removed lead from gasoline, removed lead from paint. Consumers want lead out, but at no “extra” cost.

Worldwide Pb-free Electronics Status



- Implementation is technologically achievable.
- Pb-free products are being developed and sold worldwide.

Current Status

In Europe, the WEEE/RoHS are scheduled to take effect July 1, 2006.

In Japan, legislation governing products containing Pb has already been established and Japanese electronics manufacturers have already responded.

In the United States, some U.S. states (e.g., CA, NJ) are exploring legislation to require recycling of electronics to reduce Pb in electronics.

- California Senate Bill (SB20),[1] "Electronic Waste Recycling Act of 2003," was approved in Sep. 2003. It is based on EU directives in terms of applicable electrical and electronic equipments and timeframe for Pb reduction.
- Executive Order 13148: Greening the Government Through Leadership in Environmental Management (April 2000) - Directs each Federal agency to implement formal environmental management systems and requires the reduction of use of selected toxic chemicals, hazardous substances and pollutants

In China, the Chinese Ministry of Information Industry (MII) is in the process of preparing a regulation, provisionally entitled "Management Methods for Pollution Prevention and Control in the Production of Electronic Information Products. [2]"

- The focus is to eliminate and ban six chemical substances, including Pb.
- As of now, the MII method hasn't included any exemptions.
- The scope of the draft has been expanded to include provisions concerning recycling, take-back, and material marking.

List of Restricted Hazardous Substances

With limited exemptions, the European legislation calls for removal of

- **Lead (Pb)**
- **Mercury**
- **Cadmium**
- **Hexavalent chromium**
- **Polybrominated biphenyls (PBB)**
- **Poly-brominated diphenyls ethers (PBDE)**

by July 1, 2006

“Maximum Allowable Concentration Value”

- The definition for ‘maximum allowable concentration value’ for restricted substances hasn’t been issued in current RoHS directive.
  - Concentration value, Pb= 0.1 wt% , which was defined in amendments of ELV directive* [4], is expected to be used in RoHS

- European Commission’s comments (Consultation team was launched in December 2003)
  - “It will *NOT* be a percentage of the final product but ***some measure of the materials used***, so it will be by weight per ***homogeneous material*** or by weight per applied material or some such variant [5].”
  - Pb can be measured at many levels. The homogeneous material could be solder or sub-assembly.

*ELV: End-of-Life Vehicle Directive

“Put on the Market”

The Pb-free requirement may be applied to:

- Equipment manufactured after June 30, 2006.
- Equipment leaving the manufacturer’s premises after June 30, 2006.
  - Factory premises or where manufacture takes place outside the single market, on entry to the EU market.
- Equipment on sale to the final user after June 30, 2006.
- The date on which any particular model was available for purchase by the end-user for the first time. ‘Date stamping’ was viewed as a possible loophole.
- Does not apply to spares for repair of products put on the market prior to June 30, 2006.

Update of European Union Directive (as of 2004)

- Pb-free exemptions are not yet finalized.
  - For instance, not all electronic equipments used in oil and gas electronics industry will be applicable to “Monitoring and control equipments,” which are exempt under RoHS.
    - Logging instrumentation *is covered* under Category 6 (Electrical and electronic tools).
    - Measurement while-drilling instrumentation is exempt.
    - Permanent gauges are exempt if permanently installed.
- Provisions are subject to change. The next review report of the existing EU directives is expected to be available in late 2004.
- Some exemptions are uncertain and may be excluded from the list even prior to the 2006 deadline if technologically feasible alternatives are found.

How to Ensure Compliance with Requirements?

- “Harmonized test methodologies” for evaluating the compliance for each restricted substance will be required. Test methodology should be simple, transparent, and applicable across Europe.

- An EC study on testing methodologies and their effectiveness is scheduled in April 2004.

- Each EU members will be set penalties for non-compliance. Penalties are expected to be effective, proportionate and dissuasive.

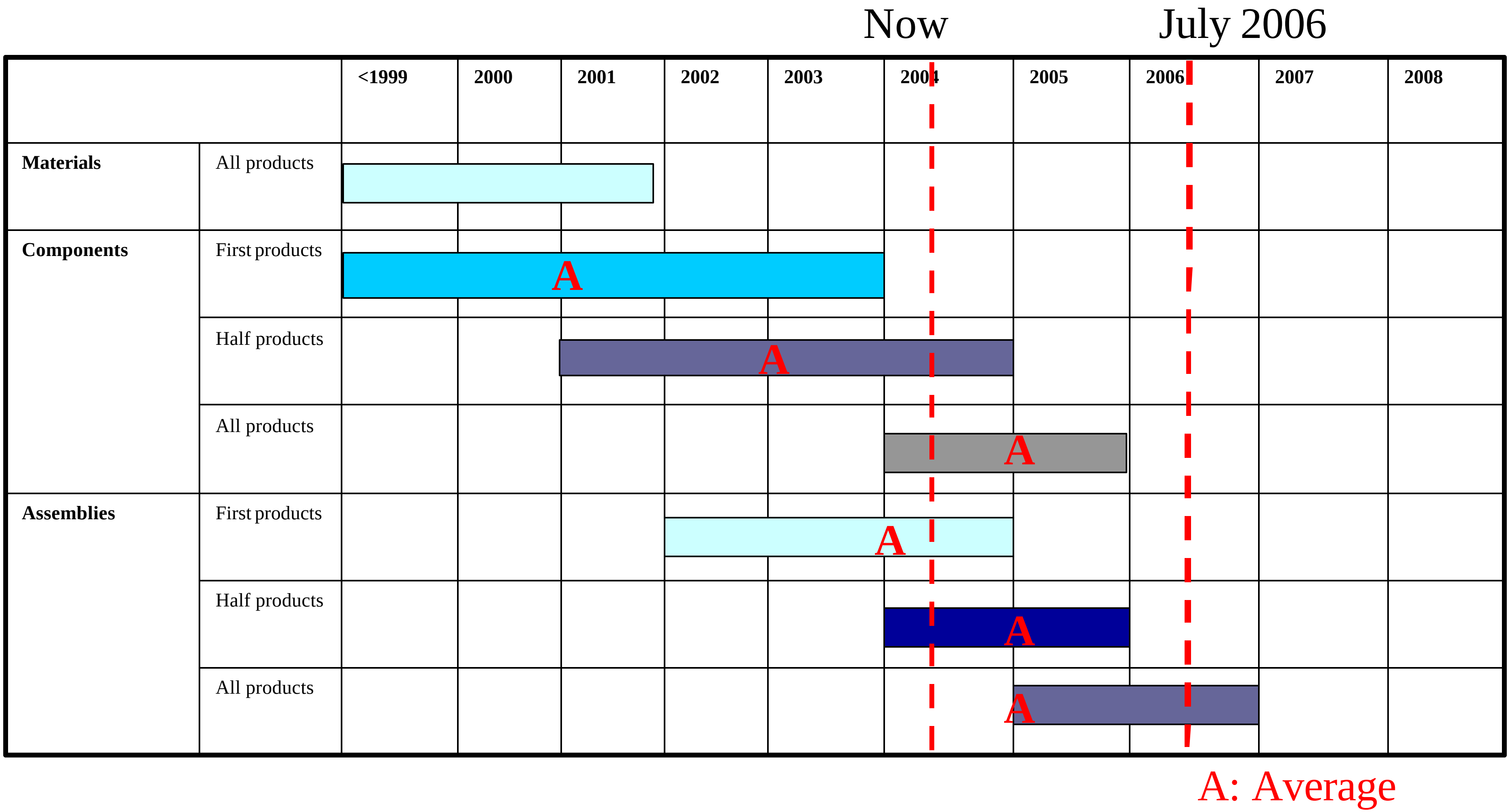
Electronics Markets

A large portion of the electronics industry is responding.

Electronic market sector	Market share 2004
Telecom	41 %
Computers	32 %
Consumer	15 %
Automotive	6 %
Industrial	5 %
Mil/Space	1%

While military electronic equipment is exempt, manufacturers of military systems will feel the impact of the Pb-free conversion process.

When will Pb-free be Completed ?
- Soldertech Survey -



Source: Soldertech at Tin Technology 2nd European Roadmap, February 2003.

Pb-free Implementation Timeframe
- Component Suppliers' Survey -

Pb-free implementation timeframe	CALCE survey
Phase-out by the end of 2004 or prior	47
Phase-out by the end of 2005	8
Phase-out by the end of 2006	7
Customer request	8
No plan	12
TBD	3
No reply	18
Total # of suppliers	104

CALCE survey contains replies from 79 semiconductor suppliers and 22 passive component suppliers.

Pb-free Implementation
- Contract Manufacturers' Readiness -

- Flextronics has a comprehensive Pb-free solder program and started volume-production with Pb-free solder since 1997. Flextronics has been several products in production in Asia, Europe, and the Americas.
- Solectron has started volume production of Pb-free in Taiwan in June 2003. This has expanded to their Pb-free volume production to six countries and strengthens the role in helping customers' transition to Pb-free assemblies.
- Sanmina has established production line of Pb-free board assemblies in three countries and the technology roll-out to its other Electronic Manufacturing Services (EMS) plants was completed by the end of 2003.
- Celestica is currently manufacturing four products using Pb-free solder, even though the finished systems still contain Pb-bearing components. Other Pb-free assemblies are in the preparation or prototype stage.
- Jabil started Pb-free volume production in China, Brazil, and Hungary in 2003.
  - Prototype Pb-free assembly for products, including printer, printer car, network adapter, and automotive keyless remote, has also been started in U.S.
  - Conversion guideline and risk assessment of Pb-free manufacturing were documented.

Examples of Pb-free Implementation/Products

- Matsushita Electric (Panasonic) has completed a switchover to Pb-free solder for PCBs in March 2003.
  - 12,000 models have been manufactured in 22 facilities in Japan and 79 overseas facilities of the Matsushita group.

- Approximately 80% of the Sony's products uses Pb-free solders.
  - Pb-free products include LCD TV, mobile phone, laptop PC, and digital camcorder. Conversion plan to be completed by the end of March 2005.

- Motorola shipped more than 10,000 units of mobile phones with the use of Pb-free solder paste to date.
  - More than 1.3 million units have been shipped with bromine-free PCBs to date.

- All of the Toshiba's new hard disk drives have already implemented Pb-free soldering and halogen-free PCB.

Which Solder Alloy Will Be Used?

Low temperature range (< 180°C)		Mid temperature range (180°C~200°C)		High temperature range (200°C~230°C)		Very high temperature range (>230°C)	
Composition	Melting range	Composition	Melting range	Composition	Melting range	Composition	Melting range
Sn-58Bi	138	Sn-9Zn	198.5	Sn-3.5Ag	221	Sn-5Sb	232~240
Sn-52In	118	Sn-8Zn-3Bi	189~199	Sn-2Ag	221~226	Sn-80Au	280
Sn-50In	118~125	Sn-20Bi-10In	143~193	Sn-0.7Cu	227	65Sn-25Ag-10Sb (Alloy J)	233
				Sn-3.5Ag-3Bi	206~213		
				Sn-7.5Bi-2Ag	207~212		
				Sn-3.8Ag-0.7Cu	217		
				Sn-2Ag-0.8Cu-0.5Sb	216~222		

Solder Alloys: Relative Cost

Solder Alloy	Bar	Paste
Sn-37Pb	1	1
Sn-3.5Ag	2.29	1.07
Sn-3Ag-2Bi	2.17	1.06
Sn-2.6Ag-0.8Cu-0.5Sb	2.06	1.05
Sn-3.4Ag-4.8Bi	2.26	1.06
Sn-3.5Ag-0.5Cu-1Zn	2.27	1.06
Sn-4.7Ag-1.7Cu	2.56	1.08
Sn-3.2Ag-0.7Cu	2.21	1.06
Sn-3.5Ag-1.3Cu	2.28	1.06
Sn-0.7Cu (wave solder)	1.50	

Bar form: Alloy composition sensitive (can fluctuate based on supply-demand)
Paste form: Not sensitive to alloy composition

Legal (Intellectual Property) Issues

- Prior to the 1990's, lead-free alloys were largely patented as plumbing or brazing materials
- U.S. companies began patenting lead-free solders for electronic uses around the time of the Reid Bill in the early 1990's
- European companies became active during the WEEE and ROHS initiatives
- The bulk of Japanese patents arose with the introduction of the household appliance take-back law of the late 1990's

Sn-Ag-Cu Patent Licensing

Patent #, Title, and Assignee	Claim Covers	Composition (wt%)			
		Sn	Ag	Cu	Others
JP3027441: High-Temperature Solder by Senju Metal /Matsushita Electric	**Solder Alloy**	Balance	<= 5.0	0.5~ 3.0	Cover: 3.0, Optional: Sb<=5
US5527628: Pb-free Sn-Ag-Cu Ternary Eutectic Solder by Iowa State University Research Foundation (ISURF)/Sandia Corp.	**1)Solder Alloy** **2)Solder Joint** **3)Soldering Process** Consisting of listed composition	93.6	4.7	1.7	-
		Balance (>89)	3.5~ 7.7	1.0~ 4.0	Optionally, Bi: <10,
		Balance (>89)	3.5~ 7.7	1.0~ 4.0	One additional element (<1), from Si, Sb, Zn, Mg, Ca, a rare earth element, or a misch metal

Note: Listed patents are in force as of 2004. Detailed information is available in CALCE Pb-free Patent Finder Software

CASTIN® Alloy Licensing

Patent #, Title, and Assignee	Claim Covers	Composition (wt%)			
		Sn	Ag	Cu	Others
US5352407* : Lead-free Bismuth free Tin Alloy Solder Composition by AIM	**Solder Alloy in all possible forms** **Solder joints in assembly**	93~98	1.5~3.5	0.2~2.0	Sb: 0.2~2.0
JP102257900: Lead-free Alloy Soldering by Samsung Electron	**Solder Alloy**	Balance	0.1~ 5.0	0.1~ 5.5	Bi: 0.1~ 5.0 Sb: 0.1~ 3.0 P: 0.001~ 0.01 Ge: 0.01~ 0.1
US5980822: Leadless Alloy for Soldering by Samsung	**Solder Alloy**	81.4~ 99.6	0.1~ 5.0	0.1~ 5.5	P: 0.001~ 0.01 Bi: 0.1~ 5.0 Sb: 0.1~ 3.0 Ge: 0.01~ 0.1

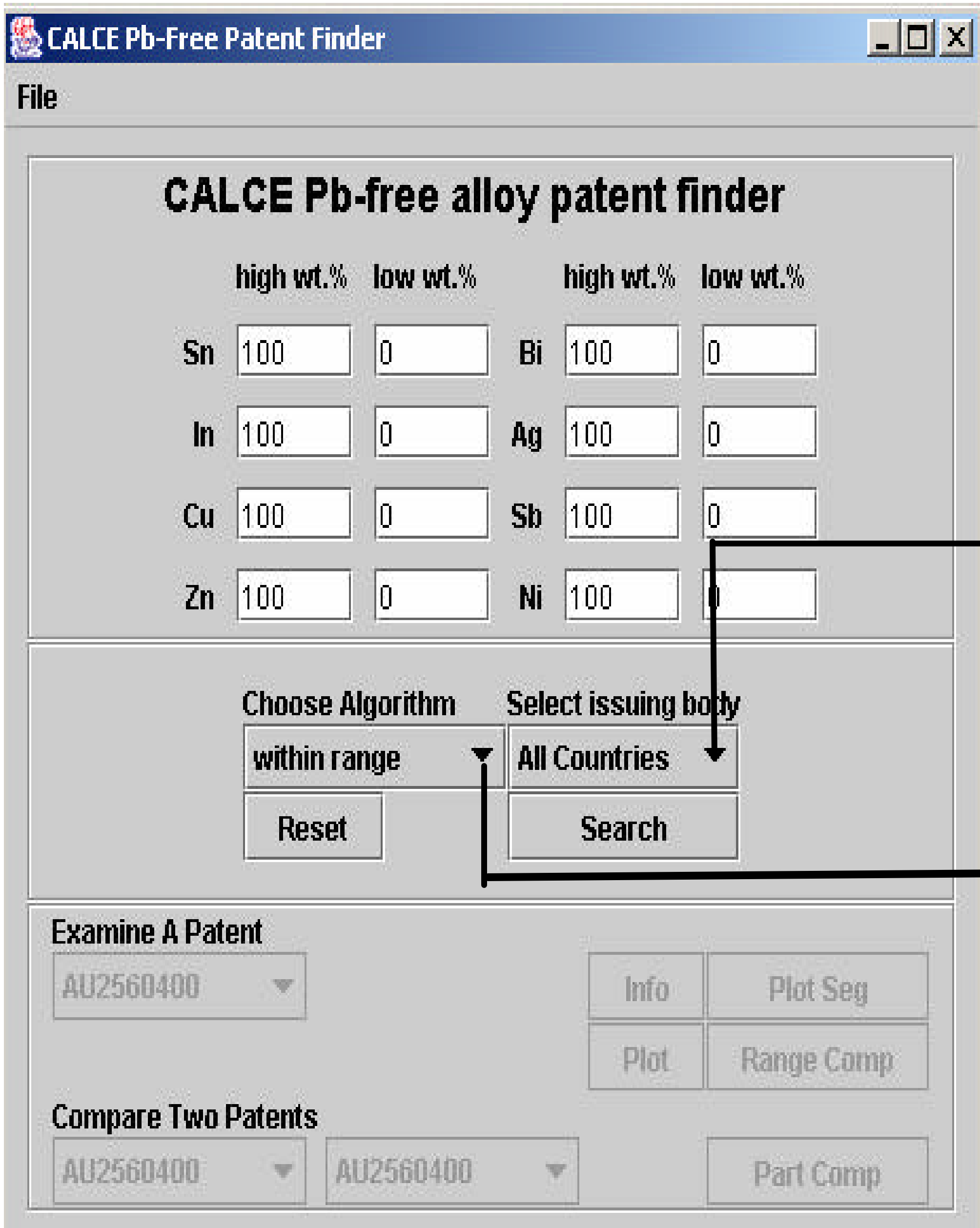
Note: Listed patents are in force as of 2004.

- AIM supplies the *CASTIN® alloy (Sn-2.5Ag-0.7Cu-0.5Sb) based on their patent, US5352407 . This AIM patent has been sublicensed to 10 solder suppliers.
- AIM also states that it does not license JP10225790 and US5980822 held by Samsung since they are similar to the CASTIN® alloy [11][12].

Coverage of License Agreement

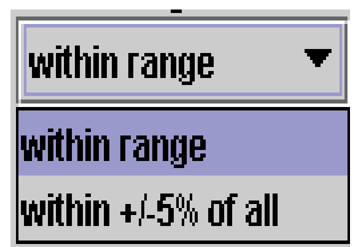
- Board assembler in US may have a risk of procuring Sn-3.5Ag-0.7Cu, Sn-3.8Ag-0.7Cu, and Sn-4.0Ag-0.5Cu from solder suppliers (worldwide), who don't have ISURF patent. The finished joint might fall under this patent if copper is picked up during processing.
  - Indium Corp. claims that Sn-4.0Ag-0.5Cu alloy is patent-free due to Dr. Petzow's prior art regarding eutectic Sn-Ag-Cu composition [13][14].
- Only holding the Senju patent doesn't not necessarily cover the board assemblers worldwide (except for Japan), if the composition falls under a different patent existing in the country where the board is assembled.
- In case bismuth containing component finishes are in use with CASTIN ® solder, there is a risk of infringing the Samsung patents.

CALCE Pb-free Alloy Patent Finder



- See if and where an alloy is patented.
- Compare patent alloys

Restrict search by country



Choice of search methods

* **Patent Finder 1.0**, versions for win95/98/Me and win2000/NT/XP is available for download at http://www.calce.umd.edu/lead-free/

Challenges-General Pb-free Electronics

- No exact drop-in replacement for Pb-based materials/components.
- Solder alloy selection may vary based on application.
- Replacements likely to see wide adoption include
  - SnAgCu – Reflow
  - SnCu – Wave
  - SnAgCu or SnAg - Rework
- Changes in component finishes, die attach materials, solders joints
  - Higher processing temperatures (pop-corning, board warpage, delamination)
  - Compatibility with Pb-free processing (mixed technology)
  - Indirect failure mechanisms (tin whiskers, creep corrosion)
  - Solder joint reliability (durability, intermetallic growth)

Technical Issues

Many of the technical issues have been solved, and lead-free products are being developed and sold. Some remaining concerns are with:

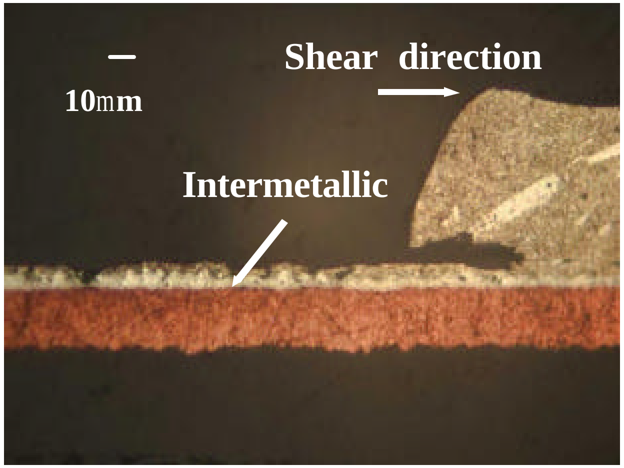
- Mixed solder technologies (cross contamination)
- Rework
- Secondary failure mechanisms (tin and zinc whiskers)
- Reliability test standards
- Very long term reliability, i.e. >8 years

Board-level Issues

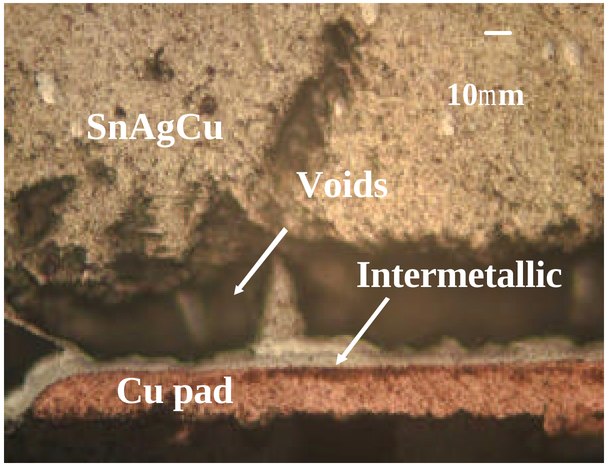
- Pb is present as an etch resist and as a plating -Hot Air Solder Level (HASL).
- Likely switch to pure tin for etch resist.
- Pb-free PCB surface finishes, replacements for HASL (cost: 1.0)
  - Organic solderability preservative (OSP) (cost: 1.2)
  - Electroless Nickel/Immersion Gold (ENIG) (cost: 4.0)
  - Immersion tin (Sn) (cost: 1.1)
  - Immersion silver (Ag) (cost: 1.1)
- Boards can be susceptible to damage in a high-temperature Pb-free manufacturing process (Tg, delamination, PTH, solder mask, inks, markings, adhesives).
  - One-third of the U.S. industry has switched to higher Tg materials 170°C vs 140°C for a greater margin in rework. With single-sided boards, FR-2 can be soldered Pb-free with care.

Sn-3.8Ag-0.7Cu and HASL[T] Boards

A CALCE Study showed a weakened interface on HASL boards, which were soldered with Sn-3.8Ag-0.7Cu. After high temperature aging, the failure mode in shear testing shifted from the bulk solder to the interface (left) and over time, void bands were observed (right).



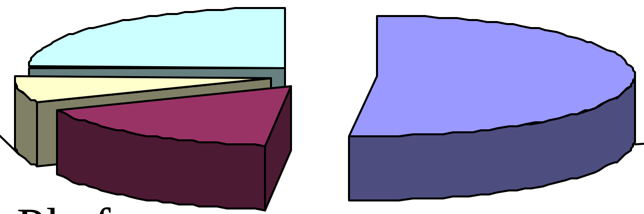
Shear testing failure at the interface between SnAgCu and intermetallic on HASL[T] after aging 100 hours at $0.9T_m$ (168°C)



Voids observed at the interface between SnAgCu and intermetallic after 1000 hours aging at $0.9T_m$

The most probable cause is tin depletion at the interface as tin from the HASL coating migrates toward the pad and forms intermetallics with copper, creating a weaker localized Pb rich region in the coating.

Component Manufacturers' Survey Update
- Pb-free Component Finishes -



Spread sheet is available for review at http://www.calce.umd.edu/leadfree/members/partsuppliers.xls

- Since October 2003, an additional 10% of companies selected pure tin (matte) as a Pb-free 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.

Tin-based Component Finishes
- Tin Whisker Formation -

- Tin is an inexpensive finish and a replacement for Sn-Pb finish.
- Tin whiskers can grow to lengths of ~10 mm, but 1mm is more common. (lead spacing as small as 50 μm)
- Tin whisker width can range from ~0.03 μm to~3 μm.

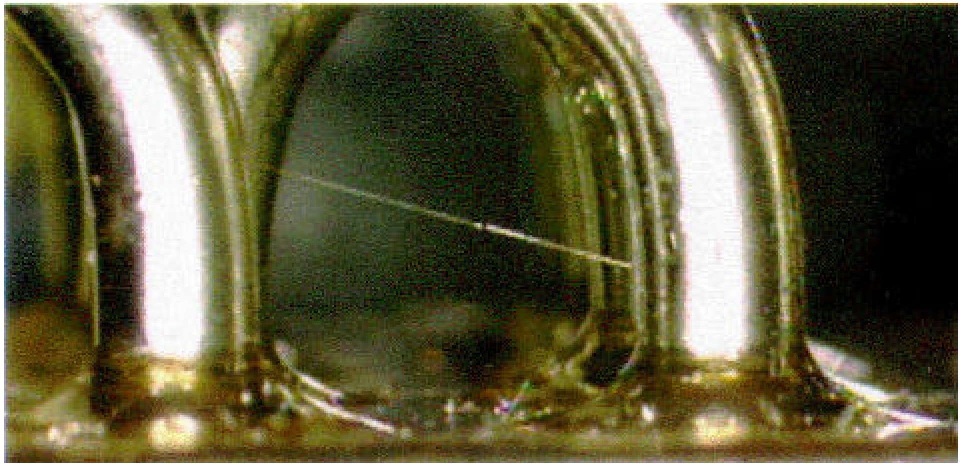


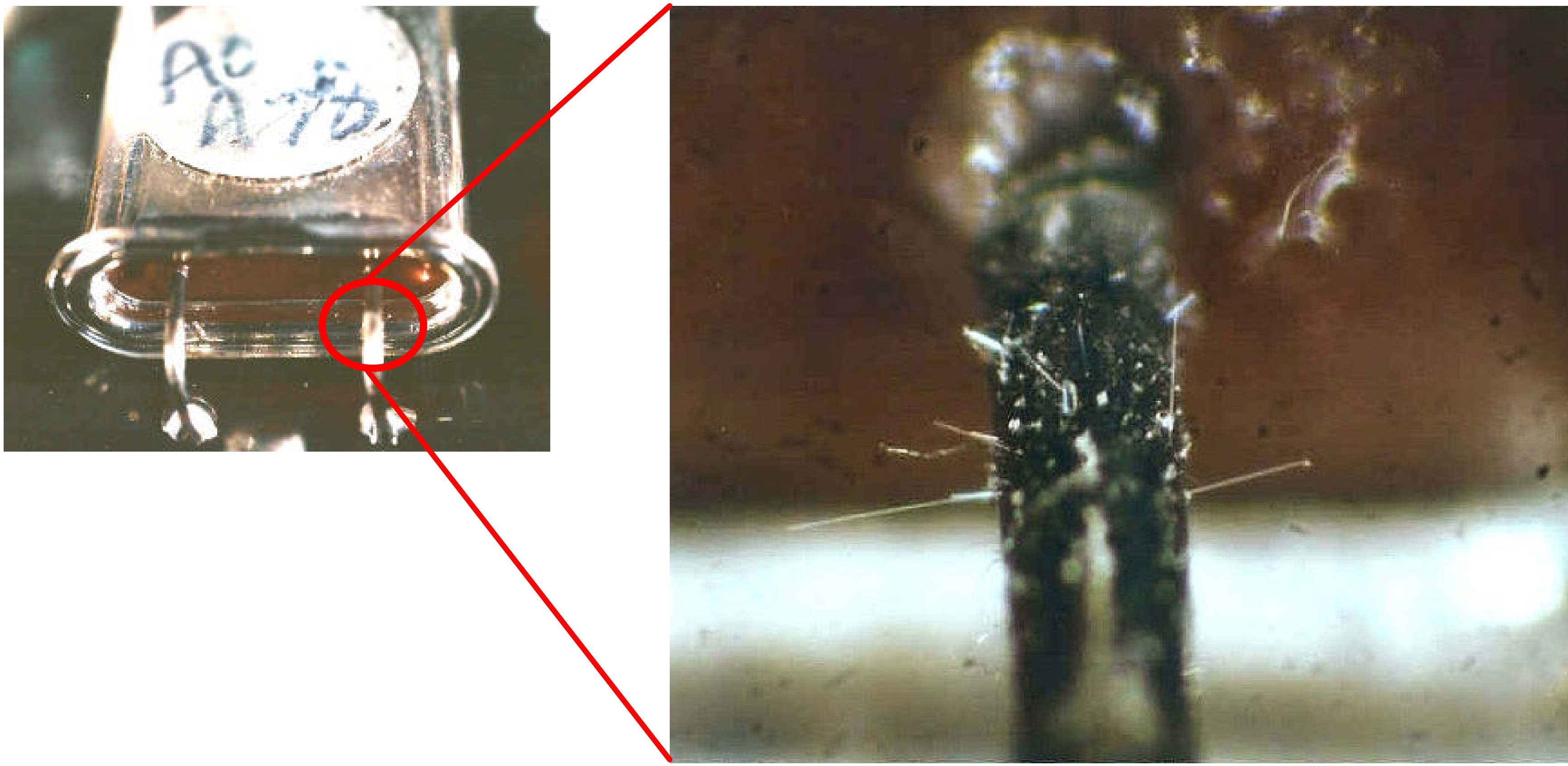
Photo of "pure tin" plated hook terminals of a MIL-R-6106 style relay with LDC 8913 from NASA GSFC stock. [Photo courtesy of Goddard Space Flight Center]

- Whisker density can be up to ~500/mm^2.
- In air, fusing currents are 10~50 mA.
- In vacuum, fusing a whisker may result in a metal vapor arc.
- Whiskers have been observed on brand new product as well as on 20-year old product.
- Latency times can be hours or decades. Growth mechanism(s) not completely understood
- Alloying (Pb, Bi, Cu) does not prevent whiskering formation, but they control the amount and rate.

Restrictions on Component Finishes

- Boeing Satellite System (BSS) prohibits the use of pure tin in the internal and external surface finish of electronic hardware. [30] To meet this criteria, they announced a supplier control policy, which excludes the manufactures providing pure tin finish as an option. BSS instituted X-ray Fluorescence (XRF), which can detect the elemental composition and thickness of plating, for all lots at in-coming inspection, as well as all terminals in inventory. [30]
- Raytheon Systems Ltd. bans the use of pure unalloyed tin on any material supplied to them. [31]
- NASA Electronic Parts and Packaging Program prohibits pure tin plating as a final finish on EEE parts and associated hardware. [32]
- IBM's acceptable pure tin finishes for server and storage systems are limited to [33]
  - Matte tin over 1 µm minimum Ni
  - Matte tin over a Cu lead/leadframe annealed at 150°C for a minimum of one hour within 2 weeks of the tin plating
  - Fused, reflowed or hot dip

Example of Whisker Growth and Failure



Electrical failure traced to tin whisker growth. Lead wire was finished with bright tin plate and dipped in SnPb solder within 1.27 mm of case.

CALCE Tin Whisker Team Studies (Roadmap)

2002

Tin Whisker Alert/Risks/Experiences

CALCE Whisker Team

2003

Tin Whisker Mitigation Guide

Solder Dip

Heat treatments

Conformal 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

2004

TMTI Project
-Solder Dipping-

Study on effect of bending, solder dipping, and current

-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 pure-tin plated components

Update of tin whisker mitigation guide

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

Part Number Changes due to Pb-free Transition

Astec Survey Result [3]		CALCE Survey Result
	Part Number Changes	
59	No Change	15
40	Changed	85
1	No Reply	0

- Typically, each component manufacturer has their own suffix number, added to the existing part numbers to distinguish the Pb-free parts. The selection of suffix is not consistent across the industry.
- Another method to identify Pb-free parts is data code transition, but it is then necessary to track Product Change Notices (PCN). Due to a limited area for designation, passive component suppliers appear to prefer distinguishing Pb-free parts from Sn-Pb parts by using data code.
- In some cases, traceability of components is not sufficient. Mistaken delivery of Sn-Pb components instead of Pb-free components can occur.

IPC/JEDEC Draft Standard for Pb-free Marking

- IPC/JEDEC released a draft standard on the “Marking, Symbols and Labels for Identification of Assemblies, Components and Devices,” including Pb-free materials in February 2004. [14]

- Labeling categories defined in a standard
  - Types of Pb-free materials (solder finish)
  - Maximum safe operating temperature during assembly
  - Type of base resin due to halogen-free requirement (optional)
  - Type of conformal coating (optional)
- Applicable devices
  - All electronic components including passives, connectors, solid-state components and other devices which use solder to attach the component to the board or assembly

Labeling for Pb-free 2nd Level Interconnect	
e1	Sn-Ag-Cu
e2	Other Sn alloys (i.e., Sn-Cu, Sn-Ag, Sn-Ag-Cu-X) (No Bi or Zn)
e3	Sn
e4	Pre-plated (i.e., Ag, Au, Ni/Pd, Ni/Pd/Au)
e5	Sn-Zn, Sn-Zn-X (No Bi)
e6	Contains Bi
e0, e7, e8, e9 symbols are unassigned categories at this time	
Sn-Pb soldered boards and components shall have no assigned label	
HF	Base resin and solder mask used making the bare board is halogen-free

Moisture Sensitivity Levels (J-STD-020B)

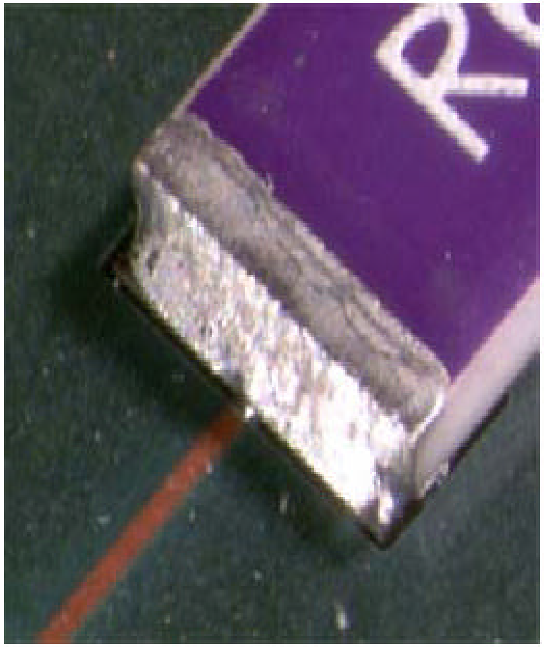
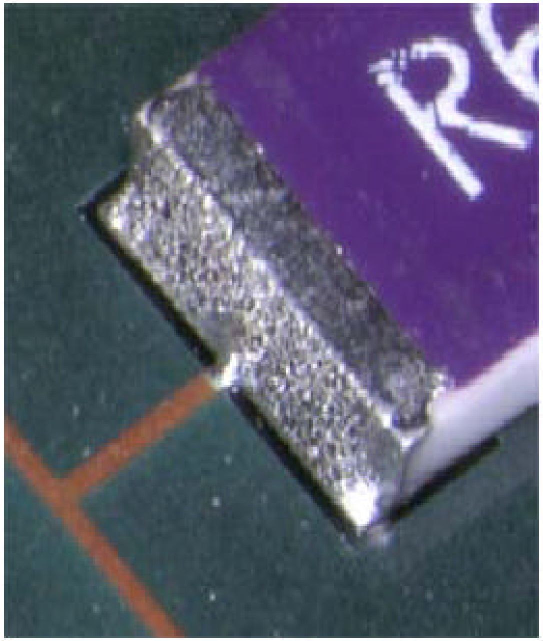
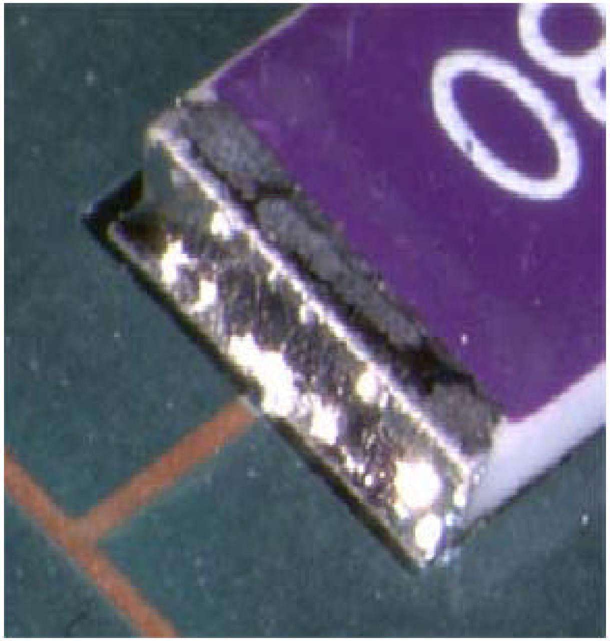
The difference between 240℃ and 260℃
(For a common molding compound)

Reflow temperature (℃)	240	260
Generated (sat) vapor pressure (kg/cm^2)	33	46
Dimensional change (%)	0.30	0.41
Flexural strength (kgf/mm^2)	2.2	2.0
Flexural modulus (kgf/mm^2)	70	66
Adhesion to Alloy-42 (kgf/mm^2)	19.6	19.2
Adhesion to Cu (kgf/mm^2)	20.0	19.0

Re-qualification may be necessary because increased reflow temperature results in:

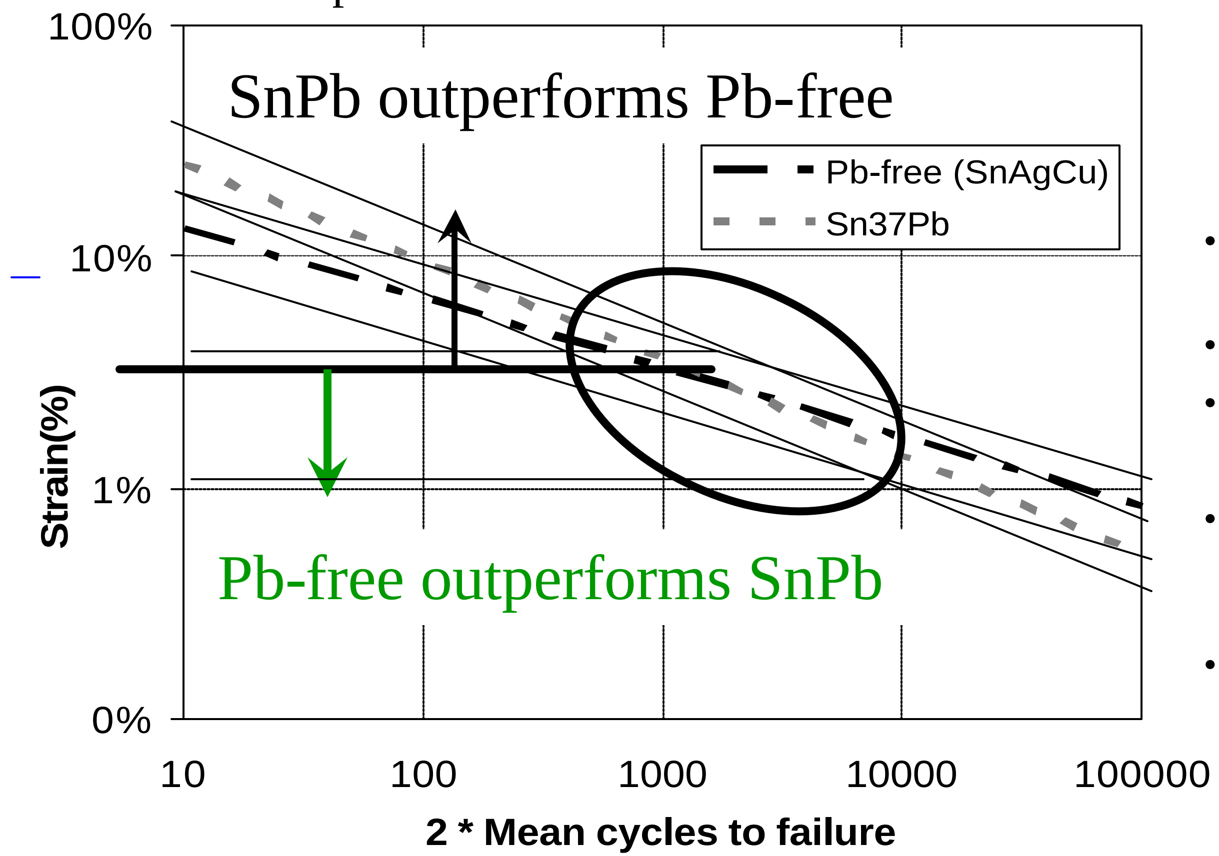
1. Significantly larger stresses
2. Decrease in compound strength and adhesion

Visual Appearance of Solder Joints

Shiny joint with Good wetting	Dull joint	Shiny joint with reduced wetting
		
Sn-Pb finish with Sn-Pb paste	Sn-Pb finish with Pb-free paste	Pure tin finish with Pb-free paste

Durability of Solder under a Temperature Cycle

Experimental data, collected by CALCE to develop a preliminary rapid assessment model for Sn4.0-3.8Ag0.7Cu solder and released in the calcePWA software, reveals a limited range to thermal test conditions. Data consists mostly of standard test conditions (i.e. -40 to 125^oC, -55 to 125^oC, and 0 to 100^oC) with little variation in dwell or mean temperature.

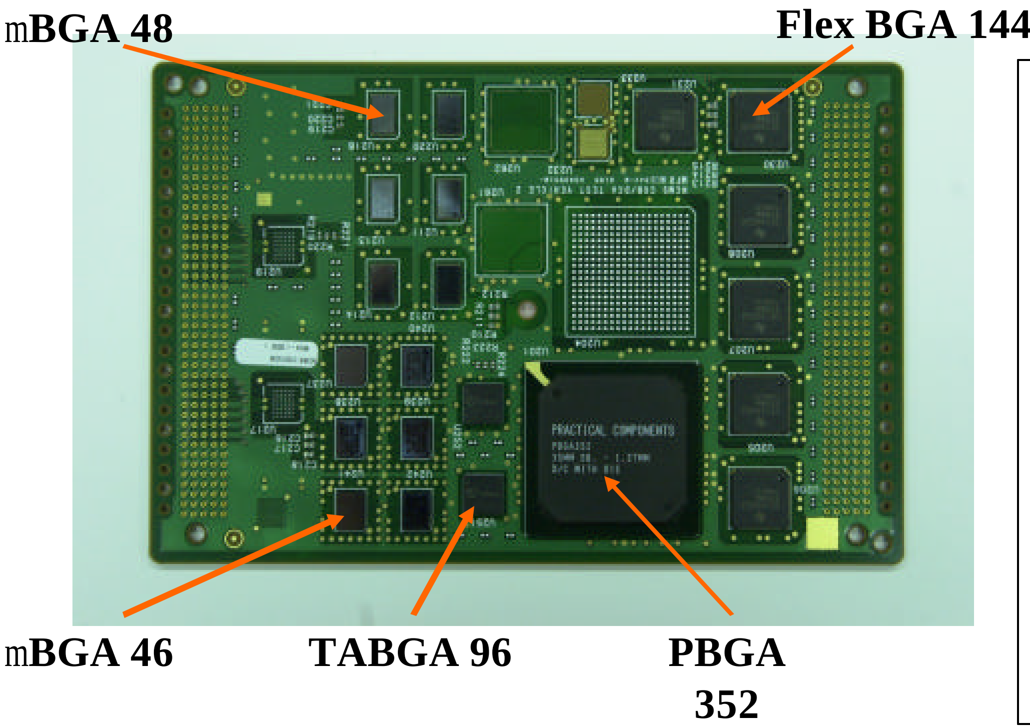


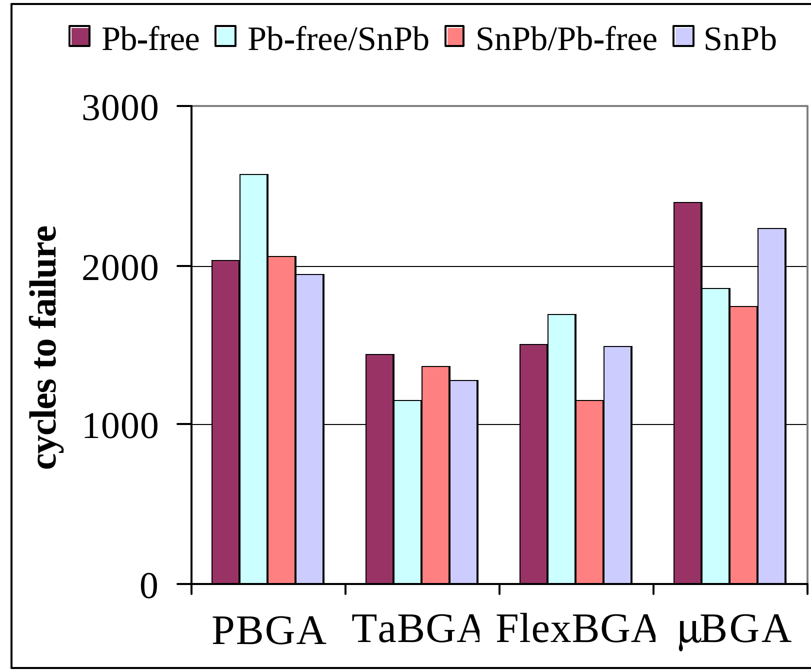
$$N_f = \frac{1}{2}\left(\frac{\Delta g}{2e_f}\right)^{\frac{1}{c}}$$

- N_f : mean number of cycles to failure
- $\Delta\gamma_p$: inelastic strain range
- ε_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)

Thermal Cycling Results





The effect of Pb contamination in mixed technologies

Some observations from tests

- Some early failures which appeared to be anomalies occurred in mixed systems.

Action Items for Pb-free Implementation

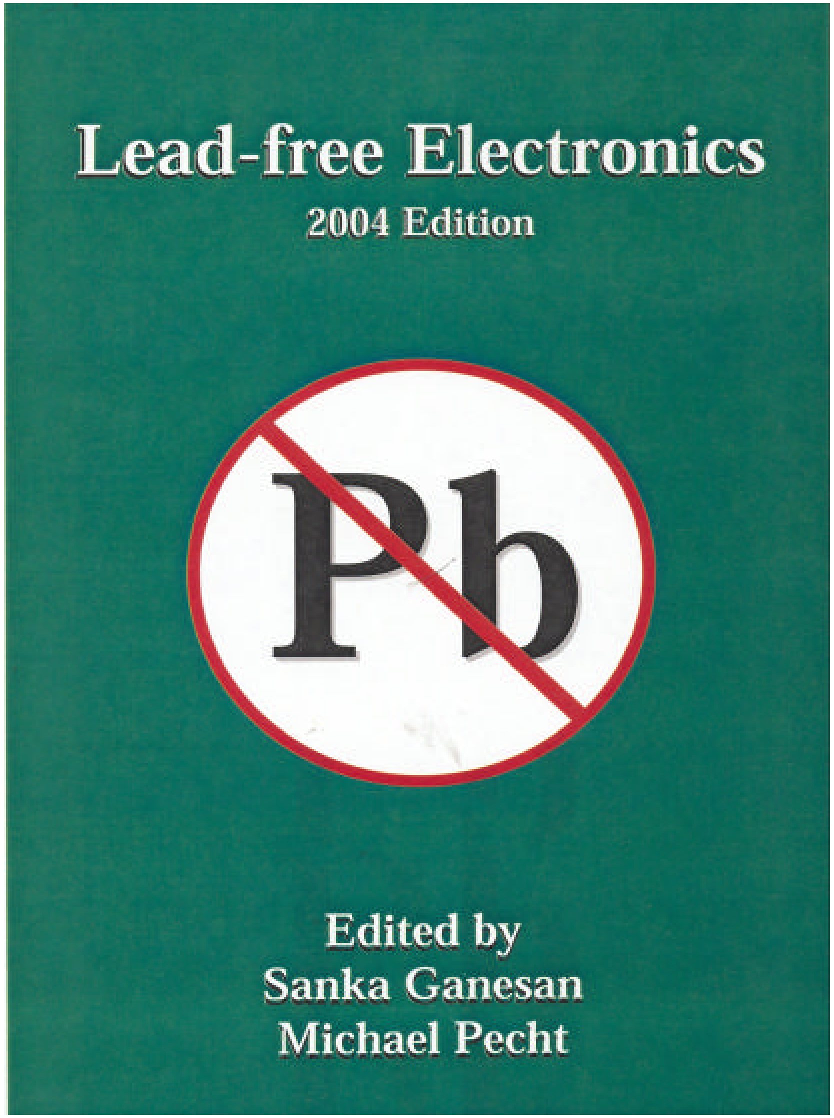
1. Determine an approach to regularly monitor the release/revisions of legislative/regulative requirements (worldwide) and required implementation deadlines
2. Determine materials/components in final product, which may contain RoHS restricted substances. For instance, Pb in tinned cables, plastic additives, PVC wiring. Brominated flame retardants in the polymers for plastics housing, connectors and switches.
3. Obtain necessary information from component suppliers and assembly facilities (e.g., material selection, allowable reflow temperature, and Moisture Sensitivity Level). Identify the finishes of components (in case of every package type) and PCBs.
4. Determine a list of Pb-free materials/components, based on availability and design requirements
5. Determine a timeline for your product release with consideration of material/component availability and qualification schedule

PVC: Polyvinyl chloride, RoHS: Restriction of usage of Hazardous Substances in electrical and electronic products

Action Items for Pb-free Implementation (cont.)

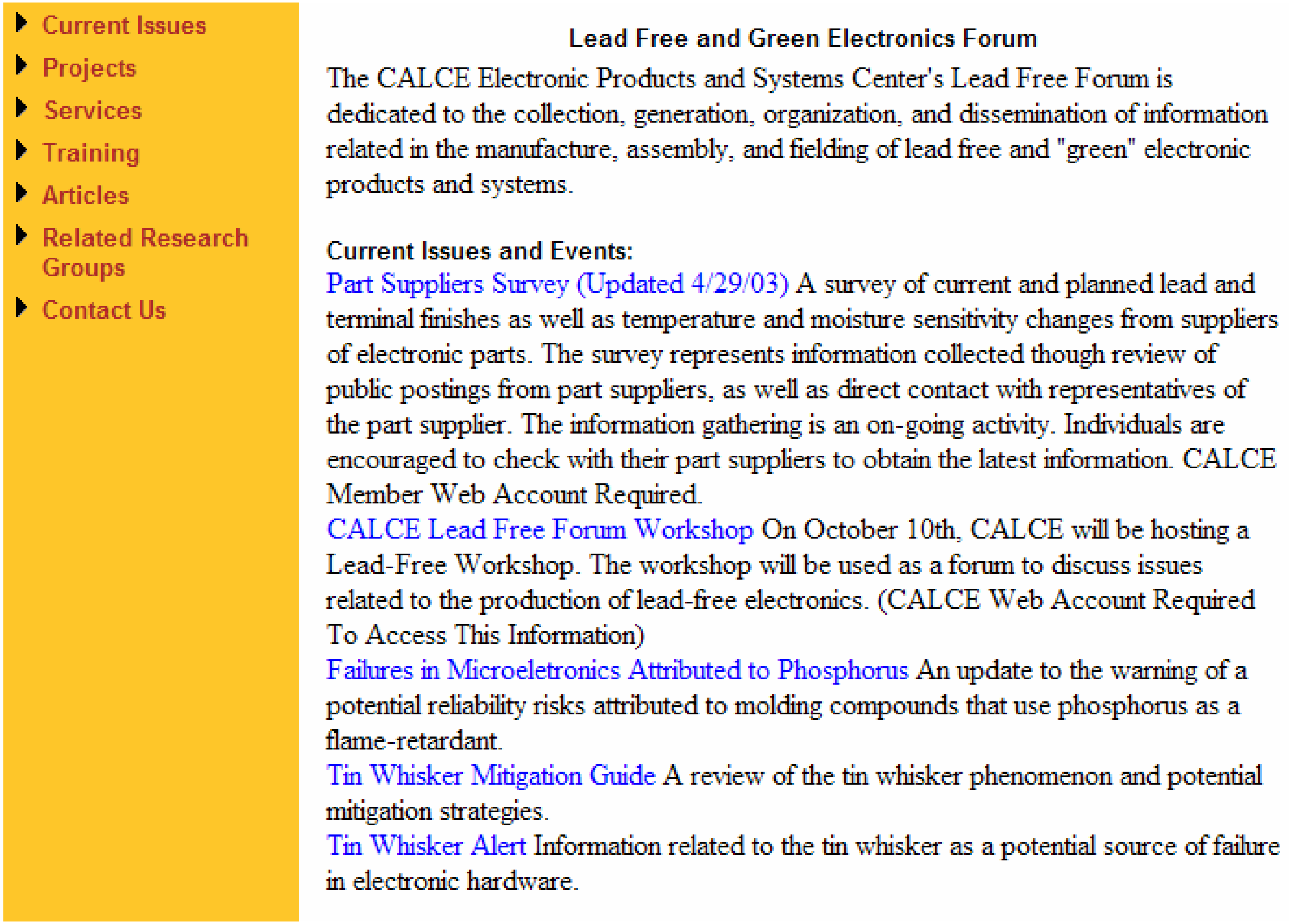
6. Determine if you want to place any restrictions on components, based on their finishes. Determine additional processes for component finishes, if necessary, e.g., re-plate, solder-dip, and heat treatment. Also determine any modifications necessary for assembly equipments due to changes in materials/process. For example, removal of dross built-up in the solder pot may be required more often than the case of Sn-Pb solders
7. Determine the licensing agreements of your Pb-free solder suppliers
8. Identify the end-of-life of Sn-Pb materials/components offerings, which may be required in some applications
9. Identify new/revised standards applicable to Pb-free assembly process/test/inspection. For example, current automated optical inspection might not work due to differences in surface and wetting characteristics
10. Determine qualification and reliability tests
11. Determine an approach for Pb-free rework/repair of components and identify any modifications needed on existing tools for rework/repair

Pb-Free Resources



Book may be order by sending a request to books@calce.umd.edu

CALCE Lead Free Forum Web Site



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