SPRING/SUMMER 2007

calceNEWS

CENTER FOR ADVANCED LIFE CYCLE ENGINEERING (CALCE)
WWW.CALCE.UMD.EDU, TEL: 301-405-5323

INSIDE

Mission Statement

To develop scientifically based innovative methodologies that decrease life-cycle risks for the next generation of electronic products and systems, and to provide an educational and technology transfer infrastructure for their rapid dissemination and utilization.

……

Message from the Director

The year 2006 marked some dramatic changes in the electronics industry. With the implementation of the RoHS legislation in July, lead-free products started to be shipped to the European Union. However, of the companies that supply parts, only about 20% provide letters of RoHS compliance, only 10% provide materials declarations, and 10% say that that they are compliant but are in fact not. Furthermore, roughly 40% of the part numbers of parts that have been converted to RoHS have not been changed.

Some companies have not transitioned to RoHS-compliant products, because their products are currently exempt and because they (and in some cases their customers) realize that there are significant risks. Making RoHS-compliant products is not simply a matter of picking a few new replacement materials; it involves significant changes in how business is conducted. In other words, many of the practices that were traditionally conducted will no longer work in this new RoHS paradigm. This is especially true of the qualification tests.

The cost to produce products that are exempt will greatly increase. For example, the price of lead-based BGA parts increased over 30% in 2006. In addition, it is becoming the norm to impose purchase limitations (not cancellable, non-returnable, 30-week advance purchase, minimum numbers of parts) on "non-RoHS compliant" components. Thus it will not only be difficult to continue developing new lead-based products, but it will also become harder to support legacy products.

Another concern that has arisen as companies change their parts to RoHS compliance is that they have made other changes to the production materials and processes. These changes must be carefully evaluated. CALCE is aware of significant reliability - cost problems that have arisen because product change notices (PCNs) were either not assessed in terms of reliability or were not obtained at all. This applies not only to high priced parts, but also to low-cost resistors and capacitors. In fact, CALCE has seen a dramatic increase in the percentage of capacitor failures throughout the industry. The solder joint problem is clearly being solved (see CALCE long-term, lead-free solder efforts), but the parts are coming back as key reliability factors.

CALCE is continuing to assist companies that are attempting to maintain lead-free electronics as well as those that have transitioned to lead-free through CALCE Consortia activities and the CALCE Test Services and Failure Analysis Laboratory. For those maintaining lead-based electronics, issues related to mixed solder are being examined in the Long-term Reliability of Mixed (Pb-free parts/SnPb paste) Soldered Assembly study. This study is examining intermetallic growth and vibration- and temperature-cycling durability of mixed solder assemblies.

In the CALCE EPS Consortium, the package and assembly reliability of reprocessed (BGA reballing/solder dipping) parts, as well as board level rework, are being studied. In addition, CALCE is examining the performance of lead-free assemblies under contamination environments in the Long-term Reliability of Lead-free Assemblies in Contaminating and Corroding Environments study. Finally, CALCE is continuing to provide companies with design review, reliability assessment, material characterization, and failure analysis support through the CALCE Test Services and Failure Analysis Laboratory.

I invite you to become an active participant with CALCE and make use of our expertise and resources. If you are interested in our research and analysis, please visit us in person in October (see p. 2) or visit us on the web at *www.calce.umd.edu*. I look forward to working together with you.

Michael Pecht
CALCE Director and George Dieter Chair Professor

ISO 9001 Certified

DEPARTMENT OF MECHANICAL ENGINEERING
A. JAMES CLARK SCHOOL OF ENGINEERING

CALCE Spring Technical Review Meeting

The CALCE EPS Consortium provides a forum for defining fundamental research needs, conducting research, and sharing research findings among participating organizations. The research focus for the CALCE EPS Consortium includes risk assessment, mitigation, and management of electronic products and systems.

CALCE EPSC will hold technical review and project planning meetings **March 20-22, 2007**, at the University of Maryland. Contact Joan Lee (*joanyuan@calce.umd.edu*) for details or go to *www.calce.umd.edu* and click on *Upcoming Events*.

The following projects will be presented at the meeting:

- Effect of Temperature Cycle on the Durability Pb-free Interconnects (Sn96.5Ag3.0Cu0.5 and SnCuNi)
- Reliability of Pb-free and Reballed PBGAs in SnPb Assembly Process
- Effect of Long Dwell on Thermal Cycling Fatigue Damage for Pb-Free Solders
- Accelerated Qualification of SAC Assembly: Combined Temperature Cycling and Vibration
- Solder Joint Reliability of Solder Dipped (SAC/SnPb) Leaded SMT Packages in a SnPb Assembly Process
- Solder Joint Reliability of Reworked/Repaired SMT Assemblies
- Tin Whisker Growth and Risk Assessment Update
- Characterization of Tin Pest Formation in Pb-free Solder Joints
- Characterization of PCB Laminate Materials Properties after Lead-free Reflow Cycles
- Effect of Solder Fillet and Composition Factors on MLCC Cracking
- Reliability of Large Electrolytic Capacitors
- Electronic Component Failure Categorization under Gun Launched High G Loading
- Advanced Thermo-mechanical Testing of Fine Pitch Flex Assemblies
- Failure Mechanism and Reliability Assessment for System-in-Package Technologies
- Durability Assessment of an Advanced Power Electronics Thermal Cooler
- Detection of Interconnect Degradation Using Impedance Analysis
- Fundamental Understanding MEMs Structures Subjected to High Shock Loads
- Characterization of Moisture-induced Degradation of Polymer Interface
- Measurement of Effective Chemical Shrinkage of Polymeric Materials
- Hygroscopic Characterization of Polymer Materials beyond Glass Transition Temperature
- Solder Assessment for SiC Device Attachment
- Life Cycle Supply Chain Data Mining and Interpretation
- Counterfeit Electronic Parts
- Implementation Cost of Lead-free and Tin Whisker Mitigation Performance Standards
- Life Cycle Cost of Component Management: Understanding the Component Reuse Business Case
- Field Programmable Gate Arrays (FPGA) Antifuse Aging during Storage
- Thermal Performance and Reliability of Thermal Interface Materials
- Enhanced Conventional Thermal Solutions for LED Packages
- Modeling Mechanical Torsion of PWA in calcePWA
- Probabilistic PoF Modeling: Effect of Number of I/O on Thermal Cycling Durability Predictions
- Model-based Design Guidelines for Shock and Drop Loading
- Shock–*calcePWA* Shock Model Improvement

Electronic Products and Systems Consortium Members

Arbitron
Argon ST
BAE SYSTEMS
Boeing Co.
Daimler Chrysler, Germany
DBD, Germany
Defense Logistics Agency
Dell Computer Corp.
EADS CCR, France
EMC Corp.
Ericsson AB, Sweden
Faraday Technologies
GE (GE Medical) Corp.
General Dynamics AIS
Goodrich Engine Control Sys., UK
Grundfos, Denmark
Hamilton Sundstrand
Honeywell
Instit. Nokia de Tecnologia, Brazil
Lockheed Martin Company
Mercury Computer Systems
Motorola
NASA
NAVAIR
Naval Surface Warfare Center
Nokia Research Center, Finland
Northrop Grumman Corp., IL & MD
Philips Electronics, The Netherlands
Qualmark
Raytheon Co.
ReliaSoft Corporation
Research in Motion, Ltd., Canada
Rockwell Collins, Inc.
Rolls-Royce plc, Derby, UK
SAIT, Korea
Samsung Electro-Mechanics Co., Ltd., Suwon City, Korea
Samsung Memory Division, Korea
Samsung Techwin Co., Ltd., Korea
Sandia National Labs.
Schlumberger Oil Field Services
Seagate Technology Inc.
Siemens AG, Germany
Smiths Aerospace
Sun Microsystems (StorageTek)
Tessera
Toshiba, Japan
TRW Automotive, UK
U.S. AMSAA
U.S. Army Research Lab.
UK Ministry of Defence
Whirlpool Corp.

For more information about the CALCE Electronic Products and Systems Consortium, contact Dr. Michael Osterman at *osterman@calce.umd.edu*, tel. 301-405-8023.

CALCE PHM Consortium Members

Army AMSAA
Army ARL
Army PMFCS
BAE Systems
Boeing
Dell
ETC (Energetic Technology Center)
L-3 Communications
NASA Ames Research Center
Raytheon
Toshiba

For more information on membership, contact Joan Lee at *joanyuan@calce.umd.edu*. The annual membership fee is $35K.

CALCE PHM Mission and Research

The CALCE PHM Consortium performs research and development on the application of prognostics and health management to complex electronic products and systems and systems-of-systems. Prognostics and health management is the estimation of remaining useful system life in terms that are useful to either the maintenance decision-making process or the improvement of product design and reliability. Participation in the PHMC places members at the forefront of prognostics and health management. Current projects being conducted within the PHM Consortium include the following.

PHM State-of-Practice Evaluation

CALCE is preparing an evaluation of the state-of-practice of global organizations involved in research, development, and implementation of prognostics and health management. The evaluation covers the prognostic approaches (including sensors, models and algorithms) used for data analysis, implementation case studies, technical publications, and discussion of intellectual property issues. This report should be completed in early 2007 and will provide organizations with cooperation and benchmarking information. To have your organization included in this report, please contact Brian Tuchband at *tuchband@calce.umd.edu*.

Online PHM Library

The PHM team at CALCE has established a comprehensive online library of prognostics-related publications, providing a one-stop resource for all those interested in learning, researching, and implementing prognostics and health management. The library is accessible through the CALCE PHMC website (www.prognostics.umd.edu). The library is currently being populated with articles, reports and presentations. For more information contact Rishi Raj at *rishiraj@calce.umd.edu*.

Prognostics Implementation under Vibration Loading

This project involves the development of prognostics for electronic equipment subjected to vibration loading using physics-of-failure PHM techniques. The CALCE PoF approach has been demonstrated by a series of experiments, where PCB assemblies were tested under random vibration loading. The strain and acceleration at different locations on the PCB were monitored in-situ. Using this data, a prediction of the time to failure of the components on the PCB was estimated. The approach is being validated by checking the actual performance values of the components. The PHM Consortium also has a project with the Army-AMSAA to assess the usage conditions and damage of electronics in vehicles, using novel prognostic techniques. For more information, contact Jie Gu at *jiegu@calce.umd.edu*.

Active RFID Sensor Tag Development and Testing

In partnership with Prognostic Systems Inc., the CALCE PHM Consortium is implementing low-cost, active RFID sensor tags in systems and has been prototype-testing the sensor tags in the unmanned Army SWORDS vehicle to assess reliability. The sensor tags use wireless communication and contain paper-thin, flexible-circuit technology, making them practical for almost any application. At this stage, we are looking for companies interested in incorporating our technology into their products. If you have an interest in using our sensor tags, please contact Brian Tuchband at *tuchband@calce.umd.edu*.

Detection of Failure Precursors for Capacitors in Electronic Products

We are developing non-traditional prognostic techniques for analyzing multilayer ceramic capacitors under temperature-humidity bias conditions. Three characteristics of the capacitors were monitored in-situ, including capacitance, dissipation factor, and insulation resistance. The Mahalanobis distance, a multivariate statistical method, was used to identify abnormal values in the data prior to actual failure of the capacitors. The study found that the failure threshold level is a very important factor in trying to identify failure precursors. With a suitable threshold level, the Mahalonobis distance method can yield an accurate time estimate of capacitor failure using insulation resistance as a precursor to failure. For more information, contact Daeil Kwon at *dkwon@calce.umd.edu*.

Return on Investment for Prognostics

The CALCE PHM Consortium is developing a stochastic decision model that determines when scheduled maintenance or PHM-based approaches make good sense for a business. The model enables the optimal interpretation of fixed-schedule maintenance, life consumption monitoring, and monitoring precursor data. A web-based tool that addresses PHM cost avoidance has been developed to optimize safety margins and prognostic distances for single LRUs and to determine best maintenance strategies for multiple LRU systems. The tool is being extended to include the costs associated with implementing various PHM approaches. If you are interested in this project, please contact Prof. Peter Sandborn at *sandborn@calce.umd.edu*.

Prognostics to Logistics Systems-of-Systems Demonstration Movie

A video demonstration showing the CALCE PHM Consortium vision of prognostics and health management was recently completed by CALCE PHM Consortium students at the University of Maryland. The movie shows how wireless sensors, active RFID technology, prognostics, and web-deployable databases can be integrated with logistics support to provide real-time health assessment for electronic equipment. With the CALCE approach, electronics inside a line replaceable unit (LRU) can be assessed in their actual environment. Then, using physics-of-failure models championed by CALCE over the past 25 years, we can predict the remaining life so that the LRU can either be repaired or replaced prior to system failure. Then condition-based maintenance and logistics methods can be applied to increase mission sustainability. The movie can be downloaded from the PHM Consortium website. For more information contact Brian Tuchband at *tuchband@calce.umd.edu*.

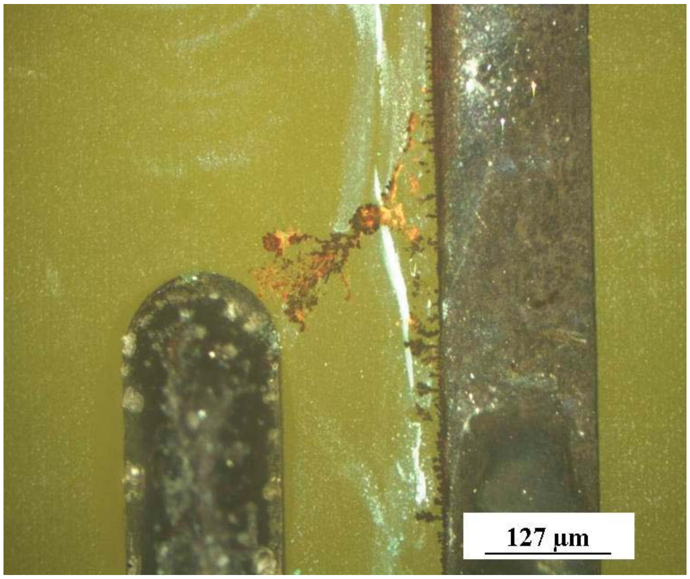
Recent Publications by CALCE PHM Team

- "Advances in Prognostics for Electronic Products and Systems," 2006 International Military & Aerospace/Avionics COTS Conference
- "Enabling Electronic Prognostics using Thermal Data," 12th International Workshop on Thermal Investigations of ICs and Systems
- "Prognostics and Sense & Respond Logistics," 2006 Department of Defense Maintenance Symposium & Exhibition
- "Prognostics and Health Management for Smart Well Applications," Halliburton (internal) Reliability Conference 2006
- "Prognostics and Health Management for Electronic Equipment and Power Supplies," Emerson (internal) Reliability Conference 2006
- "Prognostics for Civil and Military Aircraft and Space Systems," Aerospace Testing Expo 2006
- "Electronics PHM Special Issue," *Microelectronics Reliability,* Spring 2007

Long-term Reliability of Lead-free Assemblies in Contaminating and Corroding Environments

The recent adoption of lead-free materials and processes by the electronics industry has introduced uncertainty regarding reliability of electronic products, especially after several years of field use. CALCE is undertaking a study of long-term reliability of lead-free electronic assemblies subjected to contaminating and corroding environments to address one major area of concern.

A recognized cause of failure for electronic products is degradation of surface insulation resistance (SIR) associated with electrochemical migration (ECM). This is a potential reliability problem which may become more prevalent in lead-free electronic devices due to new fluxes formulated for lead-free solders, and since many lead-free solders contain silver, which is known to migrate more readily than tin or lead in temperature-humidity-bias conditions. With continued reductions in conductor spacing, long-term reliability of electronic systems could be compromised by ECM under the influence of surface contamination and no-clean flux residues. The presence of hygroscopic contamination or adsorbed ionic species (such as chlorine, bromine, and sulfates) can accelerate corrosion processes. In addition, there may be other failure mechanisms which might arise when lead-free electronic assemblies are used in contaminating environments.



The figure above shows dendritic growth on a printed circuit board after exposure to 65°C/95% RH with 6V bias. Hygroscopic flux residues from no-clean processing promoted electrochemical migration. The resulting leakage current could generate failure in an electronic product.

For more information regarding this study of long-term reliability of lead-free assemblies in contaminating and corroding environments, contact Dr. Michael Azarian at *mazarian@calce.umd.edu*, tel. 301-405-7555.

CALCE Initiates Long-term Reliability of Mixed (Pb-free Parts/SnPb Paste) Soldered Assemblies

While a large segment of electronic equipment manufacturers have converted to Pb-free parts and processes to meet government regulations and market demands, a set of manufacturers, particularly those in the high performance and reliability segments, are working to maintain Pb-based materials and processes. As the supply of Pb-based parts is reduced, manufacturers seeking to maintain Pb-based processes are faced with the decision of reprocessing Pb-free parts or using the parts as received.

For manufacturers and users of mixed components (Pb-free parts/SnPb paste) assemblies, reliability is a chief concern. Limited studies have identified potential issues with mixing Pb-free parts with the SnPb assembly process. These include poor reliability of SAC BGA solder balls due to incomplete mixing of SnPb into the final solder microstructure. In addition, there has been concern with tin bismuth (SnBi)-finished parts due to the potential formation of low-temperature ternary alloys of bismuth (Bi) with the SnPb solder paste, resulting in compromised reliability. Further, the long-term life expectancy of solder interconnects formed with Sn- and SnCu-finished parts with SnPb solder needs to be demonstrated. There is also a potential for whisker formation on Pb-free finished terminals.

CALCE has initiated an open industry study to focus on the long-term reliability of mixed (Pb-free parts/SnPb paste) soldered assemblies. Mixed test assemblies including Pb-free (Tin Silver Copper solder ball) BGAs, QFPs with Sn, SnBi, and SnCu lead finishes will be tested and compared with pure Pb-free and pure SnPb test assemblies. This study will include:

Microstructural analysis of BGA:

- As received, 100 hr, 350 hr, and 1000 hr aging at 125˚C temperature aging.

Lead pull strength test:

- Sn, SnBi, SnCu
- Pad finish SnPb-HASL, ImSn, ImAg, ENIG
- Non-Aged, Aging 125˚C/100hrs, Aging 125˚C/350, Aging 125˚C/1000

Interconnect durability tests:

- Temperature cycle (-40 to 125˚C)
- Random Vibration step stress tests (0.02-0.2 G^2/Hz over test board first frequency)
- Failure analysis of test specimens

Whisker growth:

- Sn, SnBi, and SnCu finished parts with SnPb solder will be examined for whisker formation.

For more information on the long-term reliability of mixed soldered assemblies, contact Michael Osterman at *osterman@calce.umd.edu*, tel. 301-405-8023.

CALCE Test Services and Failure Analysis Laboratory

The CALCE Test Services and Failure Analysis (TSFA) Laboratory provides a wide range of engineering services in the areas of failure analysis, materials characterization, product testing, supplier reliability capability assessment, design reviews, and virtual qualification. These services are custom-designed to help companies identify the causes of failure or poor performance in electronic products, assess and mitigate the risks of producing and incorporating new technologies, perform lifetime and life-cycle assessments of electronic products, improve product quality and reliability, and reduce time-to-market and time-to-profit..

The CALCE TSFA Laboratory houses state-of-the-art equipment that enables the laboratory to perform accelerated testing, electrical testing, non-destructive evaluation, and destructive evaluation on electronic parts, boards, and assemblies. One recent acquisition is an X-ray system capable of 2D and 3D imaging, with a maximum resolution of 0.3 µm, magnification of up to 10,000x, and maximum tube voltage of 160 kV. Automated modules help with X-ray inspection of BGAs, LSPs, QFPs, QFNs, and PTHs, void calculation, and wire sweep measurements. For a complete list of equipment visit our website at www.calce.umd.edu under Test Services and FA.

Failure Analysis

Non-Destructive Evaluation (NDE) is performed to obtain information about failure sites, modes, and mechanisms without damaging the device. The CALCE TSFA Laboratory makes use of an advanced array of NDE tools, including optical microscopy, environmental scanning electron microscopy (ESEM)/energy dispersive spectroscopy (EDS), scanning acoustic microscopy (SAM), X-ray inspection, and X-ray fluorescence spectroscopy (XRF). A recent project at the CALCE TSFA Laboratory called for investigation of a malfunctioning multi-layer ceramic chip (MLCC) capacitor. Inspection of the faulty capacitor with XRF and analysis of the spectrum revealed that the MLCC was counterfeit, evidenced by the absence of a rare-earth element in the spectrum. This element is an important constituent of the MLCC dielectric but is usually added in trace amounts; the XRF spectrum generated from the counterfeit MLCC did not contain this important element.

Destructive evaluation usually begins with decapsulation/delidding or microsectioning. These techniques are often necessary to confirm failure mechanisms identified during NDE. In another recent project, the CALCE TSFA Laboratory was asked by a customer to determine the cause of shorting on a board-mounted field effect transistor (FET). The customer was experiencing the problem on multiple boards and this issue had been isolated to two particular FETs on each board. X-ray inspection revealed the presence of stray metallic particles on the boards between the source and drain terminals. These stray particles were observed in all the boards that were experiencing the shorts. Further analysis with Energy Dispersive Spectroscopy (EDS) on cross-sections of the FET on the boards revealed the metallic particles were composed of eutectic solder – similar in composition to the solder used on the board. In this case, NDE using X-ray inspection helped in quick identification of the cause of the shorted FETs, while destructive evaluation provided the composition of the foreign material and indicated its origin.

Materials Characterization

The CALCE TSFA Laboratory uses a variety of techniques to characterize materials common to the electronic packaging industry. These techniques include differential scanning calorimetry (DSC), thermomechanical analysis (TMA), dynamic mechanical analysis (DMA), micro-indentation, contact resistance measurement, Fourier transform infrared spectroscopy (FTIR), and EDS. These techniques help measure transition temperatures (glass, melting, and vaporization), the coefficient of thermal expansion (CTE), swelling due to moisture absorption, weight change vs. temperature, fatigue/creep/stress relaxation properties, elastic modulus, hardness, electrical resistance, and material composition.

Electrical Testing

Electrical testing entails examination of important electrical connections and is a useful tool in determining both the failure site and failure mode. The CALCE Test Services and Failure Analysis Laboratory has a broad range of electrical testing capabilities:

- IC and semiconductor parametric analysis
- Surface insulation resistance measurement
- Contact resistance measurement
- Parameter monitoring during accelerated testing
- Low and high frequency impedance measurement
- Capacitor characterization

Accelerated Testing

Accelerated testing has been recognized as a necessary activity to ensure the reliability of electronic products used in military, aerospace, automotive, industrial, and mobile (cellular phones, laptop computers) applications. The CALCE TSFA Laboratory has established systematic procedures to combine physics-of-failure based use of accelerated stress tests within cost and time budgets that can achieve both quality and stress margins that are far better than those achieved using traditional design-based test approaches. The Laboratory has chambers for temperature cycling, temperature/humidity cycling, temperature/humidity bias, vibration, shock, highly accelerated life test (HALT), highly accelerated stress test (HAST), mixed flowing gas (MFG), and high-altitude simulation tests.

In 2006, CALCE TSFA conducted over 150 failure analysis studies for over 100 companies. Other services included:

- alerts for two Fortune 500 electronic companies
- reviews of mechanical and electrical design
- reviews of failure mode, mechanisms and effects analysis (FMMEA)
- identification of critical-to-quality parameters
- materials and parts characterization
- RoHS compliance evaluation
- virtual qualification and reliability assessment

For more information on CALCE TSFA Laboratory capabilities, please contact Bhanu Sood at 301-405-3498 or email *bpsood@calce.umd.edu*.

CALCE Study Shows Thermal Aging Degrades Durability of Lead-free Solders

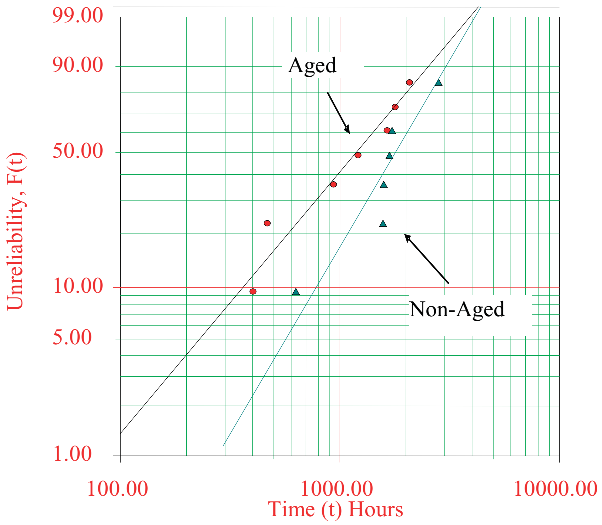
As a result of the transition to lead-free solder due to government regulations and market pressures, maintained lead-based electronic hardware may now be repaired with lead-free materials and parts. Likewise, lead-free electronic hardware may be repaired with lead-based materials and parts. While significant investigation into lead-free solder interconnect reliability has been reported in the literature, very little has focused on the reliability of thermally aged and repaired solder interconnects. This situation has raised concern about the reliability of repaired lead-free and mixed-solder (lead-free and lead-based solders) interconnects.

To address the impact of thermal aging, solder interconnect repair, and mixed solder, CALCE has initiated several research studies. With regards to mixed solder interconnects (lead-free parts/ tin-lead solder paste), it has launched the Long-term Reliability of Mixed Solder Assemblies project (discussed above). On thermal aging, CALCE has completed a long-term lead-free reliability study to assess the impact of thermal aging on intermetallic formation and solder pull strength. One finding from the long-term lead-free reliability study was that thermal aging degrades solder pull strength. However, it is unclear if the degradation due to thermal aging indicated in the pull strength test will be duplicated in other environmental testing.

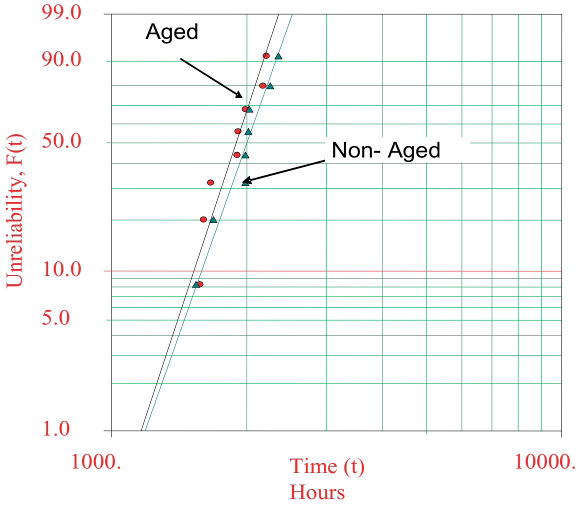
In an effort to examine the impact of aging and repair on lead-free and lead-based soldered assemblies, CALCE, in collaboration with the CALCE Electronic Products and Systems Consortium, conducted an experimental study in which lead-free and lead-based solder assemblies of the same design were subjected to manual repair. The surface mount assemblies included ball grid arrays (BGAs), leadless resistors, and quad flat packages (QFPs). For the lead-based assemblies, the boards were finished via hot air solder leveling (HASL); the leaded parts terminals were finished with tin-lead plating; and the BGA solder balls were eutectic tin-lead. For the lead-free assemblies, the boards were finished with immersion tin; the leaded parts included matte tin, tin-copper, and tin-bismuth finishes; and the BGA solder balls were SAC305. To examine the impact of thermal aging on the repair process and on interconnect reliability, half of the test specimens were aged for 350 hours at 125°C.

A set of aged and unaged lead-free and lead-based test specimens were subjected to manual repair. The repair process include removal and replacement of select parts. As part of the investigation, lead-free and lead-based components and materials were intentionally mixed. BGA replacement was conducted without application of solder paste. Observed repair defects included lead misalignment, solder mask rip-off, and non-uniform solder-joint heights in PBGAs due to package warpage.

Temperature cycle loading (-40 to 125°C) was used to examine the reliability of the solder interconnects. One finding from this study was that thermal aging had a greater impact on lead-free assemblies. The Weibull plots of time to failure for aged and non-aged BGA assembled parts show that thermal aging is more detrimental to lead-free solder interconnects than to lead-based interconnects for PBGAs. Further, the failure distribution of the lead-free assembled PBGAs was found to be wider than the distribution of the lead-based failures.



Aged and Non-aged Lead-free BGA Temperature Cycling



Aged and Non-aged Tin-lead BGA Temperature Cycling

Physical analysis of the failed PBGAs found the failure site occurred in the solder near the component-side solder-mask-defined pad, regardless of solder type.

Further study on the reliability of solder interconnects formed through rework/repair is under way in the CALCE Electronic Product and Systems Consortium. This work is being conducted in combination with studies on lead-free ball grid array reballing to tin-lead solder balls, and solder dipping of lead-free finished leaded parts. For more information please contact Michael Osterman (*osterman@calce.umd.edu*).

Announcements

Virtual Qualification Software Workshop

Over the past fifteen years, CALCE has developed software to assist engineers in evaluating, designing, and testing electronic hardware. The software provides an integrated design environment that incorporates reliability assessment and life-cycle costing tasks into the earliest stages of the design process. It produces designs that result in cost-effective and reliable electronic components, PWBs, and systems, and enables design and reliability engineers to implement physics-of–failure principles.

On **March 19, 2007,** CALCE will be offering a one-day workshop with hands-on training in the use of the current calcePWA and calceFAST software and a discussion of real-world applications, online resources, and future directions. The workshop will be held on the University of Maryland campus.

For more information visit *www.calce.umd.edu* and click on *Upcoming Events* or contact Dr. Michael Osterman at *osterman@calce.umd.edu*, tel. 301-405-8023.

International Symposium on Tin Whiskers

As a result of the global transition to lead-free electronics, a majority of electronic component manufacturers are now using pure tin or tin-rich lead-free alloys for terminal and lead finishes. The selection of pure tin and tin-rich lead-free alloys was based on cost, the anticipated lead-free solder replacements, and the need to maintain compatibility with the current tin-lead-based assembly process. A major drawback of lead-free tin-based finishes is tin whisker formation. A tin whisker is a conductive tin crystal that can spontaneously grow from tin-based lead-free finished surfaces, often in a needle-like form. These whiskers can bridge adjacent electrical conductors, causing the product to fail. Whisker-related field failures have resulted in losses of over $1B since 1990.

While the potential for tin whisker formation has been known for more than fifty years, a complete explanation of the phenomenon has remained elusive. As a result, the ability to test for low whisker formation, to prove the whisker resistance of new plating formulations, and to assess the impact of whisker mitigation strategies remains a challenge. Due to the wide adoption of lead-free tin finishes and the concern of equipment manufacturers about whisker formation, tin whisker studies are being conducted by universities, companies, and research organizations around the world. Whisker research includes examining the fundamentals of whisker growth, the influence of the plating process, the influence of materials sets, the environmental stress drivers, methods for estimating whisker failure risk, and strategies for mitigating whisker failure risk.

On **April 24-25, 2007**, CALCE will host an International Symposium on Tin Whiskers in 1111 Jeong H. Kim Building, on the University of Maryland College Park campus. The two-day event will bring together international experts engaged in tin whisker research to present the current state of knowledge on the topic. Presentations will discuss failures related to tin whisker formation, theories on tin whisker growth mechanisms, techniques for evaluating tin whisker failure risks, and strategies for mitigation of risk. Attendees will receive presentation material from the meeting and have the ability to interact with experts through question and answer periods during each presentation as well as at two planned panel sessions.

Seating is limited. To register for this event, contact Joan Lee at *joanyuan@umd.edu*. For the latest information, visit the CALCE Website (*www.calce.umd.edu*) under *Upcoming Events.*

Selected Recent Publications

1. "Assessment of Ni/Pd/Au-Pd and Ni/Pd/Au-Ag Pre-Plated Leadframe Packages Subject to Electrochemical Migration and Mixed Flowing Gas Tests," P. Zhao, M. Pecht, S. Kang, and S. Park, *IEEE Transactions on Companents and Packaging Technologies*, Vol. 29, No. 4, pp. 818-826, December, 2006.
2. "A Methodology for Assessing the Remaining Life of Electronic Products," S. Mathew, P. Rodgers, V. Eveloy, N. Vichare, and M. Pecht, *International Journal of Performability Engineering*, Vol. 2, No. 4, pp. 383-395, October 2006.
3. "The Influence of Substrate Enhancement on Moisture Sensitivity Level (MSL) Performance for Green PBGA Packages, T. Lin, M. Pecht, D. Das, and K. Teo, *IEEE Transactions on Components and Packaging Technologies*, Vol. 29, No. 3, pp. 522- 527, July 2006.
4. "Establishing a Relationship Between Warranty and Reliability," M. Pecht, *IEEE Transactions on Electronics Packaging Manufacturing*, Vol. 29, No. 3, pp. 184- 190, July 2006.
5. "Surface Insulation Resistance of Conformally Coated Printed Circuit Boards Processed With No-Clean Flux," S. Zhan, M. Azarian, and M. Pecht, *IEEE Transactions on Electronics Packaging Manufacturing*, Vol. 29, No. 3, pp. 217-233, July 2006.
6. "Statistical Analysis of Tin Whisker Growth," T. Fang, M. Osterman, and M. Pecht, *Microelectronics Reliability*, Vol. 46, Issues 5-6, pp. 846-849, May-June 2006.
7. "Isothermal Aging Effects on the Microstructure and Solder Bump Shear Strength of Eutectic Sn37Pb and Sn3.5Ag Solders," W. Chen, P. McCluskey, and S. O'Mathuna, *Microelectronics Reliability*, Vol. 46, Issues 5-6, pp. 896-904, May-June, 2006.
8. "Tin Whisker Risk Assessment," T. Fang, M. Osterman, S. Mathew, and M. Pecht, *Circuit World*, Vol. 32, No. 3, pp 25-29, May 2006.
9. "Assessing Tin Whisker Risk in Electronic Products," T. Fang, S. Mathew, M. Osterman, and M. Pecht, *SMT Magazine, PennWell*, Vol. 20, No. 5, pp 24-25, May 2006.
10. "Obsolescence-Driven Design Refresh Planning for Sustainment-Dominated Systems," P. Singh and P. Sandborn, *The Engineering Economist*, Vol. 51, No. 2, pp. 115-139, April-June 2006.
11. "Prognostics and Health Management of Electronics," N. Vichare and M. Pecht, *IEEE Transactions on Components and Packaging Technologies*, Vol. 29, No. 1, pp. 222-229, March 2006.
12. "Low Temperature Electrical Measurements of Silicon Bipolar Monolithic Microwave Integrated Circuit (MMIC) Amplifiers," M. Keimasi, S. Ganesan, and M. Pecht, *Microelectronics Reliability*, Vol. 46, pp. 326-334, 2006.
13. "Use of High Temperature Operating Life Data to Mitigate Risks in Long-Duration Space Applications that Deploy Commercial-Grade Plastic Encapsulated Semiconductor Devices," S. Ganesan, M. Pecht, and S. Ling, *Microelectronics Reliability*, Vol. 46, pp. 360-366, 2006.
14. "Impact of Environmental Regulations on Green Electronics Manufacture," R. Ciocci and M. Pecht, *Microelectronics International*, Vol. 23, No. 2, pp 45-50, 2006.
15. "Learning from the Migration to Lead-free Solder," R. Ciocci and M. Pecht, *Soldering and Surface Mount Technology*, Vol. 18, No. 3, 2006.
16. "A Variant of Conductive Filament Formation Failures in PWBs with 3 and 4 mil Spacings," K. Rogers and M. Pecht, *Circuit World*, Vol. 32, No. 3, 2006.
17. "Uprating of Electronic Parts to Address Obsolescence," M. Pecht and D. Humphrey, *Microelectronics International*, Vol. 23, No. 2, pp 32-36, 2006.

A monthly subscription to the complete text of these publications and all other published CALCE articles is available at *www.calce.umd.edu* under *Technical Information/Articles.*

A. JAMES CLARK
SCHOOL OF ENGINEERING

University of Maryland Foundation
DBA: CALCE
1103 Engineering Lab Building, 089
University of Maryland
College Park, MD 20742

calceNEWS

Spring/Summer 2007

www.calce.umd.edu

If you have recently changed your address or have colleagues who would be interested in receiving the CALCE News, please fill out the following information and either return it to the above address, fax it to 301-314-9269, or email it to *inform@calce.umd.edu*. This subscription form is also available online at *www.calce.umd.edu/general/newsletter/mailinglist.html*.

- Please add me to the CALCE News mailing list.
- My address has changed; please update it.
- Please remove me from the CALCE News mailing list.
- Please add me to the CALCE FYI email mailing list.

Name: ______________________________

Title: ______________________________

Company: ______________________________

Address: ______________________________

____

City:______________State:_______Zip:______________

Country: ______________________________

Phone#: ______________________________

Fax#: ______________________________

E-mail: ______________________________

Comments and suggestions: ____________________

____