



calceNEWS

CENTER FOR ADVANCED LIFE CYCLE ENGINEERING (CALCE)
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INSIDE

1 Message from the Director

2 Electronic Products and Systems Consortium

- EPS Consortium Fall Technical Review Meeting
- Virtual Qualification Software Workshop
- Programmability of Antifuse FPGAs after Long-term Storage

3 Prognostics and Health Management Consortium

- CALCE PHM Consortium Members
- Examples of Current CALCE PHM Consortium Research
- Andy Hess Teams up with CALCE to Lend His Expertise in PHM
- Jie Gu Takes Summer Position at Dell to Work on PHM

4 Long-term Lead-free Studies

- Symposium for RoHS Impact on Rework/Repair/Reprocessing
- Short Course on Lead-free and Mixed (Lead-free Parts/Tin-lead Paste) Solder Assemblies
- SAC Durability under Vibration Loading at Different Isothermal Temperature Conditions

5 Laboratory Services

- CALCE Test Services and Failure Analysis Laboratory
- Ahmed Amin Joins CALCE Test Services and Failure Analysis Laboratory

6 Research Highlights

- Is the MIL-STD Hermeticity Spec Valid for Packages with Ever-decreasing Internal Cavity Volumes?

7 Announcements/ Selected Recent Publications

- International Symposium on Avoiding, Detecting, and Preventing Counterfeit Electronic Parts
- Dr. C.J. Jang Joins CALCE as Assistant Research Scientist
- CALCE-mentored High School Student Wins National Junior Science Award

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



CALCE is extremely pleased to announce that it is now the world's largest electronic products and systems research center focused on electronics reliability. With our new laboratory facilities and support from over 100 corporate sponsors, this year's revenues top \$7M. We are now conducting state-of-the-art research on electronic devices, electronics packaging, product reliability and systems risk assessment; providing the most sophisticated and practical failure analysis to companies; teaching classes to industry on electronic products development and reliability; and providing guidance to companies on a host of life-cycle engineering tasks. We are also committed to providing cost-effective and practical solutions to companies.

As we move into the fall of 2007, the electronics industry is seeing continued growth, but we have been observing an increasing number of reliability concerns. For example, field failures of ceramic capacitors are occurring with greater frequency and are traceable to a number of manufacturing processes, handling, and circuit board assembly issues. To solve such problems, CALCE Test Services and Failure Analysis Laboratory continues to provide outstanding services, including proprietary design reviews, reliability assessments, material characterization, and failure analysis support. In the first half of 2007, the lab has conducted over sixty failure analysis services for companies and provides alerts for two Fortune 500 companies as well.

The CALCE Electronic Products and Systems Consortium is conducting research on a host of company-sponsored subjects, including lead-free electronics, design-for-reliability (DfR) methods, and supply chain risk assessment. One particular concern is that CALCE has been observing a rapid influx of counterfeit parts into

the supply chains of many companies. CALCE has been developing techniques to help manufacturers identify and combat counterfeiting. CALCE will hold an International Symposium on Avoiding, Detecting, and Preventing Counterfeiting in November (see p. 7) to enable dissemination of the latest knowledge in this area.

The CALCE Prognostics and Health Management (PHM) Consortium has now grown to 14 companies (see p. 3 for the complete list of members). Participation in the PHMC places members at the forefront of prognostics and health management. CALCE's accomplishments in this area include (1) mapping of sensor technologies with stress and damage models to assess real-time life consumption monitoring (LCM) of electronic systems, (2) demonstrating the LCM methodology on an electronic board operated in an automotive underhood environment, (3) evaluating diagnostic built-in-test (BIT) software-firmware systems for fault identification and isolation that incorporate error detection and correction circuits, and self-checking and self-verification circuits, (4) integrating in-situ semiconductor prognostic monitors consisting of pre-calibrated cells (circuits) to predict remaining life considering semiconductor defects and failure mechanisms, (5) developing software modules (data collection, simplification and damage accumulation and remaining life estimation) for environment and usage data collection that enable PHM, (6) assessing health using physical inspection, accelerated testing and physics-of-failure analysis combined, and (7) developing models and tools for optimizing maintenance planning and assessing ROI using PHM.

I invite you to become an active participant with CALCE and make use of our expertise and numerous resources. If you are interested in our research and analysis, 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 with you.

Michael Pecht
CALCE Director and George Dieter Chair Professor

CALCE Fall 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 **October 16-18, 2007**, at the University of Maryland. Contact Joan Lee (joanyuan@calce.umd.edu) for details or go to www.calce.umd.edu under *Upcoming Events*.

The following projects will be presented at the meeting:

- Effect of Temperature Cycle on the Durability of Pb-free Interconnects (Sn96.5Ag3.0Cu0.5 and SnCuNi)
- Reliability of Pb-free and Reballled 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) Lead 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 Thermomechanical Testing of Fine Pitch Flex Assemblies
- Failure Mechanism and Reliability Assessment for System-in-Package Technologies
- Power Cycling Durability of Advanced Power Module
- Detection of Interconnect Degradation Using Impedance Analysis
- Fundamental Understanding MEMs Structures Subjected to High Shock Loads
- Characterization of Moisture-induced Degradation of Polymer Interfaces
- Measurement of Residual Stresses Caused by Polymerization Process
- Hygroscopic Characterization of Polymer Materials beyond Glass Transition Temperature
- Solder Assessment for SiC Device Attachment
- 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/Os on Thermal Cycling Durability Predictions
- Validation of Design Guidelines for Portable Electronics
- Shock-calcePWA Shock Model Improvement

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 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 **October 15, 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 under *Upcoming Events* or contact Dr. Michael Osterman at osterman@calce.umd.edu, tel. 301-405-8023.

Programmability of Antifuse FPGAs after Long-term Storage

Field-programmable gate arrays (FPGAs) are semiconductor devices with programmable components that can duplicate the functionality of logic gates and combinatorial functions. FPGA devices generally include blocks of memory for added functionality. As manufactured, these logic blocks are not connected to each other functionally. Selective connection of the logic blocks is achieved through the process of programming. The interconnect devices used for programming FPGAs include SRAM, EPROM, and antifuses. Among these, the antifuse-based FPGAs are preferred by the commercial aerospace industry due to their non-volatility and resistance to radiation.

FPGAs are used to defend against electronic part and software obsolescence for long service-life commercial avionics systems. They can be programmed in the field and can be used to upgrade the functionality of existing electronic equipment, thus preventing the electronics from becoming obsolete. To obtain these benefits, unprogrammed FPGAs may be stored for long periods and then programmed when required. However, all these benefits cannot be realized if the parts cannot be programmed after storage.

The impact of long-term storage on the programmability of antifuse FPGAs is not known. CALCE is currently investigating the effects of long-term storage on programmability of antifuse FPGAs and is specifically focussing on two key issues:

- failure mechanisms that could affect programmability of antifuse FPGAs in storage
- qualification tests that can be performed for the identified mechanisms to ensure device reliability after 20 years of storage.

Programmability degradation can manifest itself in many modes, such as failure to form a fuse link, higher than usual resistance of the fuse link, or improper programming voltage. The causes of degradation in programmability are being separated into damage to the package and interconnects, and possible degradation to the antifuse structures. Utilization of prior CALCE work on effects of long-term storage on reliability of parts is being leveraged for isolating package-level failures to concentrate on the failures caused at antifuse structures.

For more information, please contact Dr. Diganta Das at digudas@calce.umd.edu, tel. 301-405-7770.

CALCE PHM Consortium Members

Army AMSAA	Energetics Technology Center
Army ARL	General Dynamics-AIS
Army PMFCS	Honeywell
BAE Systems	L-3 Communications
Boeing	NASA Ames Research Center
Dell	QinetiQ
EADS	Raytheon

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

Examples of Current CALCE PHM Consortium Research

Model-based Prognostics

CALCE, in partnership with Global Strategic Solutions LLC, VA, has been awarded a NAVAIR, U.S. Navy project titled “Advanced Prognostics and Health Management and Model Based Prognostic Useful Life Remaining Capabilities for Aircraft Tactical Information and Communication Systems.” The objective of this project is to develop and demonstrate new and advanced prognostic models for communication, navigation and identification (CNI) systems and their components. Within this project, CALCE will identify the required inputs/features for the models, provide a methodology for extracting them from an installed CNI subsystem and/or specific component and aid in the development of prognostic software.

CALCE-ePrognostic Systems PHM Sensor Tag

In partnership with ePrognostic Systems, the CALCE PHM team is developing low-cost, programmable, active RFID sensor tags. The sensor tags use wireless communication and contain paper-thin, flexible circuitry, making them practical for almost any application. The sensor tags, initially designed to monitor temperature conditions, are being used to assess notebook computers, refrigerators, automobiles and video projectors. The tags are also being implemented in unmanned robotic military vehicles for additional field testing. A feature extraction tool developed at CALCE is being used to extract features from raw data such as the cyclic temperature range, mean, ramp rate, and dwell time. These features are used as input to the CALCE developed remaining useful life (RUL) assessment tool to calculate the remaining life. Shock, humidity sensing, tamper-proof features, expanded memory, on-board data compression software, and micro-GPS capability are now being added.

Failure Precursors for Critical Failure Mechanisms of IGBTs

In this project, the focus is on die-level (semiconductor) failure mechanisms that can cause device failure. We have already performed an FMMEA to determine the critical failure mechanisms. Based on the FMMEA and consultation with sponsors, we are concentrating on the degradation caused by time-dependent dielectric breakdown (TDDB) of the device. We are performing parametric physics-of-failure assessment of the device by TDDB for different accelerated and typical application conditions. We will perform accelerated stress level tests to precipitate TDDB failures while monitoring a suite of electrical parameters in a modified high-temperature gate bias test condition. We will identify the failure precursors and relate them to the IGBT electrical parameters to provide guidance to electrical designers on implementing prognostics in a power electronic system.

Prognostics of System-of-Systems (with Lockheed Martin)

CALCE PHMC is involved in the development of a failure precursor-based prognostics approach that can be applied to a wide range of legacy systems-of-systems. The work is divided into three phases.

Phase I involves demonstration of failure modes, mechanisms and effects analysis (FMMEA) to legacy systems. The objective is to identify key prognostic attributes using the FMMEA process, that take into consideration the system’s life-cycle environmental and operational profiles. We will provide a systematic methodology for application of FMMEA to legacy systems-of-systems that will integrate life-cycle environmental and operational profiles with failure precursor data for prognostic implementation in systems-of-systems. This methodology will be used to process the data from the legacy systems-of-systems to identify anomalies, the onset of degradation, and the progression to failure. Phase I of the project is currently under way.

Phase II involves the validation of the PHM methodology proposed in Phase I. We will also perform a comparative analysis to other precursor-to-failure models/software and provide recommendations for developing/purchasing precursor-based prognostic models/software that can be configured for legacy systems-of-systems.

Phase III involves the development of a generic tool for a priori selection of monitoring parameters, sensors, models/algorithms, and trending methods for implementing prognostics of legacy systems-of-systems. Lockheed will implement the findings and recommendations of this work on legacy systems.

Andy Hess Teams up with CALCE to Lend His Expertise in PHM

CALCE is looking forward to working with Mr. Andy Hess, who has teamed up with CALCE and agreed to lend his expertise in an effort to expand the CALCE prognostics and health management program. Mr. Hess is considered an expert in prognostics and health management of complex systems, including electronic systems. He is world renowned for his work in fixed and rotary wing health monitoring and is recognized as the father of Naval Aviation propulsion diagnostics. More recently, Mr. Hess has been a strong advocate of prognostic capabilities and has been involved in many efforts advancing the development of these predictive capabilities for many aircraft systems and their subsystem component elements. He is a NAVAIR Senior Engineering Fellow and has written many papers on engine health monitoring, diagnostics, prognostics, and new logistic concepts. He has authored or co-authored over 30 technical papers in this field.

Jie Gu Takes Summer Position at Dell to Work on PHM

This summer, CALCE PhD student Jie Gu is at Dell working on prognostic and health management techniques applicable to computers. Jie received his M.S. degree in Mechanical Engineering from the National University of Singapore and is currently a Ph.D. student at the University of Maryland, focusing on electronic prognostics and health management. His work is part of the CALCE-Dell summer employment program.

Symposium for RoHS Impact on Rework/Repair/Reprocessing

Changes initiated by the Restriction of Hazardous Substances (RoHS) legislation have introduced a new complexity in sustaining electronic hardware that may possibly result in a mixture of lead-free and lead-based materials. Concerns include the elevated temperatures associated with lead-free materials, the use of lead-free materials in the repair of lead-based assemblies, and the long-term reliability of repair and reworked assemblies. With the decreasing availability of lead-based parts, part reprocessing in the form of solder dipping and BGA reballing are being considered as methods of maintaining lead-based assemblies.

On **September 11, 2007**, CALCE will host a *Symposium on Printed Wiring Assembly Rework/Repair and Part Reprocessing* on the University of Maryland campus. This symposium will provide a forum to discuss issues related to rework, repair and part reprocessing and will include the following presentations:

- GEIA Hot Solder Dip by Anduin Touw (Boeing)
- Hot Solder Dip and Related Risks by Russ Winslow (Six Sigma)
- Framework for Retinning and Reballing - Pb-free to SnPb by David Cavanaugh (Benchmark)
- Effect of BGA Reballing on the Formation of Intermetallic Compounds by Minerva Cruz (San Jose State University), Russ Winslow (Six Sigma), and Guna S. Selvaduray (San Jose State University)
- Hot Solder Dip Experience on TMTI Project by Charlie Minter (BMP)
- Methodology for Evaluating Data for "Reverse Compatibility" Solder Joints by William Russell (Raytheon) and Denny Fritz (SAIC)
- Overview of GEIA Handbook on Repair and Rework of Lead-free Electronics by Tim Kalt (WPAFB)
- NASA DOD Lead-free Solder Project Phase II by Dave Hillman (Rockwell Collins)
- Low Melting Point Solder Alloy for Rework by Polina Snugovsky (Celestica)
- Successful Pb-free Rework of Through-Hole Components on a Large Printed Circuit Board by Bob Farrell (Benchmark)
- Shear Strength of Hand-Soldered Components Using Mixed SnPb and Pb-free Alloys by Matt O'Keefe and Richard Colfax (University of Missouri-Rolla)
- CALCE Rework Projects by Michael Osterman (CALCE)
- Open Discussion

For more information visit www.calce.umd.edu under *Upcoming Events* or contact Dr. Michael Osterman at osterman@calce.umd.edu

Short Course on Lead-free and Mixed (Lead-free Parts/Tin-lead Paste) Solder Assemblies

With the majority of electronic hardware being manufactured with lead-free parts and lead-free processes, the availability of tin-lead parts continues to shrink. For RoHS-exempt equipment manufacturers and consumers, lead-free materials represent a challenge for legacy systems and products that continue to be manufactured and maintained with tin-lead assembly processes. For lead-free equipment manufacturers, the reliability of lead-free assemblies remains a concern with many unanswered questions.

On **October 15, 2007**, CALCE will hold a short course on lead-free and mixed (lead-free parts/tin-lead paste) assemblies. The course will cover lead-free and mixed materials and assembly issues. Topics will include: lead-free and mixed solder assembly issues, assembly reliability issues, solder interconnect reliability, tin whisker risk, and electrochemical migration issues. To register, contact Joan Lee at joanyuan@calce.umd.edu. For the latest information regarding this event, go to www.calce.umd.edu under *Upcoming Events*.

SAC Durability under Vibration Loading at Different Isothermal Temperature Conditions

Vibration loading is encountered in the service life of many electronic products. However, the fatigue life of electronic assemblies under vibration has not received as much attention as the fatigue life of electronics under temperature cycling. While electronic equipment manufacturers have been able to use lead-based electronics in a variety of challenging environments where vibration loading is substantial, the reliability of lead-free soldered electronic equipment in these environments is unproven. To provide its industry sponsors with a better understanding of the reliability of lead-free soldered electronic equipment in vibration environments, CALCE has conducted a series of tests.

For the vibration tests, a set of lead-free and lead-based test specimens was manufactured using a common design. The design included four 256 IO BGAs, four 44 IO ceramic leadless chip carriers (CLCC) (only on some test assemblies), sixteen 100 IO quad flat packs (QFPs) and ninety-six (forty-eight 2515 and forty-eight 1206) resistors. The lead-free test specimens; the QFP packages with tin, tin-copper, and tin-bismuth finishes; the resistors with tin finished terminals; and the BGAs with tin-silver-copper solder balls were assembled with tin-silver-copper (SAC) solder. For the lead-based test specimens, all component terminals were Sn37Pb and solder paste was Sn37Pb.

For vibration testing, an aluminum fixture was constructed to hold up to twenty test specimens. The test fixture and a set of test specimens were instrumented and subjected to various vibration load levels to characterize the behavior of the fixture and the cards. From the characterization tests, a four-level increasing step stress test was designed. For the first three vibration levels, the hold time was set to six hours. At the maximum test level, the hold time was set to eighteen hours. Two aging conditions, 100 hours at 125°C and 350 hours at 125°C, were used to precondition sets of test specimens. In addition, separate tests were conducted at -40°C, room temperature (approximately 25°C), and 125°C. During each test, individual resistance networks formed with soldered components were recorded. Increases in the electrical resistances were used to identify failures. Analysis of failed components was confirmed through electrical probe, cross-section and optical inspection. This process revealed fatigue cracks in the solder balls of PBGAs, cracks in the solder fillets of resistors and broken leads for QFPs.

Based on test results, the following preliminary observations can be made, in spite of the scatter in the data:

- Solder interconnect vibration durability generally decreased as the temperature increased.
- SnPb/HASL interconnects were generally found to have better vibration durability than equivalent SAC soldered interconnects.
- When samples are exposed to longer aging (350 hours) prior to the vibration durability test, SAC and SnPb vibration durability is reduced.

To obtain more information on CALCE lead-free research, please contact Dr. Michael Osterman at osterman@calce.umd.edu or 301-405-8023.

CALCE Test Services and Failure Analysis Laboratory

The CALCE Test Services and Failure Analysis (TSFA) Laboratory provides support to the electronics industry to help improve product quality and reliability. The services provided include reliability testing, physics-of-failure based reliability modeling, supplier benchmarking, design reviews, and failure analysis. The CALCE TSFA Laboratory's philosophy is that failure analysis is most effective when it allows identification of the possible root causes of failure (the most basic factor or factors which led to failure, and whose elimination will prevent its recurrence). This information can then be used to improve product reliability. The TSFA Laboratory has extensive experience in conducting failure analysis and identifying failure mechanisms for a broad spectrum of parts and products (active and passive components, printed wiring boards, optoelectronic devices, plastic encapsulated microcircuits, solder interconnects, connectors, flip-chips, etc.). Failure analysis is a systematic examination of failed devices designed to:

- identify the failure modes (the way the product failed),
- identify the failure site (where in the product failure occurred),
- identify the failure mechanism (the specific physical process which caused the failure), and
- recommend failure prevention methods.

In the first half of 2007 CALCE TSFA conducted over sixty different failure analysis and electronics reliability assessment projects to address and solve industry problems. The projects included design and process reviews, obsolescence and refresh planning analysis, reliability testing, virtual qualification, and failure analysis on active and passive devices, printed circuit boards, and solder joints. The following are a few specific examples of recent contributions.

CALCE Provides Risk Analysis of Components for RoHS Compliance

An OEM approached CALCE to conduct RoHS screening of printed circuit boards and cable assemblies for the purpose of identifying components that violate RoHS-specified maximum concentration limits (MCL). X-ray fluorescence (XRF) spectrometry was used to analyze elemental composition of the submitted parts. CALCE identified parts that clearly exceeded the RoHS MCL and, for the remaining parts, provided an assessment of the risk of non-compliance, along with recommendations for follow-up analysis.

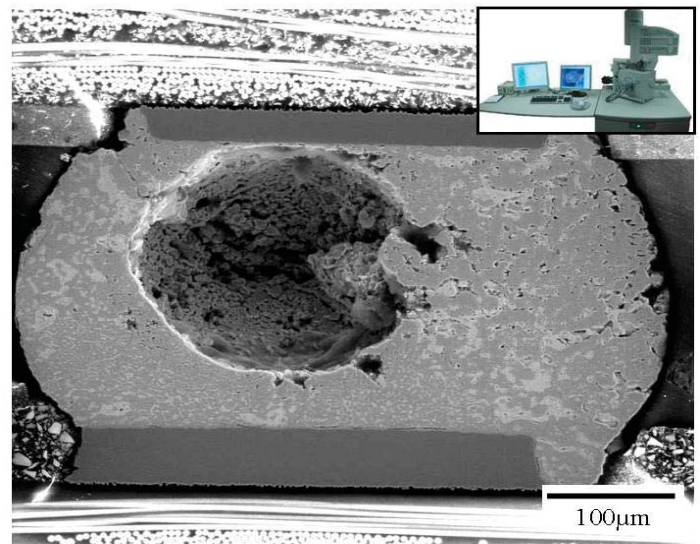
RFID Tag Failures Identified

CALCE TSFA Laboratory helped a major radio frequency identification (RFID) tag manufacturer in identifying the sources of failures in passive RFID tags. Using a combination of techniques such as electrical probing, cross-sectioning and focused ion beam (FIB) etching, CALCE identified the presence of stray under-fill polymeric material in the under-bump metallization (UBM) region of the RFID flip-chip that led to the loss of electrical continuity. CALCE worked with the manufacturer to trace certain process parameters in the RFID tag manufacturing process that contributed to the leakage of the polymeric under-fill material into the UBM region. These parameters were then adjusted to mitigate the problem and improve their RFID tag reliability.

Failure Analysis of Thick Film Power Resistor

CALCE was recently asked to investigate failures in thick-film power resistors that were demonstrating opens during highly-accelerated life testing (HALT). Using non-destructive tools like X-ray microscopy, the source of failures was quickly determined to be micro-cracks that were emanating close to the laser trim region of the thick-film resistors. Further micro-sectioning on some of the thick-film resistors revealed that the source of the cracks could be pre-existing defects on the thick film, which during HALT testing quickly developed into non-continuous cracks.

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



Environmental Scanning Electron Microscope (ESEM) image of a microsectioned Ball Grid Array (BGA) solder ball showing a void. The ESEM system is shown in the inset.

Ahmed N. Amin Joins CALCE Test Services and Failure Analysis Laboratory

Mr. Ahmed N. Amin has joined the CALCE Test Services and Failure Analysis Laboratory. He holds a BS degree in electrical engineering from Syracuse University, NY, and has over 28 years experience in device, package, and assembly-level root cause failure analysis (FA) using a variety of state-of-the-art analytical instruments and tools. He has developed and used analytical techniques appropriate for specific failure modes to document mechanisms, and has conducted device and package-level reliability testing for commercial, military, and space programs during his career. He has broad FA experience on current Low-K flip-chip and wire-bonded semiconductor devices and packages, hybrid integrated circuits (thin and thick film), fiber optic components, thin film transistor display panels, microelectronic assemblies, flex circuits, and printed circuit boards. Mr. Amin was previously with LSI Corporation/Agere Systems, Lucent Technologies, Sterling Diagnostic Imaging/Direct Radiography Corp., E-Systems, General Electric Company, and Sperry Computer Systems.

Is the MIL-STD Hermeticity Spec Valid for Packages with Ever-decreasing Internal Cavity Volumes?

MEMS-based devices can be found everywhere, including cell phones, pacemakers, and cars. According to the technical market research report, the global market for MEMS devices and production equipment was worth an estimated \$6 billion in 2006, and will increase to \$12.5 billion through 2010. In spite of their obvious advantages, such as integrated functionality and miniaturized space-saving size, there are package-level reliability concerns that have to be addressed before harnessing them for many potential applications.

One of the most critical needs for assurance of reliability is hermeticity assessment, which is of particular importance in two cases: (a) when the package internal cavity has to be maintained at near-vacuum pressures to provide a constant quality factor (e.g., in gyroscopes and accelerometers) and (b) when moisture ingress can activate failure mechanisms leading to performance degradation or frequency shift (e.g., in RF MEMS filters).

The Mil Spec Method 1014.11 of MIL-STD-883 provides guidelines for hermeticity assessment. The tests most pertinent to fine leak assessment are the helium fine leak test (Test Conditions A₁ and A₂) and the optical leak test (Test Condition C₂). MEMS packages have dimensions in the order of a few millimeters or less, and volumes less than 10⁻³ cc (1 μl). Fine leak rates usually smaller than 10⁻⁴ atm-cc/s have to be detected for reliability assessment. Due to their small volumes, MEMS packages pose a unique challenge; they are much smaller than previously conceived in the Mil Spec.

Test Condition A₁ specifies the reject limit in terms of the measured leak rate. The measured leak rate (*R*) is defined as the leak rate of a given package as measured under specified conditions and employing a specified test medium. It depends on the instantaneous value of the pressure differential and is hence time-variant and dependent on ambient conditions. On the other hand, Test Condition A₂ uses reject limits in terms of the true leak rate. The true leak rate (*L_a*) is defined as the leak rate normalized for a unit pressure differential. It is time-invariant and hence a characteristic of the package. Both tests compare the output of the helium mass spectrometer (i.e., the measured leak rate) to the reject limit to qualify hermeticity. It should be noted that for Test Condition A₂, the reject limit in terms of *L_a* is converted into a reject limit in terms of *R* using the fundamental conduction equation.

CALCE has been studying hermeticity assessment of MEMS packages through several consortium projects (C04-09, C05-17, and C06-17). This research has revealed that one-to-one correspondence between the measured leak rate and the true leak rate no longer uniquely exists as the cavity volume becomes smaller than 10⁻³ cc. As a result, using the MIL-STD guidelines in their current form for small cavities (less than 10⁻³ cc) can lead to false positives (failing good parts to pass) and false negatives (passing bad parts), as illustrated in Fig.1.

This finding has motivated a three-pronged action by CALCE: (a) extensive simulations of the helium fine leak test to generate recommendations for the new default volume-dependant reject limits for Test Condition A₂ in order to maximize the domain of leak qualification, (b) development and verification of a new procedure to infer the true leak rate from helium fine leak

test data so that comparisons can be made in terms of *L_a* rather than *R*, hence removing ambiguity in the analysis and (c) development of an optical fine leak test in which hermeticity is assessed by measuring the time-dependent surface deflection of the specimen when it is subjected to an invariant pressure.

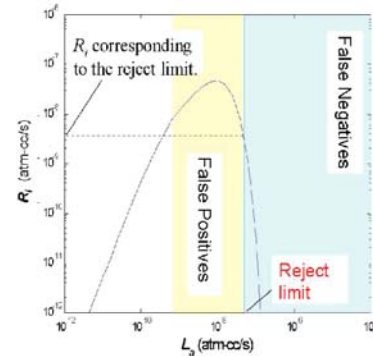


Fig. 1 An example of application of Test Condition A₂ to a package with volume = 5 x 10⁻⁵ cc and the test parameters: Bombing pressure = 5 atm, Bombing time = 6 hours, Dwell time = 10 minutes. The default reject limit as specified in the MIL-STD document for this volume is *L_a* = 5 x 10⁻⁸ atm-cc/s

For the third action, CALCE has developed a unique apparatus that employs (1) Twyman Green interferometry to document the surface deformation with a resolution of less than 20 nm and (2) a closed-loop feedback-controlled pressurization unit wherein the specimen can be pressurized up to 50 atm. The use of full field measurement allows an adjustment for rigid body rotation that almost invariably takes place when a specimen is subjected to high pressure. Representative results obtained from a package with a volume of ~ 10⁻⁵ cc are shown in Fig. 2. The true leak rate can be determined from the measured data and the results revealed that its true leak rate is on the order of 10⁻¹² atm-cc/s or less.

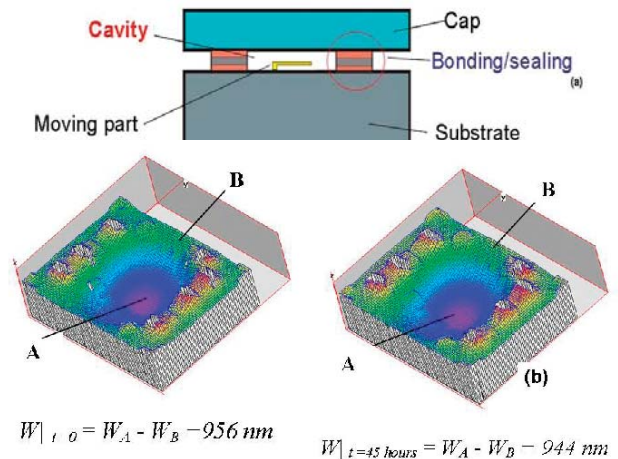


Fig. 2 (a) Schematic illustration of the package cross-section and (b) Deformation, *W*, of a package with a cavity volume of 10⁻⁵ cc, subjected to a pressure of 15 atm.

For more information, contact Arindam Goswami at agoswami@calce.umd.edu or Dr. Bongtae Han at bthan@calce.umd.edu.

International Symposium on Avoiding, Detecting, and Preventing Counterfeit Electronic Parts

On **November 7 and 8, 2007**, CALCE will be hosting an International Symposium on Avoiding, Detecting, and Preventing Counterfeit Electronic Parts. The symposium, spanning two days, will include sessions on examples of counterfeit electronic parts and risks involved; sources of counterfeit parts; part selection and management methodologies; role of authentication in preventing anti-counterfeiting; part manufacturer's approach to combating counterfeit electronic parts; part distributor's approach to combating counterfeit electronic parts; and counterfeit mil/aero parts and their impact. Panel sessions will be scheduled to provide time for discussions.

Participants are asked to submit abstracts prior to the abstract submission deadline. Participants will be expected to send accepted presentations for print-out and publication on the CALCE website prior to the presentation submission deadline. Materials should be submitted to Dr. Diganta Das at diganta@umd.edu via email.

Important Dates:

August 15:	Abstract submission deadline
September 1:	Acceptance notification
October 15:	Deadline for registration
October 20:	Presentation submission deadline

To register or obtain more information, visit the CALCE website at www.calce.umd.edu under *Upcoming Events*.

Dr. C.J. Jang Joins CALCE as Assistant Research Scientist

Dr. C.J. Jang has joined CALCE as Assistant Research Scientist. He received his Ph.D. in Mechanical Engineering from Korea Advanced Institute of Science and Technology in 2000. He has over six years of industrial experience in computer-aided design optimization and reliability assessment of various electronic products. At CALCE, he is responsible for conducting various CALCE funded projects focused on PoF-based life prediction models, design guidelines for optimum reliability, and PoF-based reliability assessments and design optimization for enhanced reliability.

He has authored or co-authored over twenty journal and conference papers in the field of design and reliability of semiconductor packaging. He also holds numerous patents related to the manufacturing process and design guidelines for electronic packages and equipment. He received the Gold Award (best paper in the Analysis and Simulation Session) at the 1st Samsung Technical Conference in 2004.

CALCE-mentored High School Student Wins National Junior Science Award

Wilde Lake High School student Phillip Sandborn won 1st place in the Engineering Division at the 2007 National Junior Science and Humanities Symposium (JSHS). JSHS is the advanced research paper competition for high school science fair students. Phillip's research project, "A Random Trimming Approach for Obtaining High-Precision Embedded Resistors," mentored by Prof. Peter Sandborn from CALCE, focused on embedded electronic resistor components inside printed circuit boards and developed an experimentally verified computer simulation for the embedded resistor trimming process.

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