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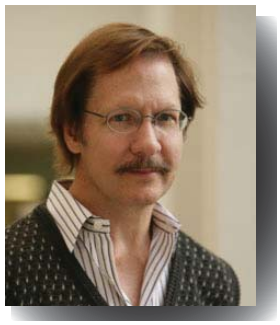
CENTER FOR ADVANCED LIFE CYCLE ENGINEERING (CALCE)
WWW.CALCE.UMD.EDU, TEL: 301-405-5323

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 create and maintain an educational and technology transfer infrastructure for their rapid dissemination and utilization.

Message from the Director



As the world's industries face difficult economic challenges, unexpected reliability issues can now incur costs that can jeopardize the sustainability of an entire company. In these times, reliability cannot be ignored and CALCE has worked to provide efficient and cost effective resources that will assist our clients in ensuring that their products are reliable.

CALCE's focus on the reliability of electronics is anchored in understanding the mechanisms that produce failure. The physics of failure (PoF) enables design for reliability (DfR) prior to the creation of physical prototypes. The PoF methods can then be used to plan accelerated tests that provide the basis for product qualification. In addition to PoF, CALCE has also been developing new supply chain methods, including approaches to assess the reliability maturity of companies, to guard against obtaining counterfeit parts, and to enhance product sustainment. The following is a brief review of selected CALCE activities:

The CALCE Electronic Product and Systems Consortium (EPSC) is addressing a wide and diverse set of critical quality and reliability challenges identified by its members. Studies include investigations of tin whisker growth and the effectiveness of test and mitigation strategies. Reliability assessments of interconnects in reworked mixed (lead-free finish/tin-lead paste) solder and lead-free assemblies as well as tin-lead solder assembled reprocessed (reballed/solder dipped) lead-free parts are being conducted. The reliability of new package formats including package-on-package assemblies is being evaluated. Effective test methods for life assessment of batteries and electrochemical migration of lead-free finishes are being examined. Simulation modeling techniques for assessing drop and torsion are being developed. The reliability of embedded capacitors is being studied. In addition, cost modeling techniques for total cost of ownership and part reprocessing are being developed. The outcomes from EPSC studies provide methods and tools to our member companies for risk informed technology insertion.

The CALCE Prognostics and Health Management (PHM) Consortium has been focusing on advancing system-level PHM fusion (pattern recognition and physics of failure) algorithms, and implementing PHM methods for various avionics, automotive, computer, telecommunications and power applications. Sensor technologies with embedded PHM algorithms are also being developed. CALCE is also working with City University of Hong Kong to have the Second IEEE Prognostics and Health Management (PHM) Conference in Macau, China, in January 2010.

In response to the ever-changing needs of the electronics industry, CALCE Test Services and Failure Analysis Laboratory has recently made additions to its already extensive facilities and services to include six state-of-the-art DOF vibration testing and battery testing systems. In addition, the lab has been offering a unique failure analysis training course in conjunction with Buehler that combines practical experience with failure analysis lab equipment, lab techniques, and a strong physics-of-failure emphasis.

CALCE is also holding a series of advanced symposiums to address practical electronics industry concerns. Major symposiums to be held by CALCE include an accelerated testing symposium, a counterfeit parts symposium, a tin whisker mitigation symposium and an assembly rework issues symposium.

Finally, in the last issue of the CALCE Newsletter, I provided a list of the over 200 companies and organizations that are clients of CALCE. In addition to supporting industry, CALCE collaborates with some of the best universities in the world to expedite research developments. On the following page I have listed these universities.

I encourage everyone to visit the CALCE web site (www.calce.umd.edu) to learn more about the resources CALCE offers and methods for engaging CALCE. And if you have any questions, please feel free to contact me at pecht@calce.umd.edu.

Michael Pecht

CALCE Awarded NSF Alexander Schwarzkopf Prize for Technological Innovation

The Center for Advanced Life Cycle Engineering (CALCE) has been awarded the National Science Foundation (NSF) Alexander Schwarzkopf Prize for Technological Innovation. The Schwarzkopf Prize is awarded to NSF industry/university cooperative research centers that have had a significant impact on the world. CALCE won the award for its research on physics-of-failure reliability analysis methods and advanced supply chain management concepts for electronic products and systems. CALCE started as an NSF center in 1985 and today conducts funded research for over 200 organizations worldwide. "The reliance of modern technologies on complex electronics poses significant and growing challenges to managing life cycle risks. CALCE is actively conducting research to address the risks," says Professor Michael Pecht, founder and director of CALCE.

CALCE Electronic Products and Systems Consortium Technical Review Meeting

The CALCE Electronic Products and Systems Consortium (EPSC) will hold its Technical Review and Project Planning Meetings on March 17-18, 2009, at Martin Hall on the University of Maryland's College Park campus. All current members of the Consortium are invited to attend. Organizations interested in becoming CALCE EPSC members and wishing to attend the meeting should contact Dr. Michael Osterman at osterman@calce.umd.edu. The agenda for this event is available at www.calce.umd.edu under Upcoming Events.

The following projects will be presented at the meeting:

- Solder Joint Reliability of Reprocessed Parts and Reworked/ Repaired SMT Assemblies
- Vibration Fatigue Life of Pb-free Interconnects
- TMM Testing of SAC105 Solder
- Electrochemical Migration of Pb-free Printed Circuit Boards with Through-hole and Surface Mount Components
- Lead-Free Electronics Use and Repair Dynamic Simulation
- Physics-of-Failure (PoF) Qualification of Complex Electronic Systems
- Shock & Drop Qualification of MEMS Structures for Hand-held Products and Fundamental Understanding of MEMS Structures Subjected to High Shock Loads
- Effect of Impact Parameters on PWA Drop Durability
- PoF Models for Vibration Fatigue Mechanisms in SAC Assemblies at Different Temperatures
- Electronic Component Failure Categorization under Gun-Launched High G Loading
- Fundamental Understanding of MEMS Structures Subjected to High Shock Loads
- Improved Flex Cracking Calculator and Failure Detection for Multilayer Ceramic Capacitors
- RF and Digital Signal Analysis for Interconnect Reliability Assessment
- Reliability of Embedded Planar Capacitors
- Reliability Assessment of Flexible Modules
- Characterization of Thermo-mechanical Behavior of FBGA DDP-applied Memory Module
- Rapid Assessment of Viscoelastic Properties of Polymeric Materials
- Virtual Qualification of Automotive Power and ECU Modules
- Reliability Assessment of Power Electronic Cooling System
- High Temperature Electronics Roadmap
- Part Total Ownership Cost Model Extensions
- Counterfeit Parts Control Plan for the Trusted Aerospace Electronics Supply Chain
- Degradation Analysis of Lithium Ion Batteries
- Role of High Current in Solder Interconnect Reliability under Temperature Cycling
- Reliability of LGA Sockets
- Evaluation of Prestacking versus Stack and Reflow Package on Package (PoP) Assembly Process
- Mechanical Torsion Reliability of Package on Package (PoP)
- Evaluation of Conformal Coat for Tin Whisker Mitigation
- Effectiveness of Tin Whisker Removal and Impact of Corrosion on Whisker Growth
- Tin Whisker Properties and Failure Mitigation Offered by Conformal Coats

CALCE Collaborating Universities

In addition to working with industry, CALCE collaborates with numerous, international universities and academic institutions with unique capabilities and expertise to expedite research developments. We are very interested in collaborating with more universities in the world. If you have an interest, please contact Prof. Pecht at pecht@calce.umd.edu.

Below is a list of universities and institutions CALCE collaborates with:

- American University
- Beihang University (formerly BUAA), China
- Beijing University of Post and Telecommunications, China
- Chalmers University of Technology, Sweden
- City University of Hong Kong, China
- Ecole Polytechnique Feminine (EPF), France
- Ensiacet, France
- George Washington University, USA
- Georgia Tech, USA
- Harbin University, China
- Hong Kong University of Science and Technology, China
- Indian Institutes of Technology, India
- Istanbul Technical University, Turkey
- Ivano-Frankivsk National Technical University, Ukraine
- JiaoTong University, China
- Johannesburg University, South Africa
- Korea Advanced Institute of Science and Technology (KAIST)
- Loughborough University, UK
- Mannheim University of Applied Sciences (Fachhochschule Mannheim), Germany
- Middle Eastern Technical University, Turkey
- Nanyang Technological University, Singapore
- National Central University, Taiwan
- National Institutes of Technology Karnataka, Surathkal, India
- National University of Singapore, Singapore
- Osaka University, Japan
- Polytechnic University of Shanghai, China
- Purdue University, USA
- Seoul National University, Korea
- Technical University of Denmark
- University of Electronic Science & Technology of China
- Vaasan Ammattikorkeakoulu/Vasa Yrkeshögskola (University of Applied Sciences), Finland
- Vanderbilt University, USA
- Wroclaw University of Technology, Poland
- Yokohama National University, Japan

CALCE Simulation-Assisted Reliability Assessment Software Workshop

On Monday, March 16, 2009, CALCE will host a workshop on Simulation-Assisted Reliability Assessment Software at the University of Maryland's College Park campus. CALCE has developed one-of-a-kind software that provides physics-of-failure-based simulation-assisted reliability assessment at the PCB and component levels. This workshop will provide an introduction to the calcePWA, calceFAST, and calceTinWhiskerRiskCalculator software packages. Attendees will be provided the opportunity to learn about new features and use the software in a classroom environment. This workshop is offered at no cost to CALCE EPS Consortium members. Seating is limited. Please register with Joan Lee as soon as possible. For more information, please contact Dr. Michael Osterman (osterman@calce.umd.edu)

CALCE Support for PHM Center of Excellence in ShenZhen, China

In collaboration with CALCE, City University (CityU), Hong Kong, is opening a Prognostics and Health Management (PHM) Center of Excellence in ShenZhen, China. A large number of companies in China, particularly electronics companies in the greater GuangDong area, which includes ShenZhen, have shown great interest in PHM. Avionics, aerospace, computer, telecommunications and power companies are expected to become members of the new Center.

The CityU PHM Center is being started with a grant of over HK$16M for the first two years in addition to extensive facilities, meeting rooms, and offices. CityU is also supporting grants for three postdoctoral positions and numerous graduate students interested in obtaining a higher education in the field of prognostics and health management. The initial studies of the new CityU PHM Center will focus on advancing system-level PHM hybrid (pattern recognition and physics of failure) algorithms and implementing PHM methods for the Chinese electronics industry. Sensor technologies with embedded PHM algorithms will also be developed. Prof. Pecht is a visiting chair professor at CityU, coordinating the activities of the new CityU PHM Center and its cooperation with CALCE PHM to promote high quality prognostics research and development of state-of-the-art methods and technologies.

CityU is an outstanding university in China with a worldwide reputation in mathematics and engineering. Its new president, Prof. Way Kuo, is a member of the U.S. National Academy of Engineering, Academia Sinica (Taiwan), the International Academy for Quality, and the Chinese Academy of Engineering. President Kuo is a strong proponent of design-for-reliability methods and prognostics and is actively supporting this new center with help from Prof. Pecht. Within CityU, there is also strong cooperation with the Center for Electronic Packaging and Assemblies (EPA) of CityU, under the leadership of Chair Professor Y. C. Chan (EPA director and IEEE Fellow). The EPA Center will enable the new CityU PHM Center to utilize the EPA electronics test and analysis resources. In addition, there is synergy with other CityU faculty in the area of PHM for vibrations, shock, aging, and mathematics. For more information on the new CityU PHM Center of Excellence and to participate in this exciting new center, please contact Prof. Pecht (pecht@calce.umd.edu).

CALCE's PHM Collaborations

Prof. Pecht is working with the PHM team at Beihang University under the direction of Prof. Rui Kang. At Beihang there are more than 30 researchers engaged in failure PHM for electronic, mechanical, and opto-electrical products. They have an excellent suite of reliability test and failure analysis equipment and are significantly supported by the Chinese government. Prof. Pecht is also cooperating with Yokohama National University (YNU) in Japan. Prof. Qiang Yu leads the electronic packaging group at YNU, and his group has excellent reliability analysis facilities and simulation approaches for electronics. Prof. Yu also has excellent working relationships with Japanese companies and CALCE. Dr. Shibutani of YNU will be a key person leading the PHM effort with Prof. Yu. They also play important roles at the JSME Research Consortium of High Density Microelectronics Reliability.

Prof. Pecht is also cooperating with the new PHM Center at the National Taipei University of Technology (NTUT) in Taiwan to coordinate advanced PHM mathematical activities for specific engineering applications. Prof. C. H. Yang is one of the PHM directors at NTUT. They are now focused on topics including the aging of power plants and PHM in the petrochemical industry. Prof. Yang and Prof. Pecht see tremendous synergy in this global cooperation of resources and activities. Prof. Pecht is also working with Prof. My Tsai, who is the chairman of the Mechanical Engineering Department and heads up the electronic packaging effort at Chang Gung University, to establish PHM in test methods. For more information on CALCE's collaborative efforts, please contact Prof. Pecht (pecht@calce.umd.edu).

New CALCE PHM Consortium Members

CALCE is pleased to welcome two new members into the PHM consortium: nCode International (UK) and Schlumberger. Schlumberger is the leading oilfield services provider for oil and gas companies around the world. The company has 23 research and engineering facilities worldwide and in 2007 invested $728 million in R&D. Schlumberger has been a CALCE EPS Consortium member for over 10 years. nCode International is a leading supplier of durability, test, and analysis products to the automotive, off-road, rail, defense and aerospace markets. They provide solutions for testing and measurement, operational monitoring and product design.

PHM 2009 Spring Technical Review Meeting

Mark your calendar: the CALCE PHM Consortium 2009 Spring Technical Review will be held on March 19–20, 2009. At this meeting we will be presenting the research that we have been conducting for Consortium members including NASA, EADS (Air Bus), the U.S. Army, Boeing, Honeywell, Raytheon, BAE Systems, nCode International, General Dynamics, Energetics Technology Center, General Motors, Schlumberger, and Dell. The focus of this CALCE PHM Consortium meeting will be on the physics-of failure, data-driven, and fusion approaches to prognostics. This meeting will help the attendees gain a better understanding of a product's usage conditions, how to conduct improved qualification using prognostics, and how to monitor products using prognostic methods. Research updates, case studies, tutorials, and future projects will be discussed during this meeting. The agenda for the meeting will be uploaded onto our website soon (www.prognostics.umd.edu). For more details on how to attend the meeting, please contact Mr. Sony Mathew (sonym@calce.umd.edu).

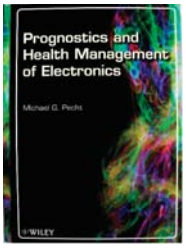
CALCE, QSI Invited for Army STTR PHASE II

CALCE and Qualtech Systems, Inc. have been invited for Phase II of the Army STTR titled "Dynamic Data-Driven Prognostics and Condition Monitoring of On-board Electronics." The project objectives are to implement a two-tiered failure prognostics approach. The first tier performs parameter forecasting and the second tier identifies the type of fault and its source. The project aims to utilize temporally adaptive decision fusion techniques for fusing evidence and probabilistic outcomes from parametric predictions. The GN&C system for an unmanned aerial vehicle is the platform of choice for this prognostics effort. The Phase-II effort aims to transform the Phase-I developments into standardized software modules and combine those modules into a deployable end-to-end prognostic and condition monitoring solution.

CALCE PHM Group Awarded Three-Year NASA Project

CALCE's Prognostics and Health Management Group has been awarded a three-year NASA project, "Reliable Diagnostics and Prognostics for Critical Avionics Systems." CALCE is developing and validating system- and component-level diagnostic and prognostic methods to increase the safety of avionic systems. This research aims to improve the accuracy of avionics fault detection capability, boost in-flight performance, reduce maintenance costs, and improve overall aircraft reliability. Additionally, this project involves developing algorithms for offline data analysis to detect soft faults and find patterns of soft faults in relation to other relevant system events. Prognostic algorithms are also being developed to track degradation and predict the remaining useful life for avionics systems. The project will include investigation of several potential mathematical techniques and/or a combination of these techniques to design diagnostic and prognostic algorithms.

New Prognostics and Health Management Book Released



CALCE is proud to announce that a new book by Prof. Pecht, titled *Prognostics and Health Management of Electronics*, has been published by Wiley Publishing Co. This book gives an overview of the concepts of PHM and the techniques being developed to enable prognostics for electronic products and systems. The state-of-the-art in sensor systems for in-situ health and usage monitoring, the various data-driven/statistical models and algorithms, the use of canaries, and the physics-of-failure based prognostics approaches are discussed. In addition, an overview of the implementation costs, including recurring, non-recurring, and infrastructure costs, as well as the cost avoidance with PHM is presented. Finally, the book presents a roadmap based on the current challenges and opportunities for research and development of PHM, and discussion of the activities associated with the prognostics research field, including companies, academia, and government organizations.

Degradation Analysis of Insulated Gate Bipolar Transistors (IGBTs)

CALCE performed degradation analysis on insulated gate bipolar transistors (IGBTs) that were aged by thermal-electrical stresses. IGBT aging was carried out by increasing the temperature and collector-emitter voltage simultaneously until the device latched (collector-emitter current was no longer controlled by the gate). The degradation analysis consisted of scanning acoustic microscopy (SAM), electrical characterization of the device over a temperature range between 25º and 200ºC, and capacitance-voltage (C-V) characterization of the gate oxide.

CSAM of the aged IGBTs revealed the presence of delamination/voids in the die-attach layer. Electrical characterization included measurement of the threshold voltage, collector-emitter voltage, and the transconductance over a range of temperatures. The Temptronic thermal stream generator was used to vary ambient temperature, and the measurements were carried out on the Tektronix 371A high power curve tracer. The results of the electrical characterization revealed an increased threshold voltage in the aged parts and a reduced collector-emitter ON voltage. The presence of gate oxide degradation was confirmed by capacitance-voltage (C-V) measurements. The C-V plots revealed degradation at the gate oxide as well as the oxide/substrate interface. From the results of the analysis, it was concluded that the die-attach degradation along with gate oxide degradation contributed to IGBT latch-up that occurred during aging. For more information, contact Dr. Diganta Das at digudas@calce.umd.edu.

Failure Analysis of Thick Film Resistors

Resistors are passive electronic devices that impede the flow of electric current in a circuit. Resistors are used in virtually all electronic systems. Common resistor types are ceramic resistors, embedded resistors inside of a printed circuit board, thin film resistors, and thick film resistors. The functionality of resistors is dependent on the electrical circuit and environmental conditions in which they are used. The three main failure modes observed in thick film resistors are electrical opens, electrical shorts and large changes in resistance values. Mechanisms such as copper dendrite growth, silver migration, sulfur atmosphere corrosion, and film cracking due to the molding compound used are primarily responsible for these failure modes. CALCE recently performed two separate failure analysis on TO-220-type thick film resistors. Failure analysis included the following techniques:

- Visual/optical inspection
- X-ray
- Cross-section
- Optical microscopy
- Environmental scanning electron microscopy (E-SEM) analysis
- Energy dispersive spectroscopy (EDS)

Starting with non-destructive techniques like visual inspection and X-ray analysis, anomalies and sites of failure were located. Once a failure site was located, it was exposed for further inspection and documentation of failure using destructive technique like cross-sectioning, followed by inspection by optical and E-SEM microscopy.

In the first failure analysis, a resistor showed an electrical open. X-ray analysis revealed a crack in the resistive thick film. This crack was exposed by cross-sectioning and imaged using optical and E-SEM microscopy. The crack explained the electrical open that the resistor exhibited. In the second study, the resistor showed a high resistance value. Visual and X-ray analysis did not reveal anomalies. The resistor was cross-sectioned from the top down to expose the connection of two leads to the resistor body. A cross-section of the joints revealed thinning of the connection between the resistive layer and the lead bond pads. The thinning explained the high value of resistance that the resistor exhibited.

Low and High Power Microscopy Capabilities Upgraded

CALCE has recently upgraded its optical imaging capabilities with a stereo inspection microscopy system with a high resolution color digital camera and an upright metallurgical microscope with an image capture system.

The stereo microscope has a trinocular 3.5-90X stereo zoom microscope, a fluorescent light ring, and an X-Y gliding table for hands-free inspection that can move a sample in the X or Y direction or both directions simultaneously. With this microscope, large standoff assemblies, cross-sectioned samples, and packaged components can be inspected and detailed images can be captured for documentation and reporting purposes.

The upright metallurgical microscope comes with reflected and transmitted illuminations as well as a true color digital imaging and capture system. This microscope offers eight magnification settings (40X, 64X, 100X, 160X, 400X, 640X, 1000X, and 1600X).

Device Microprobe and Thermal Characterization Capabilities at CALCE

Agilent continues to support the CALCE TSFA Laboratory with state-of-the-art equipment to help advance the analytical capabilities of the electrical characterization and failure analysis laboratories. The most recent addition is the Cascade Microtech M150T Platform, which addresses a wide array of device- and assembly-level DC/RF electrical measurement challenges.

The probe station has a modular design that offers a broad range of configuration possibilities for precision electrical measurements for a variety of devices such as singulated die to 150mm wafers, modules, and printed circuit board assemblies. The probe station comes with a temperature-controlled stage for electrical characterization of devices at various temperatures.

CALCE-Buehler Failure Analysis Course a Success

In September 2008, CALCE and Buehler jointly conducted another intensive four-day short course on failure analysis of electronics at the CALCE TSFA Laboratory. The course was attended by reliability engineers, device engineers, and process engineers from various companies and government organizations. The course included detailed lectures on failure mechanisms, modes, and effects analysis, non-destructive and destructive analytical techniques, and hands-on work on the latest Buehler sample preparation equipment and the state-of-the-art equipment at the CALCE TSFA Laboratory.

Based on the success of this and past courses, CALCE and Buehler are offering the course once again from April 21 to 24, 2009. Course outline and registration information can be found by visiting this website: http://www.calce.umd.edu/facourse/spring2009. Please contact Bhanu Sood at +1 (301) 405 3498 or by email at bpsood@calce.umd.edu for further information about the course.

New Version of CALCE PHM ROI Tool Available

A new version of the CALCE Prognostics and Health Management (PHM) Return-On-Investment (ROI) Tool (Version 2.2) is now available online. The PHM ROI Tool is a stochastic discrete-event simulation that can follow the life history of a population of systems containing one or more LRUs (Line Replaceable Units) and determine the effective life cycle costs, availability, and failure potential for sockets (a socket is a unique instance of an installation location for an LRU). In discrete-event simulation, the operation of a system is represented as a chronological sequence of events. Each event occurs at an instant in time and marks a change of state in the system. The PHM ROI simulator follows individual sockets through their support lives. In order to capture uncertainties in the characteristics of LRUs and in the operation of PHM approaches and structures, the simulator follows a population of sockets and determines probability distributions of life cycle costs and availabilities. For more information, contact Dr. Peter Sandborn at sandborn@calce.umd.edu.

Can the Helium Test Be Used for Polymer-Sealed MEMS Packages?

The helium fine leak test has been used widely to evaluate the hermeticity of MEMS packages. The conceptual idea behind the helium fine leak test is to "bomb" the specimen with helium, i.e., subject it to pressurized helium for a period of time and then transfer it to a helium mass spectrometer to measure the rate at which the helium inside the package leaks out.

In metallic seals, gas leakage is attributed to randomly present defects (nanoscale leak channels). CALCE has established through consortium projects (C05-17 and C06-17) a correlation to determine the true leak rate from the apparent leak data of the helium test, which is based on the gas conduction theory and expressed as

$$R(t) = \Omega \exp\left(-\frac{l_a t}{V p_0} \sqrt{\frac{M_{air}}{M_{He}}} \right) \qquad (1)$$

where R is the apparent leak rate, Ω is the initial apparent leak rate obtained by the helium spectrometer test, l_a is the true leak rate, V is the volume of the cavity, and p_0 is a constant (1 atm) and M_{air} and M_{He} are the molar mass of air and helium, respectively. Since the flow rate by gas conduction is a function of the molar mass of the gas species, the true leak rate obtained from the helium test can be used to determine the true leak rate of other gases using Equation (1).

Recently, polymers have gained widespread acceptance as a sealing material due to several advantages that they offer. These advantages include lower processing temperatures, compatibility with integrated circuit wafers, the ability to join practically every kind of wafer material, and relatively loose tolerance requirements in the planarization and cleaning processes. Unlike metal-sealed packages, gas leakage occurs due to the inherently permeable nature of sealing polymers (bulk material property). The gas diffusion in the polymeric seal is described by Fick's second law, which is given for the isothermal problem as

$$\frac{\partial p}{\partial t} = D \nabla^2 p \qquad (2)$$

where p is the gas pressure, ∇ is the gradient operator, and D is the gas diffusivity of the polymer used for the package.

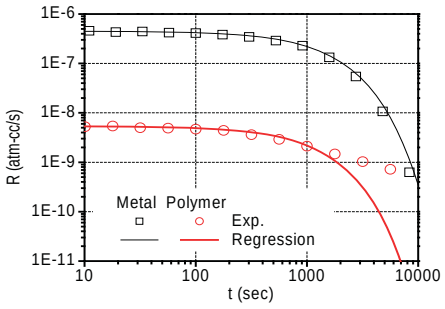


Fig. 1: Regression analysis using gas conduction equations to curve-fit helium test data of a metal-sealed package (V_{cavity} = 2.156 x 10^{-4} cc) and a polymer-sealed package (V_{cavity} = 3.1 x 10^{-4} cc). Test parameters include a bombing time of 6 hours at 4 atm and a dwell time of 10 minutes.

The different gas leakage mechanism in polymer-sealed packages incurs a gas leakage behavior different from that of metal-sealed packages. Figure 1 provides an example of gas leak behaviors of metal and polymer-sealed packages. The helium test results together with the curves from the nonlinear regression analysis using Equation (1) are plotted in the figure. Near perfect correlation exists for the metal-sealed package while for the polymer-sealed package correlation starts to fail after approximately 1000 seconds.

It is tempting to apply the helium test to polymer-sealed packages to assess the hermetic performance. Due to the different gas leakage mechanism, however, the helium test has two critical limitations when applied to polymer-sealed packages.

1) The helium signal collected by a spectrometer may not represent the true helium leak from a cavity wherein a device is present. Gas diffusion is a much slower process than gas conduction. It takes a significant amount of time for gas molecules to travel from the environment to the cavity via a polymeric seal (lag time), while the transport process occurs almost instantaneously in the leak channels of a metallic seal. The lag time ranges from several hours to even hundreds of days depending on the diffusion properties and geometry of the polymeric seal.

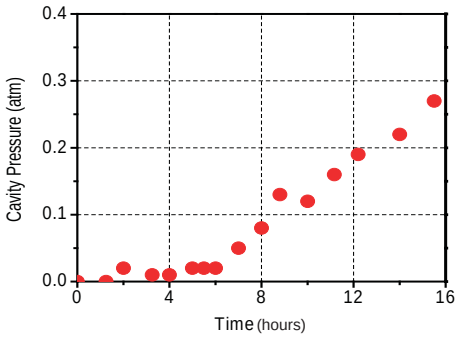


Fig. 2: Cavity pressure evolution of a polymer-sealed MEMS package obtained from the optical leak test.

Figure 2 illustrates the cavity pressure history of an MEMS package subjected to pressurized helium at 4 atm. The results were obtained from an optical leak test developed through CALCE consortium projects (C04-09 and C05-17). The results showed that for the first several hours virtually no helium gas had accumulated in the cavity. During this lag time helium did not transmit through but kept being absorbed into the polymeric seal. The opposite situation happened when the package was subjected to a spectrometer after bombing; helium molecules desorbed from the seal, not from the cavity, were detected by the spectrometer for a duration of time comparable to the lag time. Since the bombing time was shorter than the lag time, the data from the helium test contained helium gas that escaped solely from the polymeric seal.

2) There is no simple relationship of diffusion mechanisms among different gas species. Due to the complex nature of gas diffusion in geometry and governing equations, the apparent leak rate cannot be expressed by a closed-form correlation like Equation (1). Instead, the diffusion equation should be solved to assess the gas leakage of polymer-sealed packages. The diffusion properties of a sealing polymer are necessary. The properties of helium might be determined from the helium fine leak test. The helium gas is in general not a critical concern in MEMS package reliability. In order to predict the leakage of other detrimental gases using the helium test results, the properties of helium must be linked with those of other gases by some relationship such as Equation (1). However, there is no relationship among the properties of various gas species.

In conclusion, the helium leak test is absolutely of no use for polymer-sealed packages. Rather, the diffusion properties of the sealing polymer with regard to gas species of interest should be measured in order to accurately assess and predict gas leakage (diffusion) in polymer-sealed MEMS packages.

For more information, please contact Dr. C. Jang at csjang@calce.umd.edu or Prof. B. Han at bthan@calce.umd.edu.

Managing Product Reliability through Reliability Capability Assessment

The extent to which an organization's practices are successful in producing a product that meets its reliability objectives depends on the processes established to ensure the reliability of the product and the effectiveness of the individuals responsible for implementing those processes. In a more general sense, the consistency with which an organization produces reliable products over the long term is determined, in large measure, by its recognition of the influence of its various practices on the reliability of the final product, as well as ongoing efforts to maintain and improve their effectiveness.

A reliability program is the collection of practices that have a direct bearing on product reliability, whether they are formalized or not. IEEE Std 1332-1998, "IEEE Standard Reliability Program for the Development and Production of Electronics Systems and Equipment," provides broad guidelines for the development of an effective reliability program.

The standard identifies three reliability objectives:

1. The supplier, working with the customer, should determine and understand the customer's requirements and product needs so that a comprehensive design specification can be generated.
2. The supplier should structure and follow a series of engineering activities that lead to a product that satisfies the customer's requirements and product needs with regard to reliability.
3. The supplier should include activities that assure the customer that reliability requirements and product needs have been satisfied.

Reliability capability assessment is a process that was developed at CALCE for evaluating the extent to which organizational traits allow a particular organization to consistently meet the objectives of an effective reliability program. The need for reliability capability assessment as a tool for managing supply chains and product reliability has been recognized by IEEE, which has issued its formal approval of a new Standard for Organizational Reliability Capability. This document, which was developed by a CALCE-led reliability standards working group, has just been published as IEEE Std 1624.

Market forces have driven electronics manufacturers to reduce manufacturing costs and rely upon a worldwide supply chain. As the factors that influence the reliability of a manufacturer's products are dispersed to remote locations and governed by different managerial practices, reliability capability assessment becomes essential for managing reliability across all tiers of the supply chain. Furthermore, this same process can be used for self-assessment by companies seeking an independent evaluation of their own reliability practices and opportunities for improvement. CALCE has performed numerous such assessments, providing prioritized recommendations for corrective action and working hand-in-hand with organizations to implement these recommendations.

For further information on the reliability capability assessment process and how it can benefit your company, contact Dr. Michael H. Azarian at (301) 405-7555 or mazarian@calce.umd.edu.

CALCE Researchers Receive Best Paper Honor at 2008 IMAPS Symposium

On November 4, 2008, CALCE researchers Gustavo Plaza, Dr. Michael Osterman, and Dr. Michael Pecht received the Best Paper of Session Award for their paper "Vibration Durability of Mixed Solder Interconnects" at the 41st International Symposium on Microelectronics. The symposium, hosted by the International Microelectronics and Packaging Society at the Rhode Island Convention Center, focused on current developments in microelectronics packaging and comprised over 200 presentations, 17 professional development courses, and 200+ technology showcase and exhibition booths. The Best Paper of Session Award recognizes exemplary papers submitted to the symposium. Nominees for the Best Paper of Session Award are selected by the session chairs. After reviewing and discussing selected papers, session chairs select award recipients according to the IMAPS internal rating system.

For the full text of the paper please visit the following sites:
CALCE website: www.calce.umd.edu/articles/index.html
IMAPS website: www.imaps.org/imaps2008/techprogram.htm

CALCE Welcomes New Researcher

Mr. Andrew Kluger joined CALCE as a Visiting Senior Research Scientist this spring. Mr. Kluger has a BA in International Affairs and Economics from the University of California, Davis; a Juris Doctorate from the University of San Francisco School of Law; and a degree from the Johnson Graduate School of Management at Cornell University. He is an entrepreneur, a business executive, a venture capitalist, and a philanthropist. He is the founder and CEO of Early Bird Alert, Inc., a start-up home healthcare patient-centric communications device producer; chairman of the board and former CEO of Hawaii Air Ambulance; president of Kluger & Associates, a medical management company; managing partner of Bluegrass Assisted Living in Kentucky; and president of Book Bank USA, a non-profit that has donated over five million books and computers to schools and libraries worldwide since 1966. He has received numerous awards, including the Livingston M.F. Wong, MD Lifetime Achievement Award in recognition for outstanding service and dedication to the community and the emergency medical services, a commendation by the Hawaii State Senate, and a National Broadcasters Association Award presented by NBC Television. He also serves on the National Board of Directors of the Association for Air Medical Services and is a member of the International Association of Financial Planning, Practitioners Division. He has handled over forty mergers and acquisitions in the healthcare field, including the bringing of a medical IPO on the New York Stock Exchange. He has handled the debt workout of four large international enterprises in Latin America.

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CALCE Briefs U.S. DoD on Reliability of U.S. Military Electronic Equipment

On Friday, January 9, 2009, CALCE met with members of the U.S. Department of Defense, including the Honorable Dr. Charles McQueary, Mr. Chris DePitto, Mr. Brian Simmons, Col. Nina Armagno, Dr. Michael Cushing, Dr. Forrest Crain, Dr. David Mortin, and Mr. Clarke Fox. CALCE Professor Michael Pecht presented major issues facing the current and future reliability of U.S. military electronic equipment and systems. Prof Pecht discussed the complex and uncontrollable supply chains, looking specifically at China's impact, reliability maturity, and growing concerns with counterfeit material and electronics. He then addressed rapidly changing technologies, particularly issues with advanced commercial-off-the-shelf devices, environmental laws (e.g., lead free/halogen-free electronics), new failure mechanisms (e.g., tin whiskers, semiconductor packages), and obsolescence. Prof. Pecht also addressed issues associated with outdated standards and handbooks and their impact on reliability prediction (e.g., Mil-Hdbk-217 and progeny), qualification and logistics support, and sustainability. He then discussed the prognostic methods that CALCE has been applying to provide early warning of impending failures, improve testing and qualification, forecast maintenance as needed, detect counterfeit electronics and aid in addressing the No-fault-found problem common in today's electronics. Following the presentation, there were discussions on critical issues and solution approaches.

Workshop on Testing Lead-Free Assemblies

In June 2008, GEIA-STD-0005-3, "Performance Testing for Aerospace and High Performance Electronic Interconnects Containing Pb-free Solders and Finishes," was released by the ITAA. This document was one of several deliverables provided by the AIA-GEIA-AMC LEAP Working Group. The document is undergoing updates to Revision A, and, as part of the update process, additional information/data in lead-free testing is of interest.

The University of Maryland Center for Advanced Life Cycle Engineering (CALCE) is pleased to announce that it will host a workshop on April 14, 2009, at the University of Maryland, College Park, MD, to provide a forum for technical exchange regarding the testing of lead-free soldered assemblies. This work shop will present:

- Lessons learned in testing of lead-free electronics, especially their differences from Sn-Pb electronics
- Performance data (e.g., mechanical, environmental) for lead-free solders
- Critiques/comparisons of various test approaches/procedures
- New/novel test methods

For event information, please visit the CALCE Web site (www.calce.umd.edu) or contact Dr. Michael Osterman (osterman@calce.umd.edu)

Third International Symposium on Tin Whiskers

On June 23-24, 2009, CALCE will hold the Third International Symposium on Tin Whiskers at the Technical University of Denmark in Lyngby, Denmark. This symposium will provide a forum to present the latest information about tin whiskers. Despite intense research by industrial and research scientists, the growth mechanism of tin whiskers remains insufficiently understood to develop for tin whisker acceleration tests. To address the failure threat presented by tin whiskers, equipment manufacturers are using various mitigation strategies. You are invited to participate either by attending or presenting at the event. Presentations should be in the following areas:

- Whisker Growth Studies
- Tin Whisker Test Methods
- Tin Whisker Mitigation Techniques

Please submit abstracts of presentations to Dr. Michael Osterman (osterman@calce.umd.edu).

2009 Symposium on Avoiding, Detecting, and Preventing Counterfeit Electronic Parts

On June 25-26, 2009, CALCE will hold a two-day symposium on avoiding, detecting, and preventing counterfeit parts at Lyngby, Denmark in collaboration with SMTA and the Technical University of Denmark. At the request of many attendees from the two previous symposiums and interested contacts, this third symposium is being held in Europe.

This symposium will be valuable to supply chain managers, component engineers, brand protection specialists, marketing and procurement policy makers, contracts management, security specialists, and other interested engineers. Our goal is to provide relevant information that will be useful for solving problems today while planning for tomorrow's business and technology environment. If you are interested in presenting, submit an abstract of your proposed presentation to Dr. Diganta Das via email at diganta@umd.edu.

Speakers at the workshop are exempted from the registration fee. For more information, please visit, www.calce.umd.edu.

Selected Publications

1. R. Singh and M. Pecht, "Commercial Impact of Silicon Carbide," IEEE Industrial Electronics Magazine, Vol. 2, Issue 3, pp. 19-31, Sept. 2008.
2. S. Woo and M. Pecht, "Failure Analysis and Redesign of A Helix Upper Dispenser," Engineering Failure Analysis, Vol. 15, Issue 6, pp. 642-653, Sept. 2008.
3. A. Choubey, M. Osterman, and M. Pecht, "Microstructure and Intermetallics Formation in SnAgCu BGA Components Attached with SnPb Solder under Isothermal Aging," IEEE Transactions on Device and Materials Reliability, Vol. 8, Issue 1, pp. 160-167, 2008.
4. A. Choubey, H. Yu, M. Osterman, M. Pecht, F. Yun, L.Youghong, and X. Ming, "Intermetallics Characterization of Lead-free Solder Joints under Isothermal Aging," Journal of Electronic Materials, Vol. 37, No. 8, pp. 1130-1138, Aug. 2008.
5. H. Qi, S. Ganesan, and M. Pecht "No-fault-found and Intermittent Failures in Electronic Products," Microelectronics Reliability, Vol. 48, Issue 5, pp. 663-674, May 2008.
6. M. Azarian, M. Keimasi, and M. Pecht, "Flex Cracking of Multilayer Ceramic Capacitors Assembled with Lead-Free and Tin-Lead Solders," IEEE Transactions on Device and Materials Reliability, Vol. 8, Issue 1, pp. 182-192, March 2008.
7. S. Zhang, R. Kang, X. He, and M. Pecht, "China's Efforts in Prognostics and Health Management," IEEE Transactions on Components and Packaging Technologies, Vol. 31, No. 2, pp. 509-518, June 2008.
8. P. Sandborn and J. Myers, "Designing Engineering Systems for Sustainability," Handbook of Performability Engineering, ed. K. B. Misra, Springer, pp. 81-104, 2008.
9. D. P. Fitzgerald, J. W. Herrmann, P. A. Sandborn, L. C. Schmidt, and T. H. Gogoll, "Constructing a Product Design for Environment Process," Handbook of Performability Engineering, ed. K.B. Misra, Springer, pp. 57-69, 2008.
10. Y. Wang, B. Han, D. W. Kim, A. Bar-Cohen and P. Joseph, "Integrated Measurement Technique for Curing Process-dependent Mechanical Properties of Polymeric Materials Using Fiber Bragg Grating," Experimental Mechanics, Vol. 48, pp. 107-117, 2008.
11. A. Goswami and B. Han, "On Ultra-Fine Leak Detection of Hermetic Wafer Level Packages," IEEE Transactions on Advanced Packaging, Vol. 31, No. 1, pp. 14-21, 2008.
12. C. Jang, S. Park, B. Han, and S. Yoon, "Advanced Thermal-Moisture Analogy Scheme for Anisothermal Moisture Diffusion Problem," Journal of Electronic Packaging, Vol. 130, No. 1, pp. 011004-1-8, 2008.

Eighth International Conference on Reliability, Maintainability and Safety

On July 21-25, 2009, the 8th International Conference on Reliability, Maintainability and Safety will be held in Chengdu, China. The ICRMS is an international forum for the presentation of new results, research development, case studies and applications in RMS areas. This year's conference focuses on a range of topics including RMTSS Design and Analysis, RMTSS Management, Fault Analysis, and Failure Physics. To submit papers for the conference, send electronic copies (pdf or Word) of full manuscripts, not exceeding six single-spaced pages, along with the authors' names, affiliations, and complete email addresses, to Conference Secretary at secretariat@icrms.cn by February 28, 2009. The manuscript template is available at http://www.icrms.cn/en/xzzx.asp.

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