SPRING/SUMMER 2008

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CENTER FOR ADVANCED LIFE CYCLE ENGINEERING (CALCE)
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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

A friend of mine who worked at AMD told me that they had designed an IC in the USA, fabricated the wafer in Ireland, assembled the IC in Korea, and tested it in Japan. This part was probably then shipped to China for integration into a final product and sold all over the world. Clearly, every player in the supply chain is important, and any player in the supply-chain can contribute to the failure of the final product.

When CALCE was formed in 1985, research sponsorship was primarily based in the USA. Today, CALCE sponsorship represents virtually all sectors of the electronics industry with participation from organizations in Denmark, England, France, Finland, Germany, Japan, Korea, Turkey, India, and China. CALCE now reflects the growing internationalization and commercialization of electronics.

This past year, CALCE worked with over one hundred international companies and organizations. One focus has been assessment of the increasingly complex global supply chain. To assist organizations, CALCE has developed a reliability capability assessment process to provide a reliability maturity evaluation for companies. The effectiveness of this approach has been demonstrated with numerous companies, and the process is on its way to becoming IEEE Standard 1624 for Organizational Reliability Capability.

The book, China's Electronics Industry, (William Andrew Publishing 2007) addresses many of the supply chain issues of concern today. CALCE faculty have also addressed the United Nations and numerous companies regarding China's electronics industry. To be more active in China, CALCE, in collaboration with City University of Hong Kong, is establishing a new office in ShenZhen, China. This new CALCE office will offer CALCE reliability courses and consulting services. If you are interested in more information, feel free to contact me.

Through the CALCE Electronic Products and System Consortium, CALCE continues to provide research and technical support to world-leading companies. In 2008, CALCE EPSC is conducting thirty-five studies. Topics include more efficient and cost-effective accelerated testing methods, improved design-for-reliability (DfR) methods, and assessment of some new failure and degradation mechanisms. CALCE is also continuing studies on refinishing, reballing, rework and mixed solder assembly issues resulting from the transition to lead-free electronics.

The CALCE Prognostics and Health Management (PHM) Consortium now has fourteen members and continues to grow. Myra Torres, formally of Sun Microsystems, has joined CALCE to help lead PHM research efforts. CALCE has also won three new PHM contracts: "Advanced Prognostic and Health Management (PHM) and Model-based Prognostic Useful Life Remaining Capabilities for Aircraft Tactical Information and Communication Systems" with Global Strategic Solutions, funded by the U.S. Navy; "Dynamic Data-Driven Prognostics and Condition Monitoring of On-board Electronics" with Qualtech Systems, funded by the U.S. Army; and "Reliable Diagnostics and Prognostics for Critical Avionics Systems" funded by NASA. The CALCE PHM group is involved in state-of-the-art prognostics research and has been applying research outcomes to a host of electronics devices, products and systems.

The CALCE Test and Failure Analysis Laboratory continues to provide rapid and timely failure analysis and material characterization services. Ongoing investigations include thick film power resistor failures, PCB failures due to conductive filament formation, and several failures traced to poor lead-free solder joint quality. In addition, CALCE had been helping industry with development of qualification plans, virtual qualification of electronics assemblies, design review for risk identification and mitigation, and developing transition plans in the face of changing technologies and regulatory initiatives.

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, visit us in person in March (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 Electronic Products and Systems Consortium Spring Technical Review Meeting

The CALCE Electronic Products and Systems Consortium (EPSC) will hold its Spring Technical Review and Project Planning Meetings March 18-20, 2008 in Resnik Hall of the Glenn L. Martin Building, on the University of Maryland 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 Michael Osterman at osterman@calce.umd.edu. The fee to attend the meeting for non-members is $1,500. The agenda for this event is available at www.calce.umd.edu under Upcoming Events.

The following projects will be presented at the meeting:

- Factors Affecting Flex Cracking and Moisture Sensitivity of Standard and Flexible Termination Multilayer Ceramic Capacitors
- Comparative Analysis of Interconnect Degradation Using RF Impedance and DC Resistance
- Mitigation Measures for Electrochemical Migration on Lead-Free Assemblies with Low-Profile Components
- Reliability of Embedded Capacitors
- calcePWA Shock Model Improvements–Load Sequencing
- Fundamental Understanding of MEMS Structures Subjected to High Shock
- Electronic Component Failure Categorization under Gun-Launched High G Loading
- Field Programmable Gate Arrays (FPGA) Antifuse Aging during Storage
- Identification of Sources of Counterfeit Parts
- Derating Guideline Evaluation for Electronic Products
- Lead-free Solders in High Temperature Applications
- Solder Joint Reliability of Solder Dipped (SAC/SnPb) and SnBi Leaded SMT Packages in a Sn37Pb Assembly Process
- Effect of Cyclic Fatigue Damage Accumulation on Properties of SAC Solders
- Effect of Impact Pulse Parameters on PWA Drop Durability
- Model-based Design Guidelines for Shock and Drop Loading
- Durability Assessment of an Advanced Power Electronics Module
- Physics-of-Failure Qualification of Electronic Systems
- Microvia Non-destructive Inspection & Qualification
- Acceleration Parameters of Highly Accelerated Life Tests: Combined Effect of Moisture and Temperature on PEMS Reliability
- Physics of Failure of Cu/Low-k Silicon Devices
- Accelerated Testing Guideline of a COF Package Assembly
- Evaluation of Residual Stresses of PEM Induced by Effective Chemical Shrinkage of Polymer Materials
- PoF-Based Design for Optimum Reliability of High Power LED
- Virtual Qualification of Engine Control Modules
- Reliability Investigation of Power Electronic Inverter Design
- Sustainment Stovepipe Analysis and Avoidance
- Stress Relaxation in Stamped Metal Land Grid Array Sockets
- Characterization of Halogen-free PCB Laminate Materials
- Tin Whisker Shorting Propensity and Growth Assessment
- Thermal Performance and Reliability of Thermal Interface Materials
- Lead-free Synthesis
- Reliability of Pb-free and Reballed PBGAs in SnPb Assembly Process
- Solder Joint Reliability of Reworked/Repaired SMT Assemblies
- Vibration Fatigue Life of Pb-free Interconnects
- Thermal Aging Effect on Reliability of Pb-free Interconnects
- Modeling Mechanical Torsion of PWA in calcePWA

CALCE and Six Sigma Examine the Reliability of Reballed Lead-free Ball Grid Arrays

Due to the reduced availability of tin-lead ball grid arrays (BGAs), many manufacturers who are exempt from Restriction of Hazardous Substances (RoHS) regulations are using (or exploring the use of) reballing to convert lead-free BGAs to tin-lead. Of primary concern is the reliability of mixed assembly interconnects (lead-free BGAs with tin-lead paste). Some studies indicate adequate reliability can be achieved in mixed assembly products provided the assembly process is tightly controlled. However, to avoid having to re-qualify the entire assembly, many have turned to BGA reballing.

Reballing of ball grid arrays has been around for many years. The reballing process consists of ball removal and ball attachment. The removal process can be performed by solder wick or solder wave methods. Ball attachment can be performed by solder ball template and ball drop methods, or through the use of a preform (water soluble paper that holds the solder balls in the appropriate pattern). During the ball removal and ball attachment process, the parts are subjected to temperatures sufficient to melt the solder balls. These multiple heat cycles, combined with additional part handling, raise reliability concerns.

CALCE and Six Sigma are midway through a comprehensive study to examine the impact of reballing on BGA packages, and to determine the interconnect reliability of reballed BGAs. For more information on this study, please contact Michael Osterman (osterman@calce.umd.edu) or Russ Winslow (russ@solderquik.com)

CALCE and Celestica Examine Reliability of Reworked Assemblies

The conversion to lead-free materials and manufacturing processes has renewed interest in the reliability of reworked assemblies. Interest includes mixed assemblies in which tin-lead solder is used in the repair of lead-free assemblies and where lead-free parts are used on assemblies originally using tin-lead paste.

To examine the reliability of reworked assemblies, CALCE has two test vehicles that are being reworked at a facility operated by Celestica. In this study, the reliability of daisy-chained parts replaced one or three times is being examined. Part types include ball grid array, TSOP, and 2512 resistors. After the part replacement operations, the assemblies will be subjected to temperature cycling and mechanical loading. The reliability of the reworked assemblies will be compared with that of the original assemblies.

For more information on this study, please contact Michael Osterman (osterman@calce.umd.edu) or Diganta Das (diganta@umd.edu)

Vestas Joins CALCE

The Dutch wind turbine company, Vestas, has joined the CALCE Electronic Products and Systems Consortium. Vestas is the world leader in supplying wind power solutions. Through CALCE EPSC, Vestas will participate with other world-leading organizations in proactively addressing electronics reliability. Vestas joins other EPSC members in the field of alternative energy that are working with CALCE to create high-reliability systems. If your organization is interested in joining a CALCE consortium, please contact Michael Osterman (osterman@calce.umd.edu).

CALCE Prognostics and Health Management Consortium Technical Review Meeting

The CALCE Prognostics and Health Management (PHM) Consortium hosted a successful Fall 2007 Technical Review Meeting at the University of Maryland on November 7-8, 2007. In attendance at the meeting were members, as well as engineers from various industries. The progress of nine research projects was presented, along with five case studies that demonstrated PHM implementation. Key achievements presented were:

- baseline characterization and anomaly detection for electronic products
- potential failure precursor identification in multilayer ceramic capacitors
- vehicle component prognostics in vibration and shock environments
- assessment of the temperature and relative humidity environment of IC sockets in enterprise servers using health monitoring
- applications of impedance analysis for detection of interconnect degradation
- updates in PHM cost modeling software
- uncertainty assessment of prognostics for electronics under vibration loading

The CALCE PHM Consortium has scheduled the next Technical Review Meeting for March 20 – 21, 2008 at the University of Maryland, College Park campus. This meeting will be immediately after the CALCE EPS Consortium meetings. The agenda and details for the meeting will be posted at http://www.prognostics.umd.edu/announcements.htm.

CALCE Offers New PHM Course

CALCE offered a Prognostics and Health Management course at the University of Maryland, College Park, Fall 07 (ENME 808A). This course provided the fundamental tools and techniques for PHM implementation. Topics included methods for in-situ monitoring, approaches for resource-efficient data collection, algorithms for data reduction and parameter extraction, software for damage assessment, methods for identifying and analyzing precursors based on failure mechanisms, and techniques for predictions that can be used for assisting maintenance and logistic decisions. The application areas included structures, machine-tool, aerospace, mechanical, and electronic products.

This was an interdisciplinary course open to students from mechanical, electrical, civil, and aerospace engineering, as well as public policy and engineering management. In addition to the CALCE faculty, several renowned PHM experts from industry, academia, and government participated as guest lecturers in this year's course.

Myra Torres Joins as Assistant Research Director for CALCE PHM Consortium

Myra Torres is now Assistant Research Director for the CALCE PHM Consortium. Myra brings over eighteen years of experience in component reliability engineering and product risk assessment from her former position at Sun Microsystems. Her experience in PHM spans market demands for reliable and available systems, increasing technology complexity of electronics, and the limitations of conventional reliability methods. At CALCE, Myra is involved with PHM methodologies and implementations for electronic systems.

CALCE Contributes to International Technology Roadmap for Semiconductors and Prognostics

Professor Michael Pecht has contributed a special section on "prognostics of electronics" for inclusion in the new International Technology Roadmap for Semiconductors (ITRS) for 2008. Professor Pecht noted that "future electronic system designs will integrate sensing and processing modules for in-situ prognostics and health monitoring (PHM)." PHM technology will enable products with self-healing capability, autonomous fault isolation, and diagnostics. These prognostic capabilities are utilized for early warning systems when a part or system has incurred damage and is in need of maintenance. Further exploration of the enabling capabilities of PHM technology has only begun. However, applications such as resource management, supply chain optimization, and maintenance optimization are being developed. CALCE has also developed return-on-investment (ROI) software to aid in PHM implementation for maintenance optimization. PHM applications have also been demonstrated for tamper detection and counterfeit parts monitoring.

Sensors have been around for decades, so what is different about PHM? Technology advances in health monitoring and data-driven methodologies utilizing system health data have enabled significant advances to product and service reliability. Professor Pecht commented that PHM technology has reliability potential for both new product development as well as legacy systems. He added, "Advances in sensors, microprocessors, compact non-volatile memory, battery technologies, and wireless telemetry have already enabled the implementation of sensor modules and autonomous data loggers. For in-situ health monitoring, integrated, miniaturized, low-power, reliable sensor systems operated using portable power supplies are being developed. These sensor systems will have self-contained architectures with little intrusion into the host product, in addition to specialized sensors for monitoring localized parameters."

PHM technology is enabling more efficient business decisions by bridging the gap between reliability engineering and the real-time usage and environmental loads on a product. Professor Pecht projected that in the near future, "sensors with embedded algorithms will enable fault detection, diagnostics, and remaining-life prognostics, which will ultimately drive the supply chain." Prognostic information from the system will be linked via wireless communications to relay needs to maintenance officers. RFID technology used in warehouses today can then automatically locate parts within the supply chain, all integrated through a secure web portal to acquire and deliver replacement parts quickly on an as-needed basis.

PHM technology incorporated into electronic products is viable. Bill Bottom, representative of the ITRS road mapping committee for 2008, has noted the potential for semiconductor and electronic systems by incorporating a PHM track in the roadmap. To further research and develop PHM technologies, CALCE has formed a PHM laboratory and Consortium. To learn more about the CALCE PHM visit www.prognostics.umd.edu.

Virtual Qualification Software Workshop

On March 17, 2008, CALCE will be offering a one-day workshop with hands-on training on the use of the current calcePWA and calceFAST software and a discussion of real-world applications, online resources, and future directions.

For more information on the workshop, go to www.calce.umd.edu or contact Dr. Michael Osterman at osterman@calce.umd.edu, tel. 301-405-8023.

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CALCE Test Service and Failure Analysis Laboratory

The CALCE Test Services and Failure Analysis (TSFA) Laboratory provides support to the electronic 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 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 that lead 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.

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

CALCE TSFA adds Cold Bump Pull Capabilities

CALCE has added cold bump pull (CBP) capabilities to its existing range of multi-purpose, pull and shear testing facilities. Cold bump pull testing avoids the possible effects of temperature and intermetallic reactions on a bond under test (and the bond within the probe) associated with hot pull testing. The cold pull test is much faster than the hot pull alternative, taking approximately five to fifteen seconds per bump compared with, typically, two minutes for hot pull.

CALCE Acquires Drop Test Capabilities

Electronic products and assemblies are advancing towards smaller size with much larger capability and performance. Thus, the need to conduct shock testing and strength assessments for small, complex electronic devices is greater than ever before. CALCE has recently acquired Lansmont's Model M15/23 shock test system. With the system, CALCE can test more stringent shock requirements for today's electronics. The Model M15/23 incorporates an electric hoist for table position and utilizes a seismic base impact surface that is on a low frequency, damped suspension system. The seismic base itself is a massive steel block that will isolate the shock energy from transmitting through the laboratory floor into the surrounding building. The Model M15/23 has the ability to test boards and assemblies weighing up to 35 lbs. (16 kg) with a footprint up to 5.9 inches by 5.9 inches (15 cm x 15 cm). With optional machine components and shock pulse programmers, the Model M15/23's unique magnesium carriage design can generate half sine shock pulses with a maximum acceleration of 5000 g and durations as short as 0.25 msec.

Importance of Cleanliness in Reballing, Replating, and Rework

Electronic part suppliers are converting products from conventional tin-lead to lead-free assemblies to meet domestic and international regulations, making the availability of conventional SnPb parts a particular concern to electronic manufacturers that are exempt from the Pb-free requirement. These manufacturers face a shortage of ball grid array parts with tin-lead balls. In cases where conventional SnPb area arrays are not available, some manufacturers have looked into reballing lead-free area arrays with tin-lead solder balls. CALCE is investigating the assembly reliability of these assemblies (see page 2).

A major reliability concern with reballing of BGA components is the cleanliness of the components after the process is completed. Unclean substrates or flux residues can potentially lead to electrochemical growth and migration between solder balls on a reballed BGA. To avoid these failures, it is important to maintain a high level of cleanliness in reballed parts. The ion chromatograph (IC) is a common tool used in the industry for cleanliness testing of electronic devices. The IC can identify and quantify the specific ionic contaminants. The most common test method used is the IPC TM-650 2.3.28.

In a typical IC process, the extraction of the contamination on the surface is carried out, followed by injection of the extracted solution into an ion chromatograph. The retention times of ions are then analyzed and compared with standard solutions to determine the concentrations of the contaminating species.

The extraction process typically starts by placing the reballed device into an ionically clean bag and immersing in an extract solution of 75% alcohol and 25% deionized water at 80°C for one hour. The IC equipment then separates and detects each individual ion for which a standard was previously run and was calibrated. The Dionex600 IC system at CALCE can detect and measure fluoride (F-), chloride (Cl-), bromide (Br-), nitrate (NO3-), nitrite (NO2-), phosphate (PO4-), sulfate (S4O2--), and weak organic acids.

CALCE Provides Tubitak-UZAY with Reliability Training in 2007

This past November, CALCE conducted two weeks of technical training to researchers within Tubitak-UZAY, the Space Technologies Research Institute. The technical training included:

- Lead-free and Mixed Assembly Readiness
- Design for Reliability
- Virtual Qualification
- Electronic Part Selection and Management
- Obsolescence Management
- Part Uprating
- Supply Chain Management
- High Temperature and Thermal Management
- Reliability

If your group is interested in receiving technical training on the topics listed above or on topics related to electronic prognostics and health management, please contact Dr. Diganta Das (diganta@umd.edu).

CALCE Developing a Novel Technique for Detecting Solder Joint Degradation

The trend for many types of electronic products is toward higher operating frequencies or digital bit rates. At high frequencies, signal propagation is concentrated at the surface of interconnects, a phenomenon known as the skin effect. Solder joints that connect components with printed circuit boards of electronic products are exposed to various load conditions, such as temperature cycling, vibration loading, or humidity during their lifecycles. Many solder joint failures are attributed to temperature cycling due to a mismatch of the coefficients of thermal expansion (CTE) between the components and boards. Degradation of solder joints, such as cracking, usually initiates at a surface and propagates inward. Therefore, even a small crack at the surface of a solder joint may affect the performance of high speed electronic assemblies as well as the solder joint itself.

Traditional low speed resistance measurements are not appropriate for detecting such a small fault. More accurate and sensitive alternatives are required for monitoring the reliability of current and future electronic products. CALCE has been conducting research on an improved means of sensing interconnect degradation appropriate for high frequency assemblies using RF impedance analysis, which measures the effect of frequency on electrical performance. Due to the skin effect, the use of RF impedance measurements can be used as a better early indicator of the physical degradation of solder joints than DC resistance measurements.

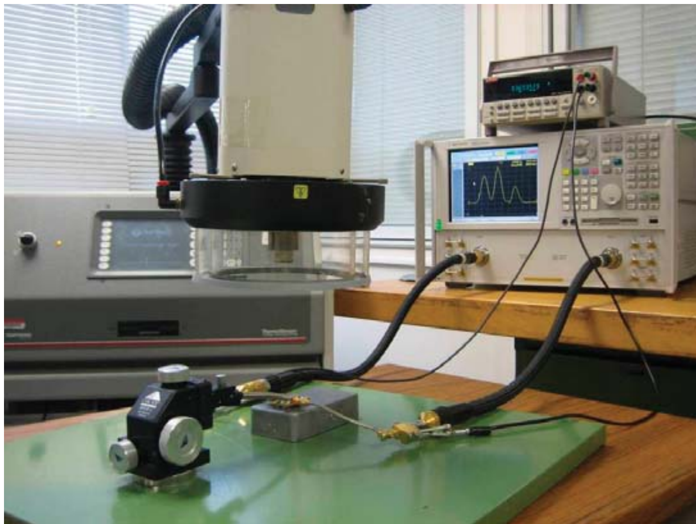

Figure 1 – Experimental setup for the shear stress testing

Recently, an experimental study has been conducted to evaluate the increased sensitivity of the RF impedance analysis in detecting solder joint degradation as shown in Figure 1. Mechanical shear stress at 150°C was applied to an impedance-controlled circuit board on which a surface mount component was soldered in order to degrade the solder joints. Automated simultaneous measurements were performed of the DC resistance and the time domain reflection (TDR) coefficient as a measure of RF impedance for continuous monitoring. This study showed that the RF impedance exhibited earlier sensitivity than the DC resistance to solder joint degradation. While DC measurements remained near the initial values until they exhibited a sudden increase indicating an open circuit, RF impedance began to increase prior to the complete separation of the solder joint. These results were qualitatively repeatable over multiple trials. Therefore, CALCE found that RF impedance analysis can serve as a non-destructive early indicator of solder joint degradation (see Figure 2).

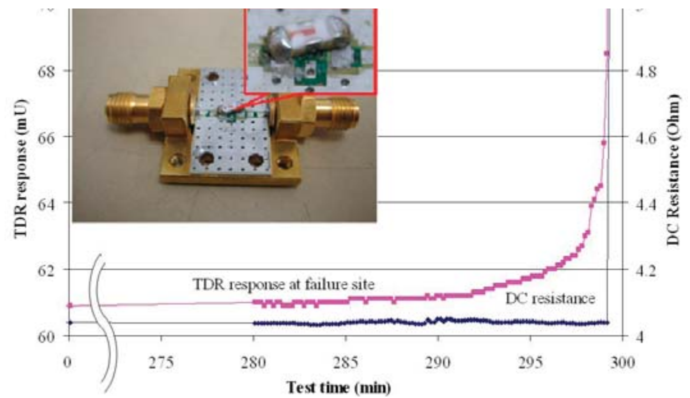

Figure 2 – Comparison between RF and DC measurements in response to solder joint degradation

Experimental results also revealed that reliability assessment based on DC resistance measurements may overestimate the lifetime of high speed electronic assemblies. RF impedance analysis can provide a more accurate assessment of the reliability of high speed electronic products in response to solder joint degradation. Furthermore, this technique shows potential as a prognostic tool that can provide advance warning of impending interconnect failures. It also offers advantages as a research tool for studying solder joint failure mechanisms at intermediate stages of progress prior to complete failure.

Further investigation of RF impedance analysis as a failure assessment metric will be conducted through fatigue and creep tests. Since RF impedance provides an early warning of impending solder joint failure, RF impedance changes are suspected to be associated with the physical degradation progress of the solder joints. During fatigue and creep testing using the MTS Tytron 250, visual inspections and failure analysis including cross-sectioning will provide evidence that correlates the RF impedance changes with the physical degradation process quantitatively. This should provide useful information for reliability assessment, such as predicting the remaining useful life.

For further information on this work, please contact Dr. Michael Azarian at 301-405-7555, or mazarian@calce.umd.edu

CALCE Works to Secure Supply Chain

CALCE and Prime Technology, LLC, a subsidiary of NCR, have successfully concluded a pilot program designed to demonstrate the capabilities of a rare earth material authentication system. The program was conducted in early 2007 for the US Department of Defense with the participation of Raytheon, a large defense contractor, and Liebert Systems, an Emerson company.

The electronic product supply chain chosen for this authentication demonstration project reflects the breadth and complexity of today's international supply chain, with a diversity of product offerings and a large number of supply chain stake-holders. The supply chain involved an original equipment manufacturer, a product distributor, a contract manufacturer, shipping companies, warehouse operators, and final users.

Prime worked with CALCE to design Prime's LumID technology evaluation. The objective was to demonstrate the value of a systematic approach to a secure covert authentication feature in the military supply chain, one that is manufacturer-specific and compatible with traditional tracking systems.

A mass-produced electronic product (desktop UPS and surge protector) was ordered by Raytheon and sourced (through a U.S. distributor) from a supplier in China. The 2D barcode that contained the identification information for the part was covered with LumID authentication "seals" and registered at the point of origin in China. The parts were then shipped by surface transportation and delivered to Raytheon's Tewksbury, Massachusetts, facility. Upon arrival the parts were unpacked and the LumID seals were read and compared to the original data that was registered at the manufacturing facility in the China. Ten units were ordered by Raytheon and delivered to the Tewksbury facility. Nine units were authentic and one was a simulated counterfeit.

A DoD-compliant UID label was constructed in accordance with the specifications contained in Mil Std 130M – 2005. The label contained a CAGE code for NCR (top level), a part number, and a serial number. CALCE and Raytheon were specifically interested in the ability of the LumID technology to track the parts to different manufacturing locations. This information was built into the part number for the purpose of this test and was intentionally entered incorrectly (Virginia instead of Massachusetts) on the UID label for three of the parts.

Absolute supply chain security requires a system approach to product authentication. The LumID technology is based on a system with interfacing components, each having inherent security features that together form a highly sophisticated means of authentication.

This system approach was designed to seamlessly dovetail with today's barcode technology. Combining a covert security feature with track and trace capability allows flexibility in addressing diverse application requirements. The benefits of a dual technology system include: scalable data gathering, the ability to determine when and where the supply chain has been compromised, speed and agility of use, minimized disruption to current supply chain management, and greatly enhanced security.

The test results showed a technologically feasible solution for securing the supply chain. It also demonstrated the inherent security of combining unique, assignable, covert codes with established track and trace features, demonstrated the ease and cost-effectiveness of adoption and determined the logistics footprint necessary for full implementation.

For more information, contact Diganta Das at diganta@umd.edu, (301) 405-7770.

Electronic Part Total Cost of Ownership

Long-term cost issues are important for most products. The life-cycle costs of specific systems can be assessed; however, it is also often useful to allocate life-cycle costs for components that may be used across multiple systems. For electronic systems, allocating life-cycle costs to specific electronic parts enables initial part selection and provides guidance on what actions should be taken at the part-management level to provide the maximum payback for an organization. The allocation of life-cycle costs can also provide a clear business case for retiring existing parts from databases (in favor of newer components), and enables the determination of the part-specific value of reusing components in multiple designs.

The effective total cost of ownership to an organization of an electronic part is usually many times the purchase price of the part and the total cost picture is important to communicate when making component decisions. The total cost of ownership includes part approval and adoption; qualification of the part; procurement; various NRE costs; manufacturing costs (assembly, test, rework); field-use costs (cost of failure); and obsolescence resolution costs. The model allows the cost of ownership to be determined for a specific part used in multiple products over a period of time, as shown in Figure 3.

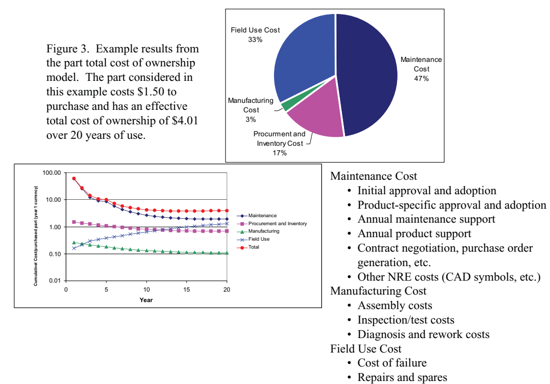

Figure 3. Example results from the part total cost of ownership model. The part considered in this example costs $1.50 to purchase and has an effective total cost of ownership of $4.01 over 20 years of use.

An additional feature of the model is the assessment of the design reuse of parts. A finite resource model has been developed to allow the assessment of the cost impacts of a part-specific problem occurring at a future point in time (at a user defined date). Finite resources (people, equipment, etc.) to address problems become an issue when multiple problems or the same problem in multiple products occur concurrently and the resolution to one or more problems or products has to be delayed due to a lack of resources. Under some conditions, the financial penalties associated with the delays may offset savings due to purchasing parts from the least expensive source and part commonality in multiple products.

The assessment of application- and organization-specific cost impacts of counterfeit electronic parts and the implementation of part-level material risk indices (MRIs) for measuring "sustainment dollars at risk" metrics based on individual part selection decisions are being considered as extensions to the part total-cost-of-ownership model.

For further information on the part total ownership cost model, contact Peter Sandborn, Sandborn@calce.umd.edu, (301) 405-3167.

SMTA Capital Chapter Makes Donation to CALCE

The Capital Chapter of Surface Mount Technology Association (SMTA), has graciously made a $1000.00 donation to the CALCE Center in appreciation of the long term relationship that the center have had with SMTA. CALCE appreciates the donation and looks forward to continued professional relationship with SMTA in meeting participations, presentations and joint hosting of conferences. SMTA is an international network of professionals who build skills, share practical experience and develop solutions in electronic assembly technologies.

CALCE Graduate Student Wins FDA Fellowship

Shunfeng Cheng, a Ph.D. student of Professor Pecht's, has won a fellowship from the ORISE Foundation after being recommended by the U.S. Food and Drug Administration (FDA). Shunfeng is involved in a project to evaluate the failure modes and mechanisms of medical devices and test methods, and then to set up a hierarchy for the Manufacturer Evaluation Code of the medical devices. The focus of his research is prognostics and health management of electronic devices.

Patent issued for "Shadow Moire Using Non-Zero Talbot Distance"

Professor Bongtae Han and colleague Dr. C.W. Han of the Reliability and Failure Analysis Center of the Korea Electronics Technology Institute recently received a patent. Their invention copes with the limitations of shadow moire encountered in high precision in-situ warpage measurements. Using the non-zero order Talbot distances, the dynamic range of measurements is increased substantially and high measurement sensitivity becomes practical--critical requirements for the warpage measurements of high-end microelectronics devices.

CALCE Graduate Student Wins IEEE Scholarship

Jie Gu, a Ph.D. student of Professor Pecht's, was selected for the 2007 IEEE Reliability Scholarship in recognition of his activity in the IEEE Reliability Society. The competition for this scholarship was strong, and being chosen is a testimony to outstanding scholastic achievements and demonstrated interest in IEEE and reliability-related professional activities. The scholarship is worth $2000. The focus of Gu's research is prognostics and health management of electronics.

Dr. Bongtae Han is an ASME (the American Society of Mechanical Engineers) Fellow

Dr. Han serves critical industrial needs through measurement and interpretation of thermomechanical deformations of microelectronic and photonic devices. His contributions center around experimental analyses by optical techniques. He developed, extended, and utilized special measurement means, including Moiré Interferometry, Micro-Moiré Interferometry, Far Infrared Fizeau Interferometry and Shadow Moiré, thereby providing instrumentation for, and analyses of, electronic package behavior. Instrumentation that he developed is widely used in industry today. His experimental analyses provide critical guidance and verification for extensive computational analyses. Dr. Han has disseminated his research and development accomplishments through extensive publications, presentations, patents and importantly through training his students. His work has been a seminal contribution to the industry.

Dr. Hao Yu Joins CALCE as a Research Scientist

Dr. Hao Yu has joined CALCE as a Research Scientist . He received Ph.D. degrees in materials science from the Central South University of Technology, China, in 1999. Beginning in 1999, he worked as a Research Scientist in the Laboratory of Electronics Production Technology (EPT), Helsinki University of Technology (HUT), Finland. In 2006, he earned his Ph.D. degree in electrical and electronics engineering from HUT. The main subject of his research is reliability of electronics using combined multiphysical modeling and simulations, including thermal modeling, and thermodynamic and kinetic analysis on the solidification and microstructure evolutions of interconnections.

Selected Recent CALCE Publications

1. Phase-shifting in Achromatic Moiré Interferometry System, C. Han and B. Han, Optics Express, Vol. 15, pp. 9970-9976, 2007.
2. Thermo-Optical Modeling of Intrinsically Heated Polymer Fiber Bragg Grating, K. J. Kim, A. Bar-Cohen and B. Han, Applied Optics, Vol. 46, No. 20 , pp. 4437-4370, 2007.
3. On Moisture Diffusion Modeling Using Thermal-Moisture Analogy, S. Yoon, B. Han and Z. Wang, Journal of Electronic Packaging, Vol. 129, pp. 421-426, 2007.
4. Integrated Measurement Technique for Curing Process-dependent Mechanical Properties of Polymeric Materials Using Fiber Bragg Grating, Y. Wang, B. Han, D. W. Kim, A. Bar-Cohen and P. Joseph, Experimental Mechanics, DOI 10.1007/s11340-007-9067-3, 2007.
5. Thermo-Optical Modeling of Polymer Fiber Bragg Grating Illuminated by Light Emitting Diode, K. J. Kim, A. Bar-Cohen and B. Han, Int'l Journal of Heat and Mass Transfer, Vol. 50, pp. 5241–5248, 2007.
6. Strain Range Fatigue Life Assessment of Lead-free Solder Interconnects Subject to Temperature Cycle Loading, M. Osterman and M. Pecht, Soldering & Surface Mount Technology, Vol. 19, No. 2, 2007.
7. Prognostics Implementation of Electronics under Vibration Loading, J. Gu, D. Barker and M. Pecht, Microelectronics Reliability, Vol. 47, Issue 12, pp. 1849-1856, Dec. 2007.
8. Isothermal Aging Effects on Flex Cracking of Multilayer Ceramic Capacitors with Standard and Flexible Terminations, M. Keimasi, M. Azarian, and M. Pecht, Microelectronics Reliability, Vol. 47, pp. 2215-2225, 2007.
9. Prognostics of Ceramic Capacitor Temperature-Humidity-Bias Reliability Using Mahalanobis Distance Analysis, L. Nie, M. Azarian, M. Keimasi, and M. Pecht, Circuit World, Vol. 33, No.3, pp. 21-28, 2007.
10. The Effect of Electrostatic Discharge on Electrical Overstress Susceptibility in a Gallium Arsenide MESFET-Based Device, V. Eveloy, Y. Hwang, and M. Pecht, IEEE Transactions on Device and Materials Reliability, Vol, 7, No. 1, pp. 200-208, March 2007.
11. Regulations and Market Trends in Lead-free and Halogen-free Electronics, L. Nie and M. Pecht, Circuit World, Vol. 33, No. 2, pp. 4-9, 2007.
12. Assessment of China's and India's Science and Technology Literature, R. Kostoff, S. Bhattacharya, and M. Pecht, Technological Forecasting and Social Change, Vol. 74, Issue 9, pp. 1519-1538, November 2007.
13. Chinese Science and Technology - Structure and infrastructure Technological Forecasting and Social Change, R. Kostoff, M. Briggs, R. Rushenberg, C. Bowles, A. Icenhour, K. Nikodym, R. Barth, and M.l Pecht, Technological Forecasting and Social Change, Vol. 74, Issue 9, pp. 1539-1573, November 2007.
14. Comparisons of the Structure and Infrastructure of Chinese and Indian Science and Technology Technological Forecasting and Social Change, R. Kostoff, M. Briggs, R. Rushenberg, C. Bowles, M. Pecht, D. Johnson, S. Bhattacharya, A. Icenhour, K. Nikodym, R. Barth, and S. Dodbele, Technological Forecasting and Social Change, Vol. 74, Issue 9, pp. 1609-1630, November 2007.

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.

CALCE Graduate Student Wins Ann G. Wylie Dissertation Fellowship Award

Arindam Goswami, a Ph.D. student of Professor Han was awarded the Ann G. Wylie Dissertation Fellowship. The fellowship will support Goswami's research in "Quantitative Assessment of Hermeticity of Micro-to Nano-liter Scale Packages." After graduating, he intends to apply his research to the characterization of current and future advanced MEMS packages.

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