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COMPUTER-AIDED LIFE CYCLE ENGINEERING (CALCE)
ELECTRONIC PRODUCTS AND SYSTEMS CENTER
DEPARTMENT OF MECHANICAL ENGINEERING
WWW.CALCE.UMD.EDU

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.

New Government-Industry-University Cooperative Research Center for Electronics Prognostics and Health Management Established

A new Cooperative Research Center for Electronics Prognostics and Health Management (CePHM), sponsored by industry and government members, has been established at the University of Maryland in cooperation with CALCE. The new center will focus on developing the science and technology required to implement prognostics and health management for electronic products and systems (ePHM).

CALCE EPSC has been working in the area of ePHM for six years, and this expertise will be incorporated into the new CePHM. Examples of past projects include:

- miniaturized modules to sense temperature and vibration, and algorithms to predict remaining useful life
- remaining useful life assessments of the space shuttle solid rocket booster and remote manipulator arm
- remaining useful life estimation of an electronic module in a car engine bay
- low current sensors to monitor the quiescent supply current of a CMOS IC for use as a precursor to failure caused by gate oxide and metallization defects
- stochastic algorithms to estimate the savings in life-cycle cost achievable with ePHM and optimize maintenance strategies.

The new center is now seeking members. For more information, please contact Prof. Michael Pecht, Prof. Peter Sandborn or Chris Wilkinson at 301-405-5323.

U.S. Navy Awards Contract on Advanced Prognostics to IAI/CALCE Team

The NAVAL Air Warfare Center AD (LKE) has awarded a new SBIR Phase I contract to IAI (Intelligent Automation, Inc.) and CALCE EPSC, the subcontractor, for a proposal entitled "Enhanced Prognostic Model for Digital Electronics." The IAI/CALCE team will develop prognostic-based methodologies to predict failures in aircraft electronic boards, their digital component elements, and devices that have the potential to reduce the risks of unanticipated failures while significantly reducing support costs. This approach will incorporate life-consumption monitoring, including failure modes and mechanism analysis, sensor data pre-processing/ feature selection, fault detection/identification/isolation, virtual reality assessment, stress and damage accumulation analysis, and remaining life estimation.

UMD, CALCE, and New CePHM Awarded $2.1 Million to Develop Interactive Supply Chain System

The Office of the U.S. Secretary of Defense has competitively awarded a $2.1 million grant to the University of Maryland team that includes the Center for Public Policy and Private Enterprise, CALCE EPSC, the new CePHM and other partners at the A. James Clark School of Engineering.

The group is conducting a twelve-month project to develop a prototype web-based supply network using the most advanced technologies to acquire and deliver replacement parts quickly on an as-needed basis. The project will involve a demonstration of real-time health assessment to enable fault detection, diagnostics, and remaining life prognostics for cost-effective maintenance of Navy fighter jets. The prognostic information will be linked with novel wireless communications to relay these needs to maintenance officers, and automatic identification techniques (RFID is the most common current example) will be used to locate parts in the supply chain--all integrated through a secure web portal. With this project, the researchers plan to develop a web portal and an implementation roadmap that can be put into practice on a wide scale for F/A 18s as well as other weapon systems.

CALCE Technical Review Meeting

The Technical Review Meeting of the CALCE Electronic Products and Systems Consortium has been scheduled for **March 21-23, 2006**, in the Judith Resnik Lecture Hall on the University of Maryland, College Park campus.

All current members of the Consortium are invited to attend. Organizations interested in becoming CALCE Consortium members and wishing to attend the meeting should contact Joan Lee at *joanyuan@calce.umd.edu*. The fee 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:

- Effect of Manufacturing Variability on Reliability of Lead-free Solder Joints-Continuation
- Accelerated Qualification of SAC Assembly: Combined Temperature Cycling and Vibration-Continuation
- Effect of Characteristic Relaxation Time on Accelerated Thermal Cycling Profiles for SAC Solders
- Effect of Load Sequencing on Pb-free Solder Durability
- Effect of Temperature Cycle on the Durability of Pb-free Interconnects (Sn96.5Ag3.0Cu0.5 and SnCuNi)
- Characterization of Tin Pest Formation in Pb-free Solder Joints
- Development of Vapor Pressure Modeling Scheme for PEMs Subjected to Pb-free Solder Reflow Profile
- Damage Caused to PTH and PWB by Compliant Pin Insertion
- Electronic Component Failure Categorization under Gun-launched High G Loading-Continuation
- Stress Relaxation Effects on the Contact Resistance of High-density I/O Sockets
- Performance of Commercially Available RF Low Noise Amplifiers
- Development of CFF Model for Today's PWB Spacings
- Assessment of High-Temperature Technologies for SiC Packaging
- Failure Risk Assessment of LCD Modules – ACF Failures
- Effects of Mechanical and Environmental Stresses on Flexible Termination Multilayer Ceramic Capacitors
- Failure Mechanism and Reliability Assessment for System-in-Package Technologies-Continuation
- Electrochemical Migration on Lead-free Printed Circuit Boards with No-clean Flux Technology
- Investigation of High-temperature Green Solder Materials
- Hermeticity of Wafer Level Package Phase III
- Effect of Intermetallic on Drop Reliability and Bulk Properties of Aged Eutectic BGA Solder Joints
- Characterization of Moisture-induced Degradation of Polymer Interface
- Durability Assessment of an Advanced Power Electronics Thermal Cooler
- Thermal Performance and Reliability of Thermal Interface Materials
- Heat Sink Fouling in Air-cooled Electronic Products
- Impact of Temperature on Performance and Lifetime of Plasma Panel Displays Using Natural Graphite-based Heat Spreaders
- Advanced Microstructured Surfaces for Thin Film Evaporative Cooling
- Integrating Refresh Planning
- Uprating of Passive Components
- Connecting Lifetime Buy Forecasting with Design Refresh Planning
- MOCA Pilot Studies
- Rapid Life Model for Temperature Cycling of Underfilled BGA Packages
- Reliability Assessment and Modeling of Clinched Insertion Interconnects
- Model-based Design Guidelines for Shock and Drop Loading
- Iddq Trending as a Precursor to CMOS IC Failure
- Vehicle Component Prognostics in a Vibration/Shock Environment
- Integrated Health and Usage Monitoring System

New CALCE Consortium Members

- DaimlerChrysler, Germany
- Defense Logistics Agency, Washington DC, USA
- NAVAIR – PaxRiver NAS, Pax River, MD, USA
- SAIT, Korea
- StorageTek, CA, USA
- Toshiba, Japan

Long-term Lead-free Reliability Study Meeting

To expand the knowledge base related to long-term reliability issues introduced by lead-free electronics, CALCE EPSC has been conducting a collaborative research study that involves the design, manufacture, and testing of printed wiring assemblies with the objective of obtaining critical missing information related to long-term (>10 year) reliability. The findings to date are significant.

On Monday, **March 20, 2006**, CALCE EPSC will hold a one-day session on the status of the long-term lead-free reliability program for participants. The purpose of this meeting is to provide a review of findings obtained so far. The meeting will be held in 2164 Martin Hall on the University of Maryland College Park campus. The review topics include vibration combined loading test results; temperature cycling test results; electrochemical migration test results; and microstructure results.

For more information, please go to *www.calce.umd.edu* and click on *Upcoming Events*, or contact Dr. Michael Osterman at *osterman@calce.umd.edu*, or Dr. Ji Wu at *jwu@calce.umd.edu*, tel. 301-405-5323.

Virtual Qualification Software Workshop

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

On **March 20, 2006**, the CALCE EPSC 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.

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

CALCE Inform Seminars

CALCE, with support from consortium members, is conducting monthly "CALCE Inform" distance seminars. Seminars are 45 minutes with an additional 15 minutes allotted for questions. The web seminars are hosted by CALCE members. Sponsors include Agilent, Boeing, Schlumberger, Raytheon, HP, and Honeywell. The next seminar, titled 'Electrochemical Migration in Printed Circuit Board Assemblies' by Dr. Michael Azarian, is scheduled for **February 23, 2006**.

For more information or if interested in sponsoring a seminar, please contact Dr. Michael Osterman at 301-405-8023, or *osterman@calce.umd.edu*.

CALCE Releases Tin Whisker Risk Calculator

CALCE has released a software program to estimate the failure risk posed by the growth of tin whiskers within electronic assemblies. The software program is based on research into tin whisker formation conducted by CALCE over the past three years. The software program is available to CALCE Consortium members. CALCE is also conducting tin whisker risk assessments for companies through its test services and failure analysis laboratory.

With the global transition of lead-bearing electronics to lead-free electronics due to government legislation and market forces, the majority of parts suppliers have moved to pure tin or tin-based lead-free alloys to replace tin-lead finishes. This selection has renewed concerns over the potential of these finishes to grow conductive whiskers capable of bridging isolated conductors and causing unintended shorts. Such whiskers have been blamed for costly failures of satellites, medical devices, and more recently nuclear power plants.

Tin whiskers and conductive whiskers were first documented in the 1940s. Since that time, the phenomenon has been periodically reviewed and studied. With the European Union Restriction of Hazardous Substances (RoHS) legislation set to take effect in July 2006, research into tin whiskers has intensified over the past few years. This research has focused on the establishment of test methods for tin whiskers and microstructural analysis in an attempt to further understand the growth phenomena. The research has resulted in the issuance of JESD 22A121, "Measuring Whisker Growth on Tin and Tin Alloy Finish" and the submission of JEDEC Standard 201, "Environmental Acceptance Requirement for Tin Whisker Susceptibility of Tin and Tin Alloy Surface Finishes." In addition, the Government Electronics Industry Association is reviewing GEIA-STD-0005-2, "Standard for Mitigating the Risk of Tin in High-Reliability Electronic Systems." While these documents provide methods for measuring whisker growth, criteria for accepting the use of tin-finished parts, and methods for mitigating failure risk posed by tin whiskers, the actual assessment of whisker risk has not been made.

To assess the risk presented by whisker formation, CALCE has developed a software program that uses a stochastic approach to estimate the probability of failure due to tin whisker bridging. The software inputs include the geometry of the "at risk" structures, whisker growth characteristics, percentage of coverage by conformal coating, and the required lifetime of the product. Geometry information defines an assembly as a set of individual conductor pairs. Each conductor pair is defined by its separating spacing and its surface area. Whisker growth characteristics include probability distribution parameters for density and length, as well as the rate of change of these parameters. For density, a normal distribution is assumed. For length, a lognormal distribution is assumed. These distributions have been established by measurements taken from tin- and tin-finished studies of both matte tin- and bright tin-finished coupons. Users may also define their own whisker growth characteristics. The software provides the probability of failure due to whisker bridging for each defined structure and the total probability of failure for a defined assembly.

The whisker growth data is derived form three years of testing conducted under CALCE Consortium research projects. From these studies, whisker growth appears to occur in three stages: whisker growth initiation, rapid whisker growth, and low whisker growth. Using the growth rate established by the measured whisker growth as a function of time, the whisker growth characteristics are extrapolated to estimate the risk at times beyond the whisker measurement period. Based on our studies, this extrapolation is expected to be somewhat conservative. The software is available for download by all CALCE Consortium members. The growth tables will be updated as new measurement data become available.

For more information on CALCE tin whisker research and research related to the transition to Pb-free electronics, visit *http://www.calce.umd.edu/lead-free*.

CALCE Acquires New X-ray System

CALCE has acquired an advanced Phoenix X-ray system: the nanomex, 160kV high-power nano-focus system, with resolution to 200nm detail detectability. The emitted intensity varies by less than 0.5 percent within eight hours, ensuring repeatable results. The dedicated surface treatments during fabrication and automated warm-up procedures prevent arcing and discharges. Tube adjustments are performed automatically during the automated warm-up procedure to achieve and maintain optimum results. The X-ray image displays the sample exactly as the operator sees it through the radiation protection window. The digital real-time image chain enables oblique views up to 70 degrees at magnification well above 10,000x without sample movement.

CALCE has also acquired microfocus computed tomography software for full 3-dimentional imaging of objects and non-destructive slicing and sectional views in any direction. For more information on CALCE TSFA facilities and capabilities, contact Dr. Keith Rogers at 301-405-5316, or *krogers@calce.umd.edu*.

Fig. 1 CALCE's New X-Ray System

CALCE Assessing Reliability of Multilayer Ceramic Capacitors with Flexible Terminations

Multilayer ceramic capacitors (MLCCs) are known to be susceptible to cracking when subjected to bending of thermal stresses. Based on the failure analysis history of the CALCE Test Services and Failure Analysis Lab, cracking is the most common cause of failure for MLCCs, representing about one-half of the MLCC failures analyzed. Flexure of a printed circuit board (PCB) can occur due to depaneling; handling during processing; testing or assembly; insertion or removal of a board from edge-mount connectors; attachment of a board to other structures (e.g., support plates, heat sinks, and chassis); connection of cables; thermal expansion of a board with respect to a cabinet or chassis; and vibration in the end-use environment. Large thermal stresses can be experienced during board assembly, especially during wave soldering.

MLCCs consist of thin layers of ceramic dielectric materials interspersed with metal electrodes that are alternately exposed on opposite edges of the laminated structure. The electrodes are connected to the end terminations, which are soldered to the PCB. Bending of the PCB causes forces to be transmitted through the solder fillets to the surface mount capacitor. These forces are concentrated at the bottom of the capacitor, where the end terminations meet the body of the capacitor.

CALCE has been researching MLCC cracking through a combination of experimentation and modeling for the past several years. With the transition to lead-free solder in the electronics industry, there is a concern that PCB assemblies processed with lead-free solder have different susceptibility to flex cracking. In general, tin-silver-based lead-free solders are stiffer than eutectic tin-lead solder; and reflow peak temperatures for tin-silver-based lead-free solders are generally higher than for eutectic tin-lead solder. Due to higher peak temperatures during reflow, the subsequent cooling may cause micro-cracks to develop in the capacitor body, thereby increasing the susceptibility to flex cracking during bending of the PCB.

Recently, an experimental study was conducted to investigate the effects of lead-free solder (Sn3.0Ag0.5Cu) on flex performance of MLCCs with different sizes (1812 vs. 0805) and different dielectric materials (C0G vs. X7R) compared to eutectic tin-lead solder. Capacitors from three different manufacturers were considered. Experimental results showed that MLCCs mounted on boards with lead-free solder are less susceptible to flex cracking than MLCCs mounted on boards with eutectic tin-lead solder. Results of flex tests for MLCCs with (C0G EIA Class I) dielectric showed that they are much more resistant to flex cracking than MLCCs with X7R (EIA Class II) dielectric.

Significantly, experimental results also showed that the maximum allowable 2 mm PCB deflection typically recommended in MLCC datasheets is a conservative value for some MLCCs, while for other MLCCs it may lead to an unacceptably high risk of cracking. CALCE has observed that X7R MLCCs of size 1812 assembled with tin-lead solder can experience failure rates greater than 10 percent for board deflection values less than 2 mm. On the other hand, MLCCs of size 0805 and X7R dielectric assembled with tin-lead solder show only 1 percent failure rate for board deflections up to 3.4 mm. Therefore, the rule of thumb of 2 mm maximum allowed deflection for PCBs is a conservative value for 0805 MLCCs, while it is too high for larger (1812 size) MLCCs. This deflection limit should therefore be used with great caution and modified according to parameters that affect flex cracking susceptibility of MLCCs, such as capacitor size and dielectric.

In order to reduce the amount of stress that is transmitted to the brittle ceramic body of MLCCs through end terminations, a flexible polymer termination system has been developed by some MLCC manufacturers. For example, AVX produces MLCCs with flexible terminations comprised of a conductive polymer used in conjunction with base metal electrode (BME) technology and an X7R dielectric. AVX's flexible-termination MLCCs have an open-mode design in which there is a larger gap between the electrode layers and opposing end terminations. Open-mode capacitors were designed to greatly reduce the likelihood of a high leakage current or short-circuit condition as a result of flex cracking. Syfer produces MLCCs with flexible terminations and precious metal electrodes (PME). Syfer's flexible-termination MLCCs use a silver-loaded polymer in end terminations plated with nickel and tin.

These capacitor designs offer the promise of reduced susceptibility to cracking due to bending or thermal stresses. CALCE is currently performing comparative evaluations of standard and flex-terminated capacitors assembled using both eutectic and lead-free solder to objectively evaluate their risk of flex cracking. In addition, these experiments will assess thermal stress effects resulting from thermal pretreatment, and will compare flex cracking of convectively reflow-soldered MLCCs with wave-soldered MLCCs having both flexible and standard terminations. Ultimately, failure analysis will be used to confirm cracking of MLCCs that have been identified as failures in flex tests.

The sensitivity of these new MLCCs to environmental stresses and DC bias is not yet well established, so CALCE will be monitoring their electrical performance in temperature-humidity-bias conditions to identify any unexpected reliability risks associated with the new designs and materials. In this study, the effects of temperature and humidity on flexible-termination MLCCs under bias will be characterized and compared with standard-termination MLCCs. In addition, the effects of temperature-humidity-bias (THB) on ceramic capacitors with base metal electrodes will be compared to that for precious metal electrode capacitors. Two kinds of preconditioning, normal and rapid temperature cycling, will be implemented before THB testing.

It is expected that this systematic assessment of the reliability of flexible termination MLCCs, examining a range of solder assembly conditions, manufacturers, pretreatments, and stress conditions, will provide industry with an opportunity to make an informed decision on the suitability of these components for applications in which the current risk of MLCC failure due to cracking is unacceptably high.

For further information on this work, please contact Dr. Michael Azarian at 301-405-8126, or *mazarian@calce.umd.edu*.

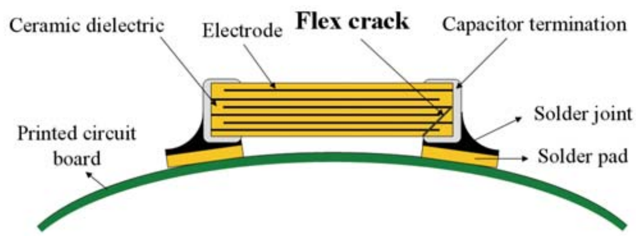


Figure 1. MLCC flex cracking due to printed circuit board bending.

Calce Develops Advanced Tool to Measure Co-Planarity of Small Surface Mount Components

Co-planarity of surface mount components is one of the most critical issues during the board-level assembly process. If the BGA side of the component exhibits excessive warpage, the assembly will yield uneven BGA joints (Fig. 1a), which could result in premature assembly failure. Because the warpage is attributed to a large coefficient of thermal expansion (CTE) mismatch, the problem is exacerbated when the component is subjected to the higher temperature *lead-free solder reflow profile*.

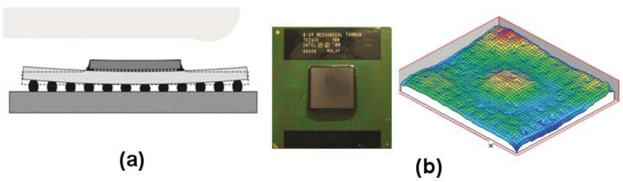


Fig. 1 (a) Illustration of undesired condition during reflow and (b) FC-PBGA package and its 3-D warpage map of the BGA pad side documented by shadow moiré.

An optical technique called *shadow moiré* has recently been adopted in the electronics industry to measure co-planarity. The method provides whole-field out-of-plane displacement maps with relatively coarse sensitivity. In this method, a reference grating placed in front of a specimen creates moiré fringes by interacting with its shadow projected onto the specimen surface. Figure 1b illustrates an example of a 3-D warpage map of the BGA pad side of an FC-PBGA package produced by shadow moiré.

Because the total warpage of a component is proportional to the component's size, small surface mount components can require a measurement resolution as small as a few microns. In theory, shadow moiré can achieve this resolution by employing a coarse reference grating and an image processing technique (e.g., phase-shifting technique). In practice, however, unrealistic idealizations assumed during image processing limit the measurement accuracy for a given reference grating. Therefore, the basic measurement sensitivity must be increased to attain the desired resolution.

Higher basic measurement sensitivity can be achieved by using finer reference gratings (i.e., frequencies greater than 20 lines per mm or 500 lines/in). For such high-sensitivity applications, it would be most practical to position the specimen away from the grating due to a limited working distance. Diffraction effects pose another technical challenge when working with the finer gratings. The diffraction effects deteriorate fringe contrast with increased distance between the reference grating and specimen surface. This deterioration reduces the dynamic range of high-sensitivity shadow moiré significantly, which makes phase shifting impractical and/or creates regions with no visible fringes (wash-out zones).

A CALCE research team recently coped with the above problems by (1) placing the specimen at the nonzero self-imaging (or Talbot) distances and (2) developing an optimized mechanical aperture. The Talbot distances are planes behind the diffraction grating where the grating lines are naturally replicated (Fig. 2).

An optical/mechanical system using this scheme (shadow moiré with nonzero Talbot distance: SM-NT) has been designed and built for implementation (Fig. 3). The system features an environmental oven for temperature cycling while an external vertical translation stage allows fringe shifting and control over the distance between the reference grating and specimen. A custom LabView program monitors and controls the oven, translation stage, and video during experimentation. The control software works in conjunction with an independently developed fringe analysis program to provide *real-time* 3-D displays of the warpage.

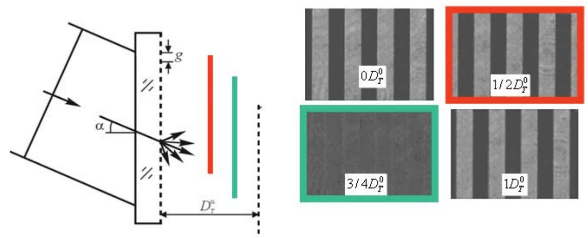


Fig. 2 Illustration of Talbot images

Figure 4 shows experimental results from an FC-PBGA package. The fringe pattern obtained by the conventional shadow moiré is shown in Fig. 4a. Note that the fringes wash out completely in some areas, causing distortion in the 3-D map.

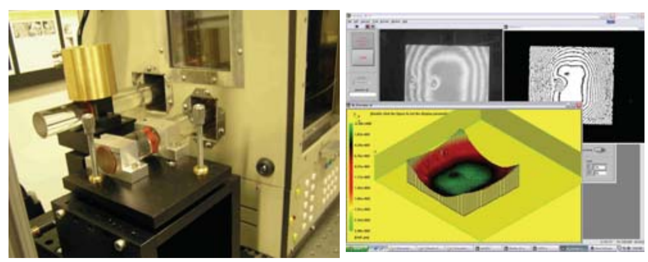


Fig. 3 SM-NT system and control software

The corresponding results obtained by SM-NT are shown in Fig. 4b. The SM-NT pattern documents the deformations faithfully, as evidenced by the excellent visibility of individual fringes. The results clearly demonstrate the advantage of using SM-NT to enhance the dynamic range of high sensitivity shadow moiré.

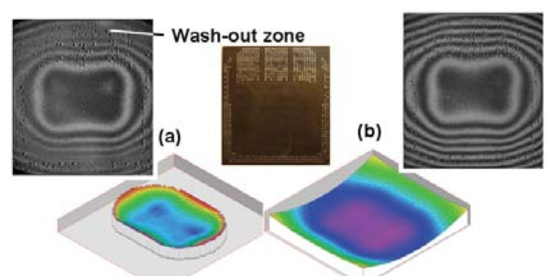
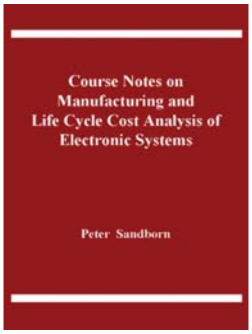


Fig. 4 Warpage of a surface mount component documented by (a) the conventional shadow moiré and (b) SM-NT. A reference grating frequency of 20 lines/mm was used in both experiments.

For more information about SM-NT or technology transfer, contact Prof. Bongtae Han at 301-405-5255, or *bthan@calce.umd.edu*.

New CALCE Course Notes Book on Manufacturing and Life-Cycle Cost Modeling of Electronic Systems



Understanding the cost ramifications of design, manufacturing, and life-cycle management decisions is of central importance to businesses associated with all types of electronic systems. These course notes meld elements of traditional engineering economics with manufacturing process and sustainment modeling to form a practical foundation for predicting the cost of electronic products and systems. Various manufacturing cost analysis methods are presented including process-flow, parametric, cost of ownership, and activity-based costing. The effects of learning curves, data uncertainty, test and rework processes, and defects are also considered. Life-cycle topics include sparing and availability analysis, warranty cost analysis, and obsolescence.

These course notes use real-life scenarios from integrated circuit fabrication, electronic systems assembly, substrate fabrication, and systems support as examples of the application of the cost estimation methods.

For further information on this book, contact Prof. Peter Sandborn at 301-405-3167, or *sandborn@calce.umd.edu*. For more information on CALCE books visit: *www.calce.umd.edu/general/published/books/books.html*.

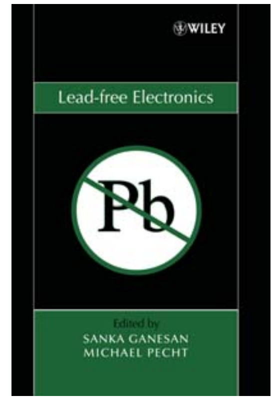
CALCE Researchers Win 2004 SOLE Proceedings Paper Award

Prof. Peter Sandborn and Pameet Singh won the 2004 SOLE (The International Society of Logistics) award for the best paper published in the SOLE Proceedings in 2004. The title of the paper was "Forecasting Technology Insertion Concurrent with Design Refresh Planning for COTS-Based Electronics Systems." The award was made at the 40th Annual International Logistics Conference and Exhibition in Orlando, FL in August 2005. For further information, contact Prof. Peter Sandborn at 301-405-3167, or *sandborn@calce.umd.edu*.

Prof. Barker Wins IPC Best U.S. Paper for 2006 Award

Prof. Donald Barker of the CALCE Electronic Products and Systems Center and Michael Freda of Sun Microsystems, Inc. have won the "Best U.S. Paper for 2006" award from the IPC Printed Circuits Expo, APEX and Designer's Summit 2006 Technical Program Committee for their paper "Predicting Plated Through Hole Life at Assembly and in the Field from Thermal Stress Data." The award will be announced at the February 8 Opening Ceremony of the Summit in Anaheim, California. The paper will be published in the *Proceedings of IPC Printed Circuits Expo, ADEX and the Designer's Summit*, February 18, 2006, Anaheim CA. For more information, contact Prof. Barker at 301-405-5264, or *dbarker@calce.umd.edu*.

Lead-free Electronics Book by Ganesan and Pecht Published by Wiley



An updated version of the 'Lead-free Electronics' book by Dr. Sanka Ganesan and Prof. Michael Pecht has been published by Wiley. The book provides guidance on the design and use of lead-free electronics as well as technical and legislative perspectives. All the complex challenges confronting the electronics industry are skillfully addressed:

- Complying with state legislation
- Implementing the transition to lead-free electronics, including anticipating associated costs and potential supply chain issues
- Understanding intellectual property issues in lead-free alloys and their applications, including licensing and infringement
- Implementing cost effective manufacturing and testing
- Reducing risks due to tin whiskers
- Finding lead-free solutions in harsh environments such as in the automotive and telecommunications industries
- Understanding the capabilities and limitations of conductive adhesives in lead-free interconnects
- Devising solutions for lead-free flip-chip interconnects in high-performance integrated circuit products

Each chapter is written by leading experts in the field and carefully edited to ensure a consistent approach. Readers will find all the latest information, including the most recent data on cyclic thermomechanical deformation properties of lead-free SnAgCu alloys and a comparison of the properties of standard Sn-Pb versus lead-free alloys, using the energy partitioning approach.

With legislative and market pressure to eliminate the use of lead in electronics manufacturing, this timely publication is essential reading for all engineers and professionals in the electronics industry.

To order the book, go to *www.wiley.com* or *www.amazon.com*.

CALCE Wins Army CECOM Design Refresh Analysis Contract

CALCE, in collaboration with ARINC, has been awarded an Army CECOM contract. CALCE will perform design refresh planning and predictive obsolescence modeling on an AN/ASN-128D Doppler Global Positioning System (GPS) Navigation System (DGNS) built by BAE Systems.

This effort will include collaborative modeling using the CALCE Mitigation of Obsolescence Cost Analysis (MOCA) tool and ARINC's Operational Impact Analysis (OIA) and Logistics Assessment and Risk Management System (ALARM).

For further information on this work, contact Prof. Peter Sandborn at 301-405-3167, or *sandborn@calce.umd.edu*.

Profs. Pecht and Sandborn on the Editorial Board of IJPE

Prof. Michael Pecht and Prof. Peter Sandborn have been appointed editorial board members of *The International Journal of Performability Engineering (IJPE)*. The *IJPE* is a quarterly journal providing a forum for refereed papers on both the theoretical and the practical aspects of dependability and sustainability. The *IJPE* is now entering its second year of publication. Further details and subscription information can be found at *www.ramsconsultants.org/journal.htm* or by writing to *kbmisra@yahoo.com*.

Prof. Michael Pecht Awarded the Grand Fellowship of the Mirce Akademy

On December 1st, 2005, Prof. Michael Pecht was awarded the Grand Fellowship of the Mirce Akademy, Exeter, UK, the highest award that the Akademy can bestow at the level of global significance upon an individual in recognition of a unique contribution to the understanding and/or predicting of the motion of functionability through system life. Previous recipients of the award are:

- Nigel Mansell OBE, 1992 F1 World and 1993 Indy Champion
- Polly Vacher MBE, the first woman in the history of aviation to fly solo around the world via all seven continents
- Prof. Arie Dubi, creator of Monte Carlo based SPAR methodology.

As part of this award, on November 30th, 2005, Prof. Pecht gave the Mirce Akademy 2005 Annual Lecture. His lecture was titled "Prognostics and Health Monitoring."

Prof. Bongtae Han Appointed SEM Fellow

Prof. Bongtae Han was recently elevated to Fellow status as a member of the Society for Experimental Mechanics (SEM). Prof. Han receives this recognition for his notable contributions to the society and to the field of experimental mechanics, specifically for his efforts in extending the applicability of moiré interferometry into the micromechanics domain, his development of new optical techniques, and stress analysis of multi-layer structures using photomechanics methods.

Prof. Han's service to SEM includes Associate Technical Editor for the international journal published by SEM, *Experimental Mechanics*, from '98 to '01; Executive Board Member of SEM from '97 to '99; Chair of the Electronics Packaging Division of SEM from '94 to '98; and General Chair for two international symposia sponsored by SEM (*The 1st International Symposium on Optical Methodologies and Metrologies for Microelectronics and Photonics* in Costa Mesa, California in June 2004; and *The 1st International Symposium on Experimental/Numerical Mechanics in Electronic Packaging* in Tennessee in 1996).

Prof. Han's research interests include mechanical design of microelectronics devices, design assessment of microelectronics devices for optimum reliability, and experimental micro and nanomechanics.

Selected Recent CALCE Publications

- **Characterization of Flexural and Thermo-mechanical Behavior of Plastic Ball Grid Package Assembly Using Moiré Interferometry**, J. Joo, S. Cho, and B. Han, *Microelectronics Reliability*, Vol. 46, pp. 637-646, 2005.
- **Contrast of Shadow Moiré at High Order Talbot Distances**, C. Han and B. Han, *Optical Engineering*, Vol. 44, No. 2, 28002:1-6, 2005.
- **Environmental Qualification Testing Assessment and Failure Analysis of Embedded Resistors**, L.J. Salzano II, C. Wilkinson, and P. Sandborn, *IEEE Transactions on Advanced Packaging*, Vol. 28, No. 3, pp. 503-520, 2005.
- **Distribution of a Minor Solid Constituent in a Transfer Molded e-Pad Leadframe Package**, Y. Huang, S. Zhan, D. Bigio, and M. Pecht, *IEEE Transactions on Components and Packaging Technologies*, Vol. 28, No. 3, pp. 549-554, September 2005.
- **Mixed Flowing Gas Studies of Creep Corrosion on Plastic Encapsulated Microcircuit Packages with Noble Metal Pre-Plated Leadframes**, P. Zhao and M. Pecht, *IEEE Transactions on Device and Materials Reliability*, Vol. 5, No. 2, pp. 268-276, June 2005.
- **A Tin Whisker Risk Assessment Algorithm**, T. Fang, M. Osterman, and M. Pecht, *38th International Symposium on Microelectronics, Reliability I, Issues in Packaging*, pp. 61-65, Philadelphia, PA, September 25-29, 2005.
- **Carbon Fiber Electrical Interconnects**, Y. Deng, J. Wu, and M. Pecht, *38th International Symposium on Microelectronics, Emerging Technologies*, pp. 169-176, Philadelphia, PA, September 25-29, 2005.
- **Non-invasive Electrocardiogram and Blood Pressure Monitors for Cardiovascular Disease**, Y. Liu, V. Eveloy, and M. Pecht, *38th International Symposium on Microelectronics, Sensor and MEMS Packaging*, pp. 66-74, Philadelphia, PA, September 25-29, 2005.
- **Reliability Issues of No-Clean Flux Technology with Lead-free Solder Alloy for High Density Printed Circuit Boards**, S. Zhan, M. Azarian, and M. Pecht, *38th International Symposium on Microelectronics*, pp. 367-375, Philadelphia, PA, September 25-29, 2005.
- **Electrochemical Migration of Land Grid Array Sockets under Highly Accelerated Stress Conditions**, S. Yang, J. Wu, and M. Pecht, *The 51st IEEE Holm Conference on Electrical Contacts*, pp. 238-244, September 2005.
- **Effect of Stress Relaxation on Board Level Reliability of Sn Based Pb-Free Solders**, S. Yoon, Z. Chen, M. Osterman, B. Han, and A. Dasgupta, *55th ECTC*, pp. 1210-1214, June 2005.
- **Key Concerns in the Assembly of Lead-free Electronics**, V. Eveloy, Y. Fukuda, S. Ganesan, J. Wu, and M. Pecht, *Proceedings IMAPS Taiwan 2005 International Technical Symposium*, pp. 167-183, June 2005.
- **Chinese Intellectual Property and Contractual Challenges**, Y. Liu, P. Campbell, D. Das, and M. Pecht, *International Conference on Electronics Packaging (ICEP)*, pp. 241-246, Japan, April 13-15, 2005.
- **Assessment of Long-term Reliability in Lead-free Assemblies**, S. Ganesan, J. Wu, and M. Pecht, *International Conference on Asian Green Electronics, Session 3*, pp. 140-155, Shang Hai, China, March 15-18, 2005.
- **A Decision Support Model for Determining the Applicability of Prognostic Health Management (PHM) Approaches to Electronic Systems**, P. Sandborn, *Proceedings of Reliability and Maintainability Symposium*, pp. 422-427, January 24-27, 2005.

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