AUBURN UNIVERSITY
SAMUEL GINN COLLEGE OF ENGINEERING

Spring 2014

cave³ News

NSF-CAVE3 Electronics Research Center
cave.auburn.edu; tel: (334) 844-3424

INSIDE

Mission Statement

CAVE is dedicated to working with industry in developing and implementing new technologies for the packaging and manufacturing of electronics, with special emphasis on the cost, harsh environment, and reliability requirements of the automotive, aerospace, military, computing, portable and other industries.

Message from Director

Reliability needs of defense electronics poses certain challenges while at the same time providing opportunities. The DoD guide for achieving reliability, maintainability, and availability published in 2005 revealed that several defense systems did not meet the reliability requirements in 1985-1990 timeframe. The number of reports indicate that the RAMS problems have had a significant impact on the DoD budget and the problems are not limited to a few systems. Put that backdrop in the context of industry transition to copper wirebonding and leadfree electronics – a materials system that industry knows much less about than the gold wire and leaded solders used previously so one can understand the risk averseness of the high-rel community in adopting new materials. The consumer industry has already migrated to leadfree solders and is contemplating transition to copper wirebonding owing to the high prices of gold wire and its extensive use for first-level interconnects. With the increased use of COTS parts in defense systems, technology changes in the consumer industry affect defense systems as well. Long-life systems rely on continued supply of components for system sustainment. Procurement of the leaded parts and gold wire parts will eventually be difficult if that is not the case already for some applications. There is a need for tools and techniques for risk mitigation of issues related to adoption of new emerging materials in high-rel systems. Emergence of newer materials also provides new opportunities to better understand the failure mechanisms under harsh environments. Traditionally, the modeling and predictive tools have generally lagged behind the introduction of technology. Even though the commercial modeling platforms available to engineers today are far superior in terms of capability and the physics that can be captured in the computational framework, the information required to drive models including material properties and damage relationships are still scarce. Better understanding of the constitutive behavior of the materials in the model under conditions of operation, coupled with a better understanding of the failure mechanisms, and development of newer approaches to quantifying and predicting reliability of complex electronic systems may perhaps go a long way to increasing the comfort-level towards the use of new materials and new packaging architectures in high-rel systems.

I want to take this opportunity to welcome Schlumberger to the CAVE3 Consortium.

- Pradeep Lall, T. Walter Professor and Director

Professor Lall Honored with ASME Applied Mechanics Award

Pradeep Lall was honored for his contributions to electronics packaging, reliability and prognostics research with the applied mechanics award from the American Society of Mechanical Engineers (ASME) Electronic and Photonic Packaging Division. Lall was recognized for his research on finding methods to make electronics systems safer, more reliable, energy efficient and survivable in harsh conditions. His work includes the development of dynamic models for electronic assemblies and products subjected to mechanical shock and accidental drop, as well as prognostics to identify impending electronic failures based on leading indicators. Lall's work in these areas has had a profound impact on product design and development. Lall is a Fellow of the ASME and has served as the Technical Program Chair of the ASME Congress in 2009, the General Chair of ASME Congress in 2010 and as Chair of the ASME Congress Steering Committee in 2012-13.

CAVE³ Consortium Spring-2014 Technical Review Meeting

The Center for Advanced Vehicle and Extreme Environment Electronics (CAVE³) will hold its Spring Technical Review and Project Planning Meeting on March 5-6, 2014 in Auburn University Wiggins Hall. All current members of the Consortium are invited to attend. The agenda for this event is available at cave.auburn.edu under CAVE³ Reviews. The following projects will be presented at the meeting:

- Acceleration Factors and Life Prediction Models for on-chip and off-chip Failure Mechanisms
- Advanced Interconnect Systems and 3D-Packaging Architectures in Harsh Environments
- Prognostic Health Monitoring Methodologies for Damage Estimation in Leaded and Lead-Free Solder Alloys
- PHM for Field-Deployed Electronics Subjected to Multiple Thermal Environments
- Leadfree Part Reliability, Crack Propagation and Life Prediction under Extreme Environments
- The Effects of Environmental Exposure on Underfill Behavior and Flip Chip Reliability
- Models for Underfill Stress-Strain and Failure Behavior with Aging Effects
- Insitu Die Stress Measurements in Flip Chip Packaging
- Modeling and Material Characterization for Flip Chip Packaging
- Theoretical and Experimental Investigation on Fretting Corrosion and Thermal Degradation for Hybrid and Electric Vehicles
- Complaint Pin/Press Fit Technology
- Model Simulation and Validation for Vibration-Induced Fretting Corrosion
- Vibration Based Interfaces for Information Transmission
- Microstructural and Mechanical Studies of SAC/Sn-37Pb Mixed Solders
- Aging Behavior of Next Generation Pb-Free Alloys
- Extreme Low Temperature Behavior of Solders
- Composition, Microstructure, and Reliability of Mixed Formulation Solder Joints
- QFP Reliability on Powered and Non-powered Thermal Cycle Environment
- Harsh Environment Substrate Performance
- Module Overmolding for Harsh Environments
- Systems Reliability of Lead Free for Harsh Environment Electronics

A block of rooms has been reserved for Review attendees at the preferred group rate. Room block will expire on March 1, 2014.

Contact Information:
Auburn University Hotel & Conference Center
241 South College Street
Tele: (334) 821-8200

SPECIAL EVENTS

2014 IEEE International Conference on Prognostics and Health Management

June 22-25, 2014
Eastern Washington University, Spokane, WA

The 5th Annual IEEE Reliability Society PHM conference will be held June 22-25 at Eastern Washington University in Spokane, WA. The conference will bring together persons from Industry and Academia, including engineers, scientists and managers from around the world to share and discuss the state of the art, state of practice, and future of Prognostics and Health Management. The conference includes Tutorials, Panel Sessions, and Papers that address the wide-ranging, interdisciplinary topics related to PHM technology and application. There will be a special working session on the in-process development of a PHM Standard. There will be a special session with presentations from the most successful entries in the conference PHM Challenge. Although the deadline for abstracts is past, the conference is accepting submission of full papers through the end of January. Papers will be reviewed, and those meeting the publication criteria, selected and presented at the conference will be published by the IEEE. Additional information about the conference, the challenge, and submitting papers is available on the conference web site at: phmconf.org.

Harsh Environment Electronics Symposium at the SMTA International 2014

Conference: Sep. 28—Oct. 2, 2014
Donald Stephens Convention Center, Rosemont, IL

The SMTA and CAVE3 at Auburn University are pleased to announce the 2013 AIMS (Automotive, Industrial, Military and Space) Harsh Environment Electronics Symposium. Dr. Pradeep Lall and Dr. John Evans, Conference Chairs and the SMTA International technical committee invite you to submit an abstract to participate in this timely program. The symposium will once again focus on harsh environments with an emphasis on military and space. We are soliciting abstracts that will provide NEW and TIMELY INFORMATION to attendees on the LATEST DEVELOPMENTS in these areas. Specific subject areas include, but are not limited to:

► Alternative Energy (including, wind, water transportation, battery)
► Components and Component Reliability
► Corrosion
► Extreme Environmental Applications
► Lead-Free Issues for Harsh Environments
► Substrate Surface Finishes for Harsh Environment Applications
► Thermal Management
► Tin Whiskers

Submit abstracts online at www.smta.org/smtai/call_for_papers.cfm

Abstracts Due: February 28, 2014
Acceptance: April 29, 2014

Prediction of Lumen Output and Chromaticity Shift in LEDs

Solid-state lighting (SSL) luminaires containing light emitting diodes (LEDs) have the potential of seeing excessive temperatures when being transported across country or being stored in non-climate controlled warehouses. They are also being used in outdoor applications in desert environments that see little or no humidity but will experience extremely high temperatures during the day. This makes it important to increase our understanding of what effects high temperature exposure for a prolonged period of time will have on the usability and survivability of these devices. Traditional light sources "burn out" at end-of-life. For an incandescent bulb, the lamp life is defined by B50 life. However, the LEDs have no filament to "burn". The LEDs continually degrade and the light output decreases eventually below useful levels causing failure. Presently, the TM-21 test standard is used to predict the L70 life of LEDs from LM-80 test data. Several failure mechanisms may be active in a LED at a single time causing lumen depreciation. The underlying TM-21 Model may not capture the failure physics in presence of multiple failure mechanisms. Correlation of lumen maintenance with underlying physics of degradation at system-level is needed. In this paper, Kalman Filter (KF) and Extended Kalman Filters (EKF) have been used to develop a 70-percent Lumen Maintenance Life Prediction Model for LEDs used in SSL luminaires. Ten-thousand hour LM-80 test data for various LEDs have been used for model development. System state at each future time has been computed based on the state space at preceding time step, system dynamics matrix, control vector, control matrix, measurement matrix, measured vector, process noise and measurement noise. The future state of the lumen depreciation has been estimated based on a second order Kalman Filter model and a Bayesian Framework. Life prediction of L70 life for the LEDs used in SSL luminaires from KF and EKF based models have been compared with the TM-21 model predictions and experimental data.

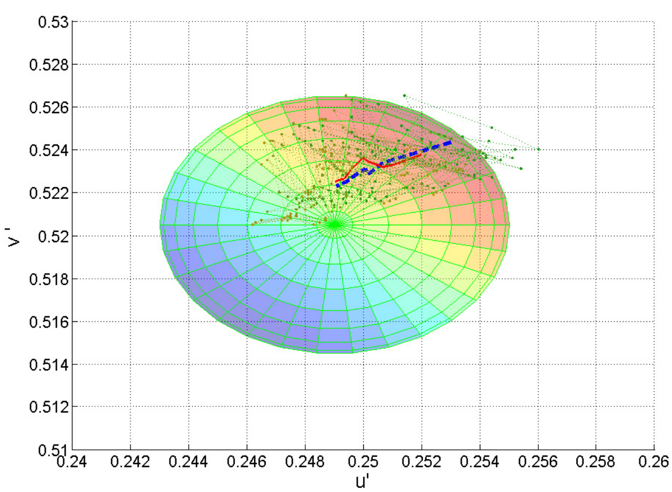

Figure 1: KF Tracking in u'v' Color Space.

Revised Anand Constitutive Model For Lead Free Solder to include Aging Effects

Traditional finite element based predictions for solder joint reliability during thermal cycling accelerated life testing are based on solder constitutive equations (e.g. Anand viscoplastic model) and failure models (e.g. energy dissipation per cycle model) that do not evolve with material aging. Thus, there will be significant errors in the calculations with lead free SAC alloys that illustrate dramatic aging phenomena. In this study, we have developed a revised set of Anand viscoplastic stress-strain relations for solder that include material parameters that evolve with the thermal history of the solder material. The effects of aging on the nine Anand model parameters have been examined by performing stress-strain tests on SAC305 samples that were aged for various durations (0-6 months) at temperature of 100 C. The stress-strain data were measured at three strain rates (.001, .0001, and .00001 1/sec) and five temperatures (25, 50, 75, 100, and 125 C). The mechanical tests have been performed using both water quenched (WQ) and reflowed (RF) samples (two unique specimen microstructures). In the case of the water quenched samples, there is rapid microstructural transitioning during the brief time that occurs between placing molten solder into the glass tubes and immersing the tubes in water bath. On the other hand, the reflowed samples are first cooled by water quenching, and then sent through a reflow oven to re-melt the solder in the tubes and subject them to a desired temperature profile matching that used in PCB assembly. Using the measured stress-strain and creep data, mathematical expressions have been developed for the evolution of the Anand model parameter with aging time. Our results show that 2 of the 9 constants remain essentially constant during aging, while the other 7 show large changes (30-70%) with up to 6 months of aging. The revised Anand constitutive equations for solder with aging effects have also been incorporated into commercial finite element codes (ANSYS and ABAQUS).

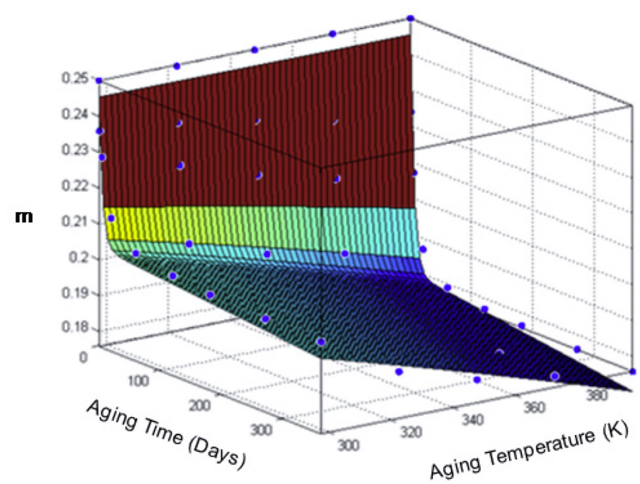

Figure 2: Variation of Anand Parameter 'm' for SAC305 with Aging time and temperature

Research Highlights

Prediction Model for Temperature –Vibration

Current trends in the automotive industry warrant a variety of electronics for improved control, safety, efficiency and entertainment. Many of these electronic systems like engine control units, variable valve sensor, crankshaft-camshaft sensors are located under-hood. Electronics installed in under-hood applications are subjected simultaneously to mechanical vibrations and thermal loads. Typical failure modes caused by vibration induced high cycle fatigue include solder fatigue, copper trace or lead fracture. The solder interconnects accrue damage much faster when vibrated at elevated temperatures. Industry migration to lead-free solders has resulted in a proliferation of a wide variety of solder alloy compositions. Presently, the literature on mechanical behavior of lead-free alloys under simultaneous harsh environment of high-temperature vibration is sparse.

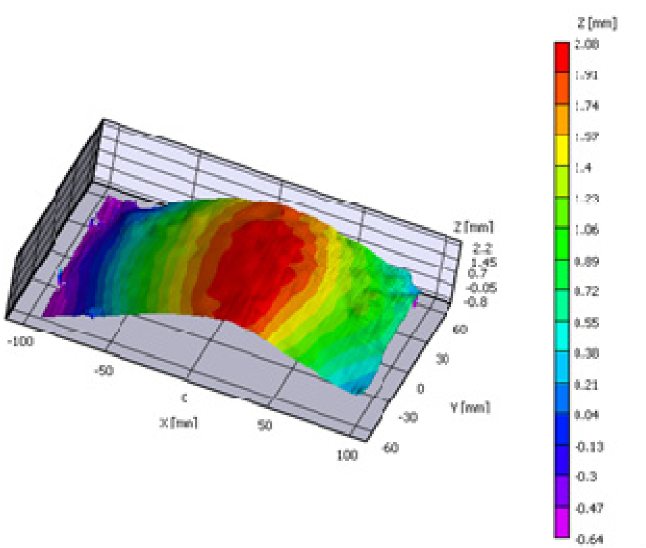

Figure 3: Experimental mode shape and full field out of plane displacement contour at 1st natural frequency

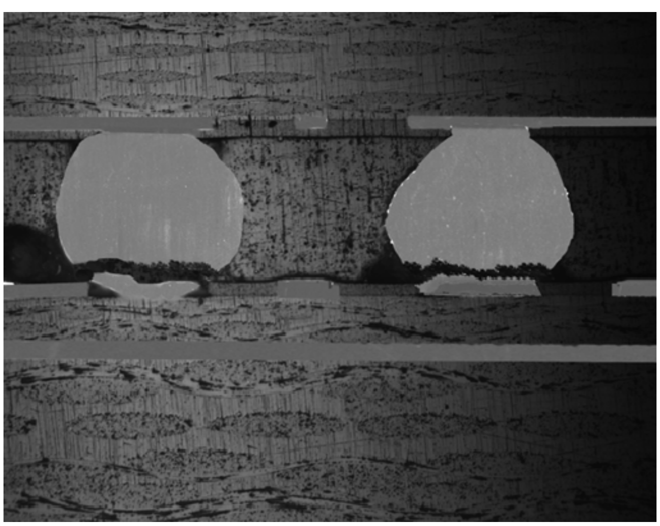

Figure 4: BGA Solder Joint Failure

In this project, the reduction in stiffness of the PCB with temperature has been demonstrated by measuring the shift in natural frequencies. The test vehicle consisting of a variety of lead-free SAC305 daisy chain components including BGA, QFP, SOP and TSOPs has been tested to failure by subjecting it to two elevated temperatures and harmonic vibrations at the corresponding first natural frequency. The test matrix includes three test temperatures of 25C, 75C and 125C and simple harmonic vibration amplitude of 10G which are values typical in automotive testing. PCB deflection has been shown to increase with increase in temperature. The full field strain has been extracted using high speed cameras operating at 100,000 fps in conjunction with digital image correlation. Material properties of the PCB at test temperatures have been measured using tensile tests and dynamic mechanical analysis. FE simulation using global-local finite element models is thus correlated with the system characteristics such as modal shapes, natural frequencies and displacement amplitudes for every temperature. The solder level stresses have been extracted from the sub-models. Stress amplitude versus cycles to failure curves are obtained at all the three test temperatures. A comparison of failure modes for different surface mount packages at elevated test temperatures and vibration has been presented in this study.

Nano-indentation of Leadfree Solders

The mechanical properties of a lead free solder are strongly influenced by its microstructure, which is controlled by its thermal history including solidification rate and thermal aging after solidification. Due to aging phenomena, the microstructure, mechanical response, and failure behavior of lead free solder joints in electronic assemblies are constantly evolving when exposed to isothermal and/or thermal cycling environments. Through uniaxial testing of miniature bulk solder tensile specimens, we have previously demonstrated that large changes occur in the stress-strain and creep behaviors of lead free solder alloys with aging. Complementary studies by other research groups have verified aging induced degradations of SAC mechanical properties. In those investigations, mechanical testing was performed on a variety of sample geometries including lap shear specimens, Iosipescu shear specimens, and custom solder ball array shear specimens. While there are clearly aging effects in SAC solder materials, there have been limited prior mechanical loading studies on aging effects in actual solder joints extracted from area array assemblies (e.g. PBGA or flip chip). This is due to the extremely small size of the individual joints, and the difficulty in gripping them and applying controlled loadings (tension, compression, or shear). In the current work, we have explored aging phenomena in actual solder joints by nano-mechanical testing of single SAC305 lead free solder joints extracted from PBGA assemblies. Using nanoindentation techniques, the stress-strain and creep behavior of the SAC solder materials have been explored at the joint scale for various aging conditions. Mechanical properties characterized as a function of aging include the elastic modulus, hardness, and yield stress. Using a constant force at max indentation, the creep response of the aged and non-aged solder joint materials has also been measured as a function of the applied stress level. With these approaches, aging effects in solder joints were quantified and correlated to the magnitudes of those observed in testing of miniature bulk specimens. Our results show that the aging induced degradations of the mechanical properties (modulus, hardness) of single grain SAC305 joints were similar to those seen previously by testing of larger "bulk" solder specimens. However, due to the single grain nature of the joints considered in this study, the degradations of the creep responses were significantly less in the solder joints relative to those in larger uniaxial tensile specimens. The magnitude of aging effects in multi-grain lead free solder joints remains to be quantified. Due to the variety of crystal orientations realized during solidification, it was important to identify the grain structure and crystal orientations in the tested joints. Polarized light microscopy and Electron Back Scattered Diffraction (EBSD) techniques have been utilized for this purpose. The test results show that the elastic, plastic, and creep properties of the solder joints and their sensitivities to aging are highly dependent on the crystal orientation. In addition, an approach has been developed to predict tensile creep strain rates for low stress levels using nanoindentation creep data measured at very high compressive stress levels.

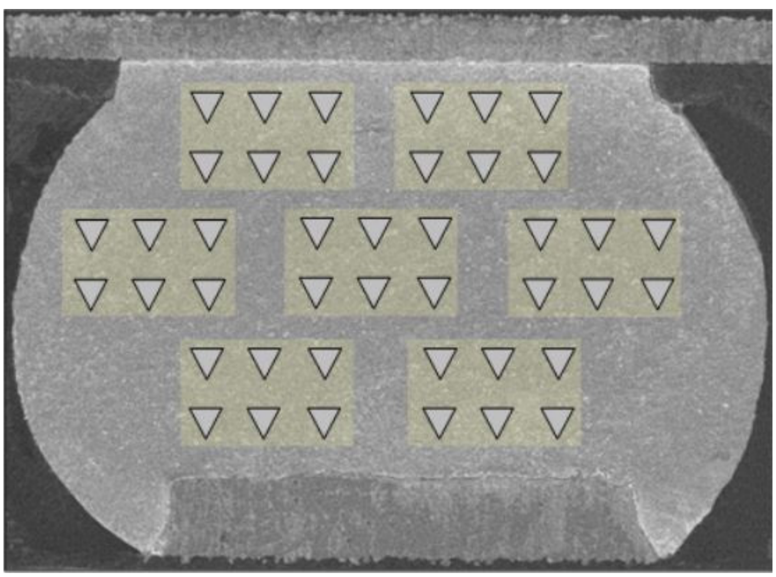

Figure 5: Indentation Regions for Various Aging Conditions.

Leading Indicators For Prognostication Of Impending Failures On Cu-Al Interconnects

Wire bonding is predominant mode of interconnect in electronics packaging. Traditionally material used for wire bonding is gold. But industry is slowly replacing gold wire bond by copper-aluminum wire bond because of the lower cost and better mechanical properties than gold, such as high strength, high thermal conductivity etc. Numerous studies have been done to analyze failure mechanism of Cu-Al wire bonds. Cu-Al interface is a predominant location for failure of the wirebond interconnects. In this paper, the use of intermetallic thickness as leading indicator-of-failure for prognostication of remaining useful life for Cu-Al wire bond interconnects has been studied. For analysis, 32 pin chip scale packages were used. Packages were aged isothermally at 200°C and 250°C for 10 days. Packages were withdrawn periodically after 24 hours and its IMC thickness was measured using SEM. The parts have been prognosticated for accrued damage and remaining useful life in current or anticipated future deployment environment. The presented methodology uses evolution of the IMC thickness in conjunction with the Levenberg-Marquardt Algorithm to identify accrued damage in wire bond subjected to thermal aging. The proposed method can be used for equivalency of damage accrued in Cu-Al parts subjected to multiple thermal aging environments.

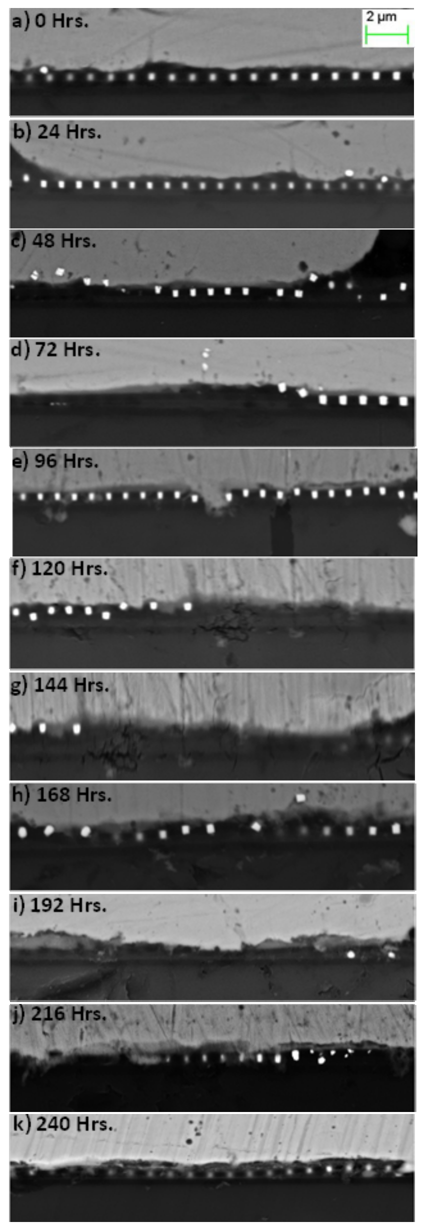

Figure 6: Cu-Al IMC growth at different aging time, under thermal aging (200^{o}C)

.

Effect of Intermittent Storage On Reliability Of Leadfree Electronics Using Leading Indicators

Electronic systems may be subjected to prolonged and intermittent periods of storage prior to deployment or usage. Prior studies have shown that leadfree solder interconnects show measurable degradation in the mechanical properties even after brief exposures to high temperature. In this paper, a method has been developed for the determining equivalent storage time to produce identical damage at a different temperature. Electronics subjected to accelerated tests often have a well-defined thermal profile for a specified period of time. Quantification of the thermal profile in field deployed electronics may be often difficult because of variance in the environment conditions and usage profile. There is need for tools and techniques to quantify damage in deployed systems in absence of macro-indicators of damage without knowledge of prior stress history. Approach for mapping damage in leadfree second-level interconnects under between thermal conditions is new. High reliability applications such as avionics and missile systems may be often exposed to long periods of storage prior to deployment. Effect of storage at different temperature conditions can be mapped using the presented approach.

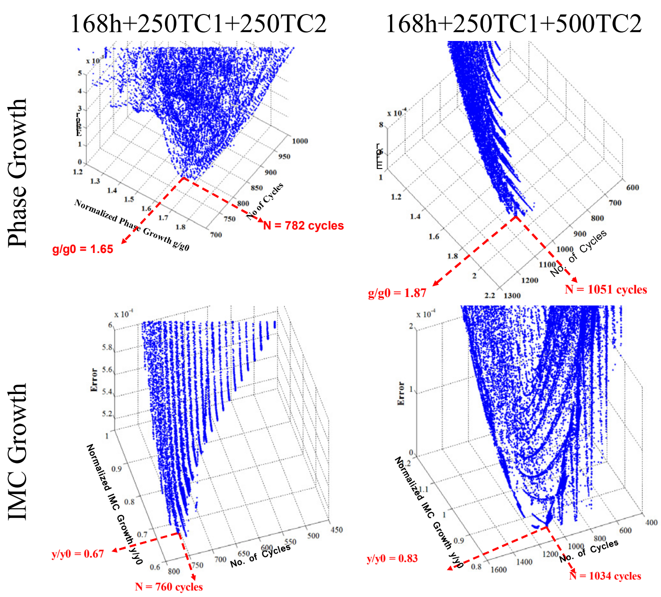

Figure 7: Prognosticated Damage of High Temperature Storage in Leadfree Systems

A framework has been developed to investigate the system state and estimate the remaining useful life of solder ball subjected to a variety of isothermal aging conditions including 60°C, 75°C and 125°C for periods of time between 1-week and 4-week. Data on damage precursors has been collected and analyzed to derive physics based damage mapping relationships for aging. Mathematical relationships have been derived for the damage mapping to various thermal storage environments to facilitate determining appropriate time-temperature combination to reach a particular level of damage state. Activation energy for the leading indicators of failure is also computed. Specific damage proxies examined include the phase-growth indicator and the intermetallic thickness. The viability of the approach has been demonstrated for leadfree test assemblies subjected to multiple thermal aging at 60° C, 75°C and 125°C. Damage mapping relationships are derived from data based on the two separate leading indicators.

Figure 9: Iso-phase growth plots of aging temperature vs. aging time for phase growth.

Effect of Nitrogen vs. Vacuum-Environments on Sn Whiskering

Recent work by Hoffman (Savannah River National Laboratory) reported Sn whiskers which grew longer in nitrogen (sealed jar) environments compared to air environments. This is of concern in electronics systems which operate in nitrogen-backfilled environments, such as hybrid circuits and sensor systems. In this work we compare whiskers grown from a thin sputtered Sn film in two different environments—pure N_2 and ultrahigh vacuum (UHV). The ~1000 Å Sn films were sputter deposited onto silicon (Si) substrates under tensile, neutral, and compressive intrinsic film stress conditions. After 140 days of incubation in N_2, the compressive films had the highest whisker density (8320 cm^{-2}), compared to the neutral stress films (3520 cm^{-2}) and tensile stress films (4640 cm^{-2}). In UHV, whisker densities and lengths were characteristically lower, e.g., for the compressive case, the average whisker length was 2.6 µm compared to 13.3 µm in N_2. The N_2 samples also produced whiskers earlier (at 30 days) than the UHV samples. X-ray photoelectron spectroscopy (XPS) analysis of the sputtered Sn surface after the incubation period indicate a more complex surface structure on the samples exposed to the N_2 compared to UHV, suggesting that the surface structure of the Sn oxide influences the whisker growth. The photos below show whiskering after 140 days of incubation in a pure nitrogen environment.

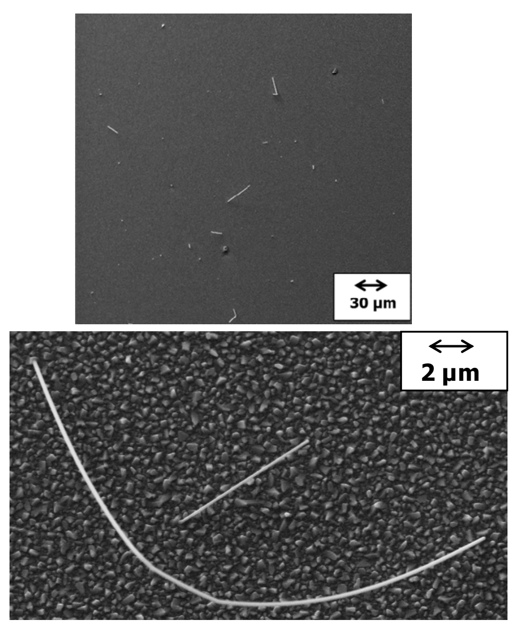

Figure 8: Whiskering after 140 days of incubation in a pure nitrogen environment

Research Highlights

Prognostics Of Damage Accrual In SSL Luminaires and Drivers Subjected To HTSL Accelerated Aging

This paper will show an investigation of off-the-shelf luminaires with the focus on the LED electronic drivers, specifically the aluminum electrolytic capacitors (AECs), that have been aged using high temperature shelf life (HTSL) testing of 135°C in order to prognosticate the remaining useful life of the luminaires. Luminaires have the potential of seeing excessive temperatures when being transported across the country or being stored in non-climate controlled warehouses. They are also being used in outdoor applications in desert environments that see little or no humidity but will experience extremely high temperatures during the day. This makes it important to increase our understanding of what effects being stored at high temperatures for a prolonged period of time will have on the usability and survivability of these devices. The U.S. Department of Energy has made a long term commitment to advance the efficiency, understanding and development of solid-state lighting (SSL) and is making a strong push for the acceptance and use of SSL products. In this work, the four AECs of three different types inside each LED electronic driver were studied. The change in capacitance and the change in equivalent series resistance (ESR) of the AECs were measured and considered to be a leading indication of failure of the LED system. These indicators were used to make remaining useful life predictions to develop an algorithm to predict the end of life of the AECs. The luminous flux of a pristine downlight module was also monitored using each LED electronic driver that was subjected to HTSL through the progression of the testing to determine a correlation between the light output of the lamp and the failing components of the LED electronic driver. Prognostic and Health Management (PHM) is a useful tool for assessment of the remaining life of electrical components and is demonstrated for AECs in this work.

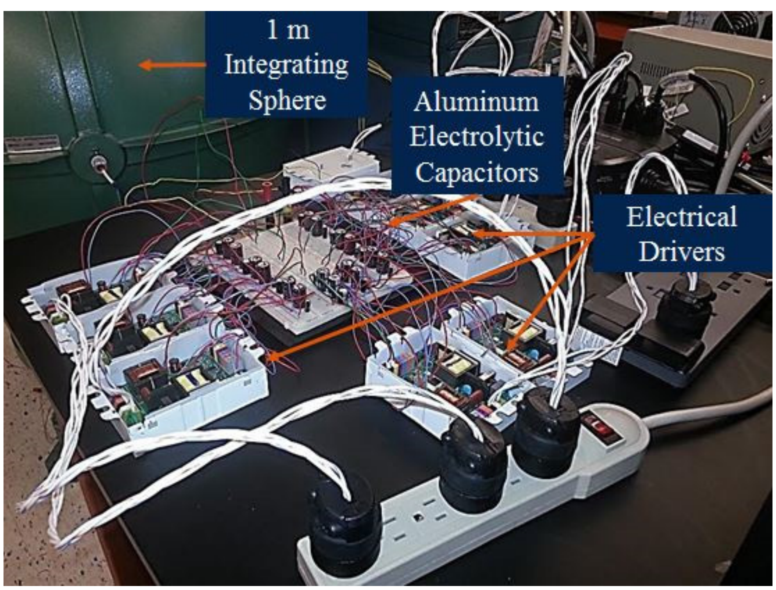

Figure 9: Luminous Flux Measurement Setup.

Resistance Spectroscopy Based Assessment Of Degradation In Cu-Al Wire Bond Interconnects

Escalation of the expense of gold has resulted in industry interest in use of copper as alternative wire bonds interconnect material. Copper wire has the advantage of lower price and comparable electrical resistance to gold wire. In this paper, 32-pin copper-aluminum wire bond chip scale packages are aged at three types of environment conditions separately. Environmental conditions included: 200°C for 10 days, 85°C and 85% RH for 8 weeks and -40°C to 125°C for 500 thermal cycles. The resistances of the wire bond are obtained every 24 hours for 200°C environment, every 7 days for 85C/85RH environment and every 5 days (50 thermal cycles) for the thermal cycling environment. A leading indicator has been developed in order to monitor the progression effect of the different thermal aging condition on the package and prognosticate remaining useful life based on the resistance spectroscopy. The Cu-Al wire bond resistance has been measured using a modified Wheatstone bridge. It has been shown previously that precise resistance spectroscopy is able to offer the failure of a leading indicator prior to the traditional definition of failure. The prognostic health management is qualified to be an efficient and accuracy tool for assessment of the remaining life of the wire bond. The ability to predict the remaining useful life of Cu-Al wire bond provides several advantages, including increasing safety by providing warning ahead of time before the failure.

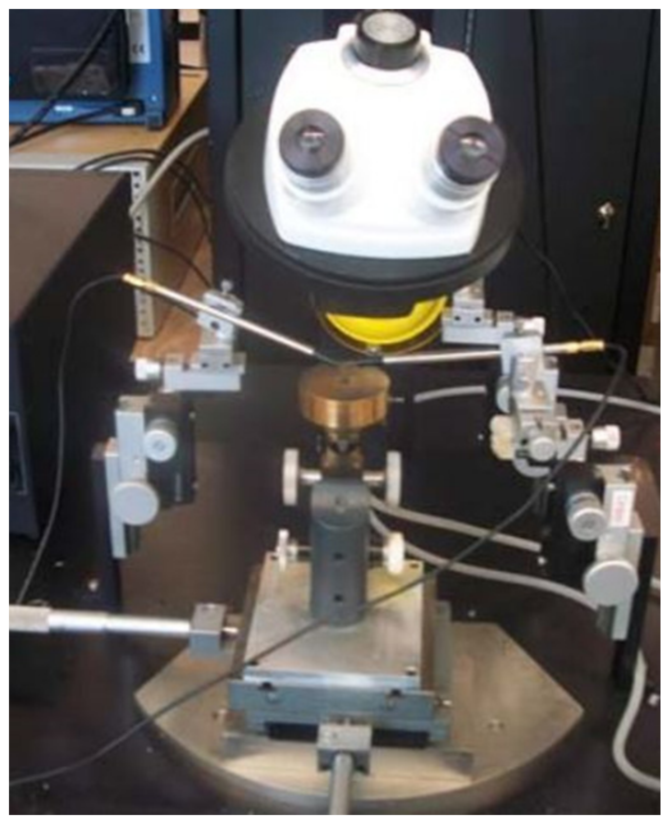

Figure 10: Probing station used in the investigation of Cu-Al wire-bonds.

Research Highlights

Long-Term Aging Effects SAC105 and SAC305 High Strain Rate Properties

Electronics subjected to shock and vibration may experience strain rates of 1-100 sec-1. High strain rate data is scarce for leadfree solders at strain rates in the range of 1-100 sec-1, typical of drop-impact, shock and vibration. A new experimental method has been developed to achieve constant strain rate in the neighborhood of 1 to 100 sec-1 during the entire deformation history. SAC105 and SAC305, which are two of the widely used leadfree alloys, have been tested at strain rates of 10, 35, 50 and 75 per sec. Effect of aging on the high strain rate properties has also been quantified by subjecting the test specimen to thermal aging for varied periods of time at various temperatures. The leadfree solders have been exposed to constant temperatures of 25°C, 50°C, 75°C, 100°C and 125°C for 1 day, 30 days and 60 days prior to high strain-rate test. Full-field strain in the specimen has been measured using high speed imaging at frame rates up to 75,000 fps in combination with digital image correlation. The cross-head velocity has been measured prior-to, during, and after deformation to ensure the constancy of cross-head velocity. Experimental data for the unaged and the aged specimen has been fit to the non-linear Ramberg-Osgood model using two methods.

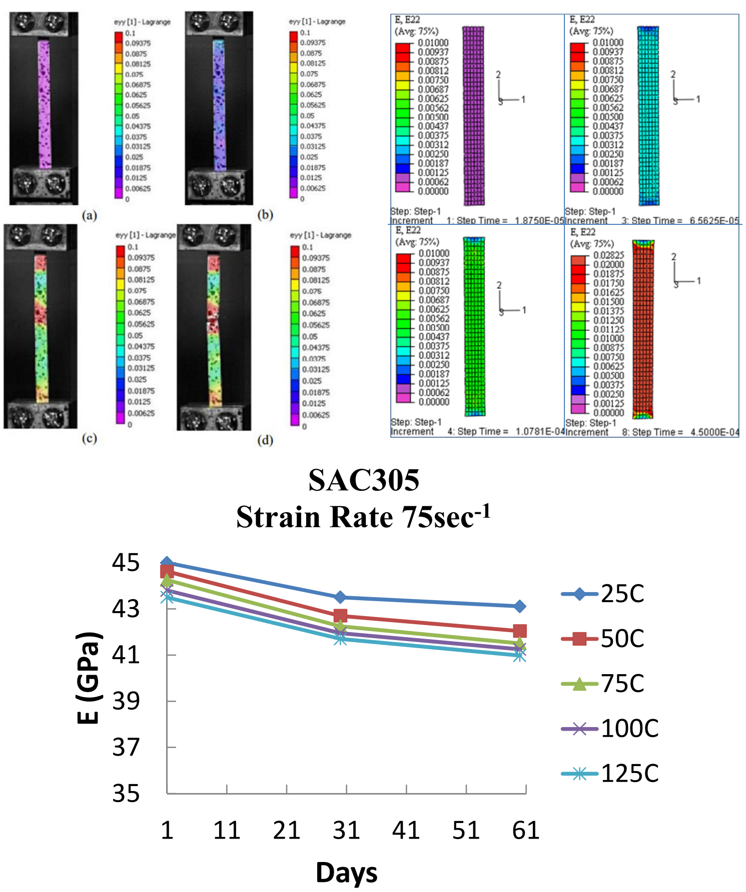

Figure 11: Effect of temperature on Elastic modulus of SAC305 at strain rate of 75 sec^{-1}.

Long-term Aging Effects on Reliability Performance of Lead-Free Solder Joints

In order to provide a better understanding of lead-free solder joint behavior in harsh environment, the paper contributed a perspective of isothermal aging Sn-Ag-Cu (SAC) alloy in elevated temperature and studied the its thermal-mechanical properties by examining the microstructure. A full experiment matrix with varying aging temperatures and solder alloys on two finish levels (ImAg and ImSn) was considered. Also, the test samples sizes ranged from 19mm, 0.8mm pitch ball grid arrays (BGAs) to 5mm, 0.4mm pitch μBGAs and in additional, 0.65mm MLF and 2512 resistors be particularly tested. The test specimens all subjected to aging at temperatures leveling up from 25°C, 55°C, 85°C and 125 °C with aging over time periods of 0, 6 months, 12 months and 24 months and then accelerated thermally cycled from -40°C to 125°C with 15 min dwell times at the high and low peak temperature. It was found that the thermal performance of lead-free fine-pitch packages significantly degrades up to 70% after 2 year aging at high temperature.

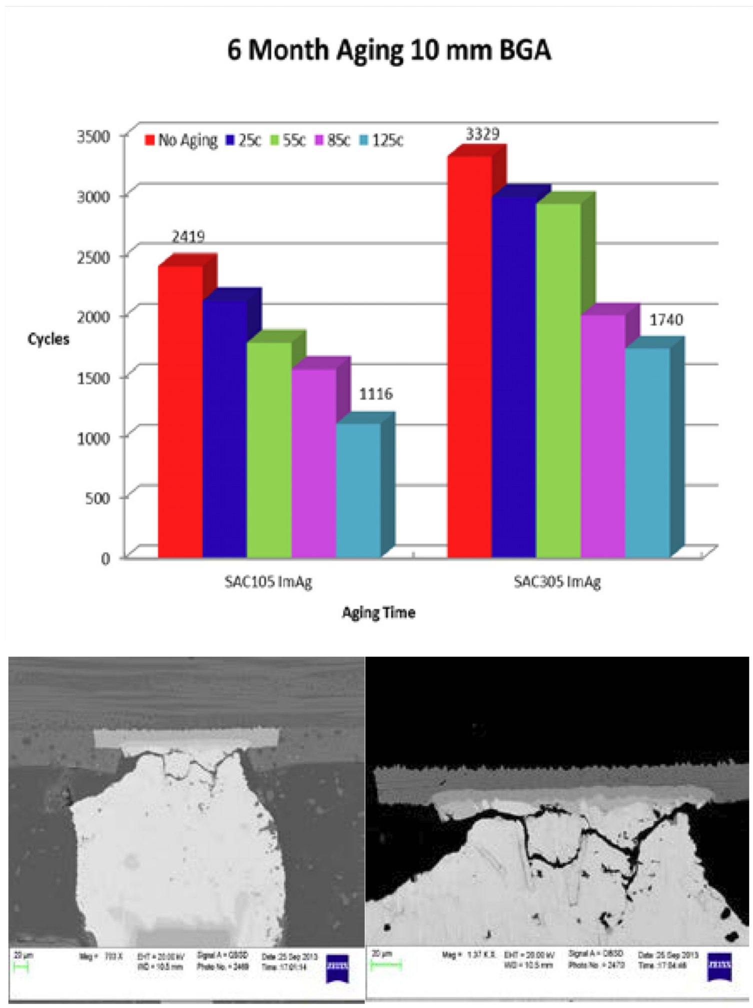

Figure 12: Effect of Aging on SAC105 and SAC305 Solder Reliability

Announcements

Drs. Evans and Lall Chair the Harsh Environment Symposium at SMTAI 2013

The harsh environment symposium was held at the SMTAI 2013 in Ft. Worth, Texas on October 14, 2013. The year 2013 is the 10th year of the symposium. The symposium featured 6-sessions with 18-technical presentations on various aspects of harsh environment electronics reliability and manufacturing. The sessions were attended by over 100-conference attendees from industry and academia.

Lall Cuts Ribbon to Open ASME Congress 2013 in Role of CSC Chair

Pradeep Lall the Walter Professor in Mechanical Engineering and the Director of the NSF-CAVE3 Electronics Research Center at Auburn University is serving as the Congress Steering Committee (CSC) Chair of the ASME Congress being held in San Diego, California from Nov 15-21, 2013. Pradeep Lall along with Tom Loughlin (Executive Director of ASME) and Madiha El Mehelmy Kotb (ASME President) Cut the Ribbon to Open ASME Congress 2013 on November 17, 2013. The Congress Steering Committee's major responsibilities relate to its mission of organizing a quality multidisciplinary engineering research and innovation technical program, and facilitating professional interactions of engineering research and innovation communities with focus on the technical program and exhibits.

Pradeep Lall along with Tom Loughlin (Executive Director of ASME) and Madiha El Mehelmy Kotb (ASME President) Cut the Ribbon to Open ASME Congress 2013 on November 17, 2013.

Given that Society-wide functions such as its business meetings immediately precede the Technical Program at the same venue, the CSC works with Divisions and Events Management in conference planning, and content development of technical program at IMECE. In the role of CSC Chair, Lall oversees all responsibilities of the CSC. Prior to serving as the CSC Chair, Lall has served as the Technical Program Vice-Chair of ASME Congress in 2008, Technical Program Chair of ASME Congress in 2009 and the General chair of the ASME Congress in 2010. Lall is the author and co-author of 2-books, 13 book chapters, and over 325 journal and conference papers in the field of electronic packaging with emphasis on design, modeling and predictive techniques. He has earned the distinction of Fellow of the ASME and Fellow of the IEEE for his contributions and achievements in the field of engineering.

Lall Selected For Member of Technical Distinction Award

Lall was recognized for his research in the area of electronics reliability and prognostics through Member of Technical Distinction Award by the Surface Mount Technology Association. Member of Technical Distinction Award recognizes individuals who have made significant and continuing contributions to the SMTA and the electronics manufacturing industry.

Prof. Pradeep Lall (Right) receiving the SMTA Member of Technical Distinction Award from Prof. John Evans (Left) at the SMTAI 2013.

The award was presented at a reception dinner hosted at the Surface Mount Technology Association International Conference (SMTAI) held in Ft. Worth, Texas. SMTAI is an international conference which was attended by over 1300 attendees from 27 countries in 2013. The quote from the SMTA website reads, "Dr. Lall's experience in both industry and academics brings a unique and pragmatic perspective to the assessment of complex technical issues that are of interest to the SMTA membership. Pradeep willingly shares that perspective with the SMTA membership through highly rated presentations and publications. As an educator, he has also introduced many students to the SMTA through co-authoring of papers and participation at SMTA events".

Dr. Evans Presents Paper on Effects of Solder Aging on Reliability at the SMTAI 2013

The paper is titled—Long-term Aging Effects on Reliability Performance of Lead-free Solder Joints, co-authored by Dr. Evans provides the first comprehensive treatment of the effects of thermal aging on reliability of SAC solders.

Selected Recent Publications

1. Lall, P., Wei, J., Davis, L., Prediction of Lumen Output and Chromaticity Shift in LEDS Using Kalman Filter and Extended Kalman Filter Based Models, 2013 IEEE International Conference on Prognostics and Health Management (PHM), Gaithersburg, MD, Session: S.2.06 PHM Devices/Sensors, June 24-27, 2013
2. Lall, P., Lowe, R., Goebel K., Prognostic Health Monitoring For A Micro-Coil Spring Interconnect Subjected To Drop Impacts, 2013 IEEE International Conference on Prognostics and Health Management (PHM), Gaithersburg, MD, Session: S.3.09 PHM Applications: Electronics, June 24-27, 2013
3. Motalab, M., Basit, M., Suhling, J., Lall, P., A Revised Anand Constitutive Model For Lead Free Solder That Includes Aging Effects, ASME 2013 International Technical Conference and Exhibition On Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73232, July 16-18, 2013
4. Motalab, M., Mustafa, M., Suhling, J., Zhang, J., Evans, J., Bozack, M., Lall, P., Thermal Cycling Reliability Predictions For PBGA Assemblies That Include Aging Effects, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73230, July 16-18, 2013
5. Hasnine, M., Mustafa, M., Zou, J., Suhling, J., Prorok, B., Bozack, M., Lall, P., Nanomechanical Characterization Of Aging Effects In Solder Joints In Microelectronic Packaging, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73234, July 16-18, 2013
6. Cai, Z., Suhling, J., Lall, P., Bozack, M., Aging Induced Mechanical Property Degradation and Microstructure Evolution Of SAC+X Lead Free Solder Alloys, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73241, July 16-18, 2013
7. Chhanda, N., Suhling, J., Lall, P., Effects Of Moisture Exposure On The Mechanical Behavior Of Polymer Encapsulants In Microelectronic Packaging, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73242, July 16-18, 2013
8. Lall, P., Deshpande, S., Leading Indicators For Prognostication Of Impending Failures On Cu-Al Interconnects, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73287, July 16-18, 2013
9. Lall, P., Harsha, M., Suhling, J., Goebel, K., Damage Pre-Cursors Based Prognostication Of Accrued Damage and Assessment Of Operational Readiness Of Leadfree Electronics, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73251, July 16-18, 2013
10. Lall, P., Mirza, K., Harsha, M., Suhling, J., Goebel, K., Method For Assessment Of Prolonged and Intermittent Storage On Reliability Of Leadfree Electronics Using Leading Indicators, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73309, July 16-18, 2013
11. Roberts, J., Motalab, M., Hussain, S., Suhling, J., Jaeger, R., Lall, P., Measurement Of Microprocessor Die Stress Due To Thermal Cycling, Power Cycling, and Second Level Assembly, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73244, July 16-18, 2013
12. Jaeger, R., Motalab, M., Hussain, S., Suhling, J., Four-Wire Bridge Measurements Of Van Der Pauw Stress Sensors On (100) and (111) Silicon, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73249, July 16-18, 2013
13. Mustafa, M., Roberts, J., Suhling, J., Lall, P., The Effects Of Aging Of The Cyclic Stress-Strain and Fatigue Behaviors Of Lead Free Solders, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73240, July 16-18, 2013
14. Lall, P., Limaye, G., A Methodology For High Cycle Fatigue Characterization Of Lead-Free Interconnects Under Simultaneous Harsh Environments Of High Temperature and Vibration, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73245, July 16-18, 2013
15. Lall, P., Limaye, G., Shantaram, S., Suhling, J., Effect Of Isothermal Aging and High Strain Rate On Material Properties Of Innolot, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73246, July 16-18, 2013
16. Lall, P., Sakalaukus, P., Davis, L., Prognostics Of Damage Accrual In SSL Luminaires and Drivers Subjected To HTSL Accelerated Aging, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73250, July 16-18, 2013
17. Lall, P., Lowe, R., Goebel, K., Comparison Of Prognostic Health Management Algorithms For Assessment Of Electronic Interconnect Reliability, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73252, July 16-18, 2013
18. Jaeger, R., Motalab, M., Hussain, S., Suhling, Four-Wire Bridge Measurements of van der Pauw Stress Sensors on (100) and (111) Silicon, Proceedings of the ASME InterPACK, InterPACK2013-73249, 2013.
19. Lall, P., Wei, J., Davis, L., Solid State Lighting Life Prediction Using Extended Kalman Filter ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73288, July 16-18, 2013
20. Lall, P., Zhang, H., Davis, L., Assessment Of Lumen Degradation and Remaining Life Of LEDS Using Particle Filter, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73305, July 16-18, 2013

Selected Recent Publications

21. Lall, P., Luo, Y., Resistance Spectroscopy Based Assessment Of Degradation In CU-AL Wire Bond Interconnects, ASME 2013 International Technical Conference and Exhibition on Packaging and Integration Of Electronic and Photonic Microsystems (InterPACK), Burlingame, CA, Session: IPACK2013-73308, July 16-18, 2013
22. Hai, Z., Zhang, J., Shen, C., Thirugnanasambandam, S., Evans, J., Bozack, M., Sesek, R., Long-Term Aging Effects On Reliability Performance Of Lead-Free Solder Joints, SMTA International Conference (SMTA), Fort Worth, TX, p.362, October 13-17, 2013
23. Lall, P., Patel, K., Narayan, V., Process and Material Envelope For Allowable Package-On-Package Warpage, SMTA International Conference (SMTA), Fort Worth, TX, p.123-137, October 13-17, 2013
24. Lall, P., Limaye, G., Life Prediction Of Lead-Free Electronics Under Simultaneous Automotive Environments Of High Temperature and Vibration, SMTA International Conference (SMTA), Fort Worth, TX, p.310-325, October 13-17, 2013
25. Lall, P., Shantaram, S., High Strain Rate Properties Of SAC105 and SAC305 Leadfree Alloys After Extended High Temperature Storage, SMTA International Conference (SMTA), Fort Worth, TX, p.363-377, October 13-17, 2013
26. Lall, P., Limaye, G., High Cycle Fatigue Life-Prediction For Lead-Free Interconnects Under Simultaneous High Temperature and Vibration, ASME 2013 International Mechanical Engineering Congress and Exposition (IMECE), San Diego, CA, Session: IMECE2013-66820, November 15-21, 2013
27. Lall, P., Zhang, H., LED Lumen Degradation and Remaining Life Under Exposure To Temperature and Humidity, ASME 2013 International Mechanical Engineering Congress and Exposition (IMECE), San Diego, CA, Session: IMECE2013-66832, November 15-21, 2013

All other published CAVE³ articles are available at cave.auburn.edu under Publications

Auburn University
CAVE 3
Samuel Ginn College of Engineering
735 Extension Loop
Auburn, AL 36849

Non-profit Org.
U.S. Postage
PAID
Permit No. 9
Auburn, AL
36849

Mechanical Engineering-CAVE3-9/2011

cave³ News

Spring 2014

cave.auburn.edu

www.auburn.edu

If you have recently changed your address or have colleagues who would be interested in receiving the CAVE^3 News, please fill out the following information and either return it to the above address, fax it to 334-844-1898, or email it to *cave@auburn.edu*.

☐ Please add me to the CAVE News mailing list.

☐ Please remove me from the CAVE News mailing list.

☐ My address has changed, please update it.

☐ Please add me to the CAVE email mailing list.

Name: ____________________

Title: ____________________

Company: ____________________

Address: ____________________

City: __________ State: _______ Zip: __________

Country: ____________________

Phone #: ____________________

Fax #: ____________________

E-mail: ____________________

Comments and suggestions: ____________________