AUBURN UNIVERSITY

SAMUEL GINN
COLLEGE OF ENGINEERING

Fall 2015

cave³ News

NSF-CAVE3 Electronics Research Center

cave.auburn.edu; PH: (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 the Director

I am glad to report that Auburn University is part of the FlexTech team that won the Flexible Hybrid Electronics Manufacturing Innovation Institute (FHEMII). Auburn University will be leading the Harsh Environment Electronics Node for the FHEMII. Defense Secretary Ashton Carter last Friday announced a cooperative agreement with the research consortium FlexTech Alliance to establish and manage the Manufacturing Innovation Institute for Flexible Hybrid Electronics, or FHE MII. FlexTech Alliance, based in San Jose, Calif., will coordinate the FHE MII, which comprises 96 companies, 11 laboratories and non-profits, 43 universities and 15 state and regional organizations. Auburn University will head the only node in Alabama. The harsh environment focus of the node aligns well with the core strengths of the CAVE3 Consortium which has been working on electronics performance, reliability and survivability in extreme environments for the automotive, military, and defense companies and federal agencies. Establishment of a national harsh environment node for FHEMII at Auburn University will provide engineers with the integrated skills and theoretical background for the manufacture of flexible hybrid electronics for extreme environment applications, create intellectual property, expenditures on research, education and related activities leading to a measurable economic impact in creation of jobs and catalyze development of technologies which can be manufactured in the Alabama. The AU harsh environment node has developed strategic partnerships with industry and research labs in Alabama and nationally for development and demonstration of technologies for harsh environment operation. Alabama is home to over 200 aerospace and defense companies including notables such as Lockheed Martin, Northrop Grumman, Raytheon, and Boeing. In addition, Alabama is home to several automotive manufacturers and their electronics suppliers. Redstone Arsenal is home to government agencies including US Army, NASA, and MDA. Auburn University Flexible Electronics Harsh Environment Node will focus on the TRL4 technologies for use in automotive, military and defense environments. The focus of flexible electronics fabrication will be on processes which meet the demands of soft, pliant and often easily damaged surfaces capable of low temperature processing. The node will create technology demonstrators for new technologies such as printed flexible roll-to-roll electronics in partnership with companies, in order to mitigate the risk associated with the use of the new technologies in end-applications. Since semiconductor manufacturing is highly automated, utilizing complex processes developed by multiple vendors which cannot be integrated without coordination between the layers of the electronics supply chain – the node will focus on the manufacturing challenges related to raw materials, materials handling, fabrication and assembly of flexible electronics for harsh environments. Stretchable electronics will need device designs for mitigating the interconnect failures due to fracture and delamination under operational loads, flexible encapsulation for physical packaging of electronics, innovative thermal management schemes to ensure thermal and thermo-mechanical survivability in the presence of multi-material thin film interfaces. . In parallel with the development of manufacturing protocols, it is envisioned that the development of modeling tools and prediction methods is needed to assess the device design, layout, and fabrication parameters. CAVE3 Consortium's prior expertise uniquely positions the AU Flexible Electronics Harsh Environments Node to make a positive impact on the creation of manufacturing jobs related to the manufacture of flexible electronics.

- Pradeep Lall, John and Anne MacFarlane Endowed Professor and Director

CAVE^3 Consortium Spring-2016 Technical Review Meeting

The Center for Advanced Vehicle and Extreme Environment Electronics (CAVE^3) will hold its Spring Technical Review and Project Planning Meeting on March 2-3, 2016 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 CAVE^3 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

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

SPECIAL EVENTS

CAVE3 to host the PERM Group on AU-Campus

The CAVE3 Consortium will host the PERM group on AU Campus on March 5, 2016, i.e., the day following the Spring CAVE3 Review.

2016 IEEE International Conference on Prognostics and Health Management

June 22-25, 2016
Carleton University, Ottawa, Canada

Professor Pradeep Lall is serving as the General Chair of the 6th Annual IEEE Reliability Society PHM conference will be held June 22-25 at Carleton University, Ottawa, Canada. 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.

SMTA International 2015

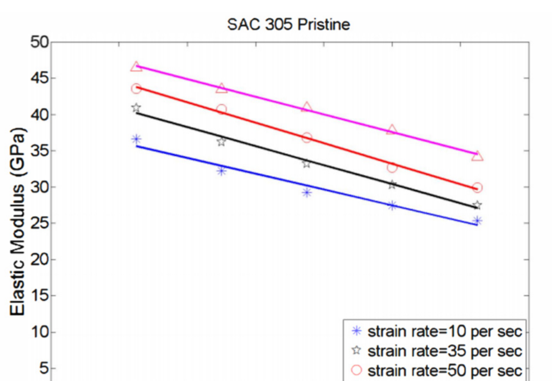
Conference: Sep. 27—Oct. 1, 2015
Exhibition: Sep. 29—Sep. 30, 2015
Donald Stephens Convention Center
Rosemont, IL

CAVE3 is co-organizer for the Harsh Environments Workshop at the SMTAI Conference to be held at the Donald Stephens Convention Center in Rosemont, Illinois from Sept 27-Oct 1, 2015. The workshop will be jointly chaired by Prof(s) Pradeep Lall (AU), John Evans (AU), and Dr. Robert Kinyanjui (John Deere). Abstract submission is presently open till March 13, 2015. The workshop focuses on issues of relevance to the use of electronics in extreme environment applications. The papers will focus on environments including thermal, thermo-mechanical, vibration, mechanical shock, corrosion, and contamination. Design methods for the use of commercial off the shelf electronics in extreme environments will be presented in addition to modeling and design methods to ensure survivability over lifetimes much longer than expected in consumer applications. SMTAI has been recognized as a truly different type of industry event because of the high quality technical information and the networking opportunities that cannot be found anywhere else in the industry. Abstract Submission can be accessed at http://www.smta.org/smtai/call_for_papers.cfm

Research Highlights

High Strain-Rate Constitutive Behavior of SACI05 and SAC305 Leadfree Solder During Operation at High Temperature

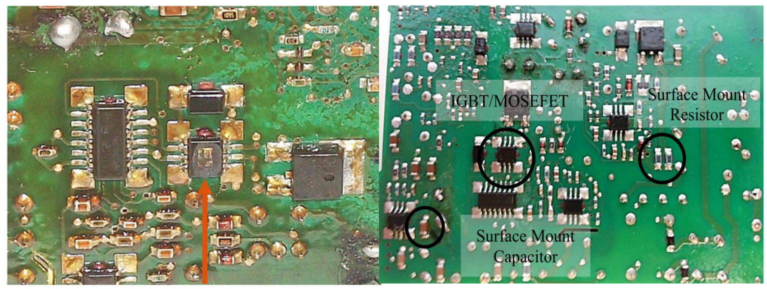
Industry migration to leadfree solders has resulted in a proliferation of a wide variety of solder alloy compositions. The most popular amongst these are the Sn-Ag-Cu family of alloys like SAC lOS and SAC30S. Electronics subjected to shock and vibration may experience strain rates of 1-100 per sec. Electronic product may often be exposed to high temperature during storage, operation and handling in addition to high strain rate transient dynamic loads during drop-impact, shock and . vibration. Properties of leadfree solder alloys at high stram rates at low and high temperatures experienced by the solder joint during typical mechanical shock events are scarce. Previous studies have showed the effect of high strain rates and thermal aging on the mechanical properties of leadfree alloys including elastic modulus and the ultimate tensile strength. The ANAND visco-plastic constitutive model has been widely used to describe the inelastic deformation behavior of solders in electronic components. In this study, SAC lOS and SAC30S leadfree alloys have been tested at strain rates of 10, 3S, SO and 7S per sec at various operating temperatures of SO°C, 7SoC, 100°C and 12S°C. Full-field strain in the specimen have been measured using high speed imaging at frame rates up to 7S,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. Stress-Strain curves have been plotted over a wide range of strain rates and temperatures. Experimental data for the pristine specimen has been fit to the ANAND's viscoplastic model.



Effect of Elastic Modulus of pristing SAC 305 alloy

Reliability and Failure Modes of Solid State Lighting Electric Drivers Subjected to Accelerated Aging

An investigation of an off-the-shelf solid-state lighting device with the primary focus on the accompanied light-emitting diode (LED) electrical driver (ED) has been conducted. A set of 10 EDs were exposed to temperature humidity life testing of 85% RH and 85 ◦C (85/85) without an electrical bias per the JEDEC standard JESD22-A101C in order to accelerate the ingress of moisture into the aluminum electrolytic capacitor (AEC) and the EDs in order to assess the reliability of the LED drivers for harsh environment applications. The capacitance and equivalent series resistance for each AEC inside the ED were measured using a handheld LCR meter as possible leading indications of failure. The photometric quantities of a single pristine light engine were monitored in order to investigate the interaction between the light engine and the EDs. These parameters were used in assessing the overall reliability of the EDs. In addition, a comparative analysis has been conducted between the 85/85 accelerated test data and a previously published high-temperature storage life accelerated test of 135 ◦C. The results of the 85/85 acceleration test and the comparative analysis are presented in this paper.



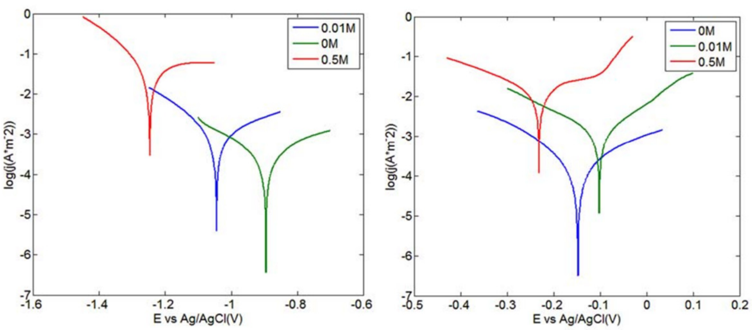
Identification of the failure site locations inside the EDs: A) top view and B) bottom view

Multiphysics-Modeling of Corrosion in Copper-Aluminum Interconnects in High Humidity Environments

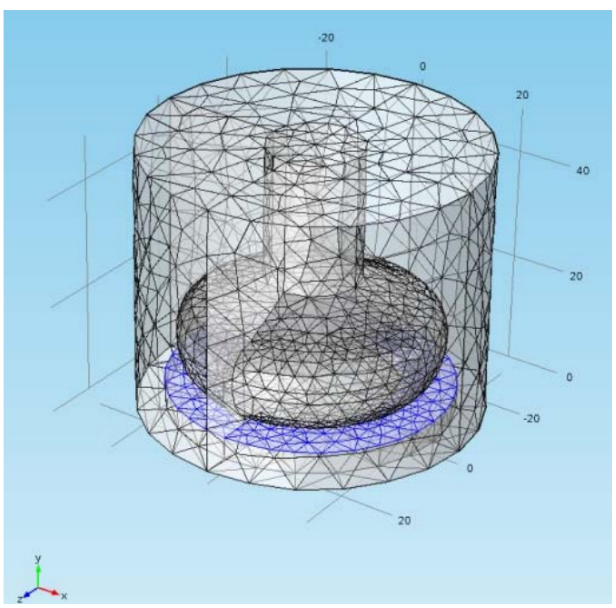
Copper aluminum interconnects are being used in automotive applications for deployment underhood, on-engine and on-transmission. Electronics is widely used for enabling safety function including lane departure warning systems, collision avoidance systems, anti-lock braking systems, and vehicle stability systems. Models for copper interconnect degradation are needed for life prediction modeling to ensure 10-year, 100,000 mile reliability for electronics in automotive applications. Small concentrations of chloride ions may diffuse towards the bond pad interface under temperature, humidity, and electrical bias. The chloride ions may act as a catalyst breaking down the passivation layer of aluminum pad and accelerate the micro-galvanic corrosion at the copperaluminum leading to the failure of the wirebond. Models for prediction of the diffusion of the chloride ions and the corrosion of the copper-aluminum interface have been difficult to develop, because of the small scale of the interface and the lack of appropriate electro-chemical properties for the Cu-Al system and the Electronic Molding Compounds under conditions relevant to operation. In this effort, a multiphysics model for electrolytic corrosion in the presence of chloride has been presented. The contaminant diffusion along with the corrosion kinetics has been modeled. In addition, contaminated samples with known concentration of KCl contaminant have been subjected to the temperature humidity conditions of 130°C/100RH. The resistance of the Cu -Al interconnects in the PARR test have been monitored periodically using resistance spectroscopy. The diffusion coefficients of chloride ion has been measured in the electronic molding compound at various temperatures using two methods including diffusion cell and inductively coupled plasma (ICPMS). Moisture ingress into the

Research Highlights

EMC has been quantified through measurements of the weight gain in the EMC as a function of time. Tafel parameters including the open circuit potential and the slope of the polarization curve has been measured for both copper, aluminum under different concentrations of the ionic species and pH values in the EMC. The measurements have been incorporated into the COMSOL model to predict the corrosion current at the Cu-Al bond pad. The model predictions have been correlated with experimental data.



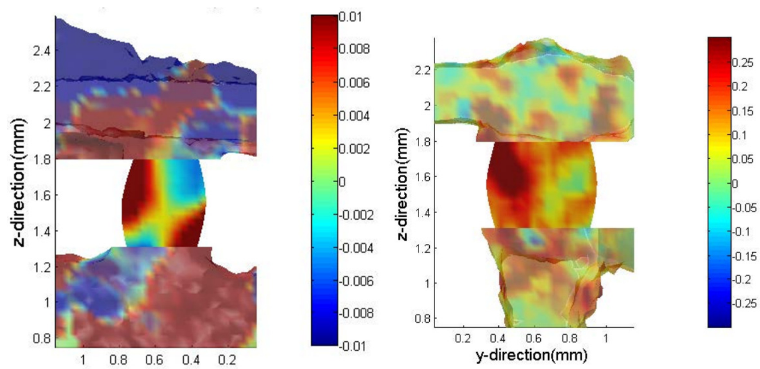
Polarization curves for (a) Copper (b) Aluminum for different chlorine contamination values at pH=7.



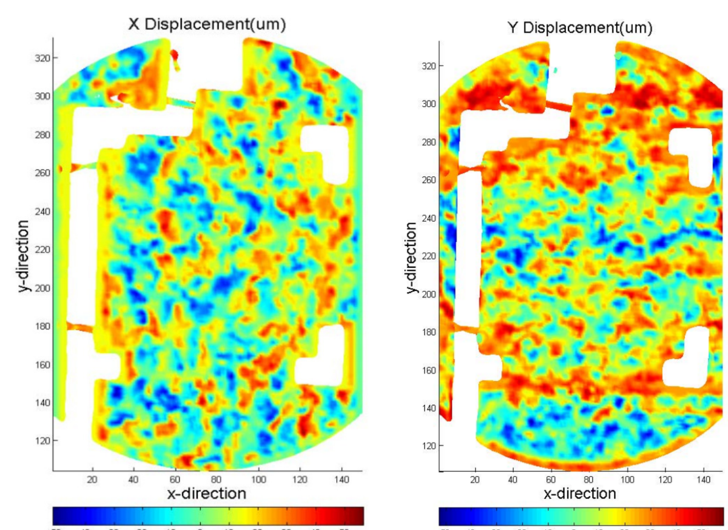
Model Geometry

X-Ray Micro-CT and DVC Based 3D Measurements of Deformation and Strain in Operational Electronics

Electronic components may be subjected to significant deformation under the action of thermal and mechanical loads during operation and storage. The use of thin material layers in addition to fine embedded interconnects limits the possibilities for the integration of sensors to measure deformation and strain. Previously, deformations in in electronic components and assemblies have been measured using optical methods including moiré interferometry and digital image correlation – both of which require the crosssectioning of the solder joint to gain access to the joint of interest for the purpose of strain and deformation measurement. Cross-sectioning is an invasive technique which requires discarding a portion of the package. In addition, the measurements are often limited to line of sight allowing measurement of only the optically visible cut-section. In this paper, a new method has been presented for measurement of displacements in solder joints non-invasively using a combination of x-ray computed tomography and digital volume correlation. The new method does not require cross-sectioning of the part for the purpose of deformation and strain measurement. In addition, the measurements are not limited to the joints in the line of sight. The three-dimensional measurements of deformation and strain have been visualized on the geometry of the solder joints in the package. It is envisioned that the method will allow the validation of the deformation and strain field in interconnects of the electronic package. Measurements of deformation and strain on light-emitting diodes and ball-grid array packages have been made using the combination of digital volume correlation and x-ray computed tomography.



(a) X direction displacement in solder ball (b) E11 Strain contour in Solder ball

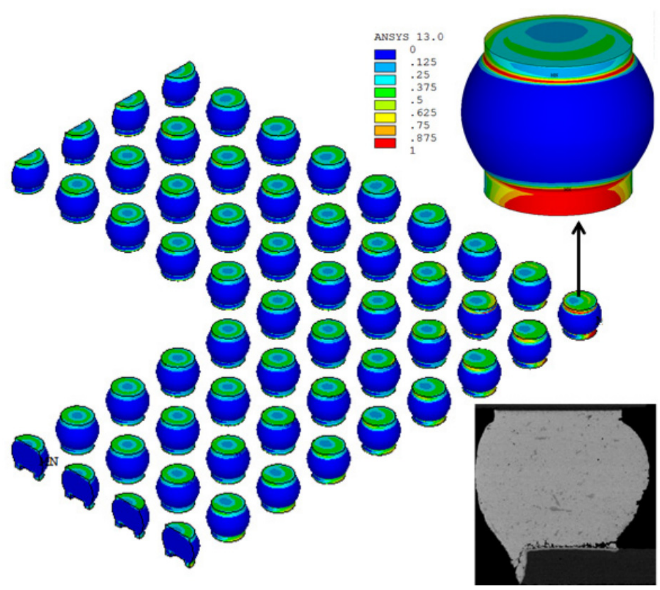


(a) *(b)*
LED substrate deformation (a) X displacement (b) Y Displacement

Research Highlights

Thermal Cycling Reliability of Aged PBGA Assemblies - Comparison of Weibull Failure Data and Finite Element Model Predictions

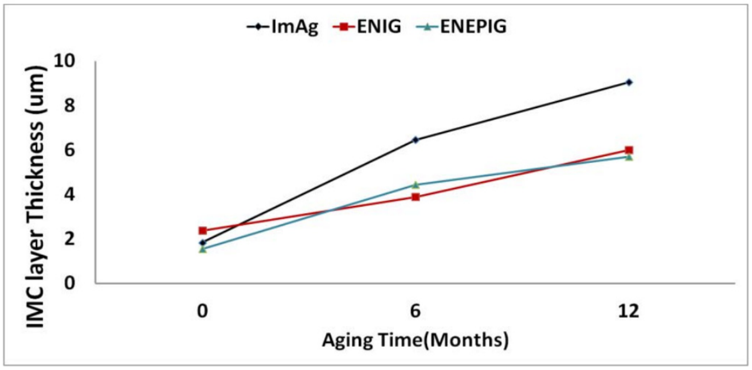
Isothermal aging causes detrimental changes in the microstructure, mechanical response, and failure behavior of lead free solder joints in electronic assemblies. These material changes also degrade the reliability of solder joints in assemblies subjected to aging prior to field use. In the current work, we have extended our previous research on the effects of aging on lead free solder material behavior to explore the effects of prior aging on solder joint (board level) reliability in actual assemblies. Our overall objective was to develop new reliability prediction procedures that incorporate aging effects, and then to validate the new approaches through correlation with thermal cycling accelerated life testing experimental data for pre-aged assemblies. 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. This work has implemented a theoretical framework for correcting this limitation and including aging effects in the reliability modeling. The developed approach involved the use of: (1) a revised set off Anand viscoplastic stress-strain relations for solder that included material parameters that evolve with the thermal history of the solder material, and (2) a revised solder joint failure criterion that included aging effects. The effects of aging on the nine Anand model parameters were determined experimentally for SAC305 lead free solder as a function of aging temperature and aging time. The revised Anand constitutive equations for solder with aging effects were then incorporated into standard finite element codes. The applied aging-aware failure criterion was based on the Morrow-Darveaux (dissipated energy based, DeltaW) approach, with both the fatigue criterion for crack initiation and the crack growth law incorporating material constants that depend on the prior aging of the solder material. Fatigue data were measured for SAC solder using uniaxial and shear test specimens that were aged for various durations and temperatures prior to cycling. The developed reliability modeling procedure has been applied to a family of assembled PBGA components. In the simulations, the packages were subjected to isothermal aging followed by thermal cycling accelerated life testing. The model predictions were correlated with solder joint reliability test data for the same components. The experimental test vehicle incorporated several sizes (5, 10, 15, 19 mm) of BGA daisy chain components with 0.4 and 0.8 mm solder joint pitches (SAC305). PCB test boards with 3 different surface finishes (ImAg, ENIG and ENEPIG) were utilized. Before thermal cycling began, the assembled test boards were divided up into test groups that were subjected to several sets of aging conditions (preconditioning) including 0, 6, and 12 months aging at T = 125 o C. After aging, the assemblies were subjected to thermal cycling (-40 to +125 o C) until failure occurred. The failure data for each test group were fit with the two parameter Weibull model, and the failure plots have demonstrated that the thermal cycling reliabilities of pre-aged assemblies were significantly less than those of analogous non-aged assemblies with degradations of up to 53% for one year of prior aging. Finite element modeling using the modified Anand model for solder was performed for the four different components sizes to predict the stress-strain histories of both non-aged PBGA assemblies and aged assemblies that had been subjected to constant temperature exposures for various times before being subjected to thermal cycling. The plastic work (DeltaW) per cycle results from the finite element calculations were then combined with the aging aware fatigue and crack growth models to estimate the reliability (cycles to failure) for the aged and non-aged assemblies. As expected, the predictions showed significant degradations in the solder joint life for assemblies that had been pre-aged before accelerated life testing. The coefficients in the aging aware crack growth model were selected to reflect the board surface finish and SAC solder combination. With this approach, good correlation was obtained between the new reliability modeling procedure that includes aging and the entire set of measured solder joint reliability data that includes multiple component sizes, prior aging conditions, and board surface finishes.



Plastic work in solder ball for 15 mm BGA

Reliability Comparison of Aged SAC Fine-Pitch Ball Grid Array Packages Versus Surface Finishes

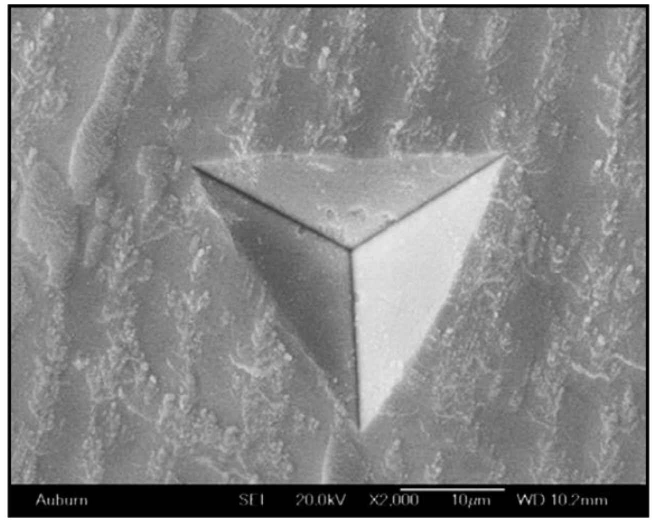
Pb-free solder joints exposed to elevated isothermal temperatures for prolonged periods of time undergo microstructural and mechanical evolution, which degrades the joint electrical performance. We report the effect of isothermal aging on the reliability of Sn–Ag–Cu (SAC) assemblies on three different surface finishes [immersion Ag (ImAg), electroless Ni/immersion Au (ENIG), and electroless Ni/electroless Pd/immersion Au (ENEPIG)]. The characteristic life for SAC alloys in 10- and 15-mm ball grid array packages on ImAg degraded over 40% after an 85 °C/12 months aging and over 50% during a 125 °C/12 months aging. ENIG and ENEPIG outperformed ImAg for all aging treatments. For passive components



Board-side SAC305 IMC thickness on ImAg, ENIG, and ENEPIG.

Nanomechanical Characterization of SAC Solder Joints - Reduction of Aging Effects using Microalloy Additions

In this work, we have examined the ability of microalloy additions (dopants) to reduce aging effects in solder joints by nanoindentation testing of several sets of doped/non-doped alloys. The investigated solder joint alloys included SAC105, SAC105+Ni, and SAC105+Mn. For the doped alloys, the base SAC105 solder in the PBGA component solder balls was modified by microalloying an additional small amount (< 0.05%) of the dopant material (Ni, Mn, etc.). The tested joints were extracted from 14 x 14 mm PBGA assemblies (0.8 mm ball pitch, 0.46 mm ball diameter) that were part of the iNEMI Characterization of Pb-Free Alloy Alternatives Project. After extraction, the joints were then subjected to various aging conditions at high temperature (0-6 months aging at T = 125 o C). After aging, the joints were loaded in the nanoindentation system, and the load-deformation behavior during indentation was used to characterize the mechanical properties of the solder joints for various aging conditions including modulus, hardness, and yield stress. Using constant force at max indentation, we have also measured the creep response of the aged and non-aged solder joint materials for various stress levels. With this approach, we have been able to quantify aging effects in joints and compare the behavior of the standard and doped alloys. Our results have shown that addition of the microalloy elements significantly reduced the aging degradations of the mechanical properties and creep resistance in the joints. For example, the average reduction of the effective elastic modulus of SAC105 joints was 32.9% with 180 days of aging, while the analogous average reductions were 7.0% and 8.1% for the SAC105+Ni and SAC105+Mn joints. Similarly, the average hardness (yield stress) degradation for the SAC105 joints was 45.9%, while those for the SAC105+Ni and SAC105+Mn were 10.5% and 10.7%, respectively. Finally, the creep rate increased 69.1X for the aged SAC105 joints, while the creep rate degradations for the SAC105+Ni (6.5X) and SAC105+Mn (9.0X) were an order of magnitude smaller. Our findings have also suggested that the addition of Ni was slightly more effective than Mn for the SAC105+X dopants.



Nano-Indentation after Testing

Principal Components Regression Model for Prediction of Life-Reduction in SAC Leadfree Interconnects During Long-Term High Temperature Storage

Electronics in military and defense applications may be stored for prolonged period of time prior to deployment in mission critical applications. In addition, electronics in automotive applications may be used underhood, mounted directly onengine and on-transmission with expectation to survive in excess of 10 years, 100,000 miles of usage in a variety of environments. Previous researchers have studied the microstructure, mechanical response and failure behavior of leadfree solder alloys when subjected to elevated isothermal aging and/or thermal cycling. The effects are most pronounced in the widely used SnAgCu based alloys including SAC105, SAC205, SAC305 and SAC405 solders. Lower silver solders such as the SAC105, often touted for their resistance to transient dynamic shock and vibration, are the most susceptible to thermal aging amongst the SAC solders. The effects have been verified in the solder alloys at both lower strain rates in the neighborhood of 1e-4 sec-1 to 1e-5 per sec typical of thermal cycling, and at 1-to-100 per sec typical of shock and vibration. Degradation in the neighborhood of 50% has been measured at low temperature exposures. In this paper, accelerated test thermal cycle data collected on SAC leadfree assemblies subjected to high temperature thermal aging for period of up to 1-year has been used for development of model for prediction of life reduction from long term storage at elevated temperatures. The input parameters to the model include geometry parameters including chip size, mold compound thickness, package size, board thickness, solder joint height, pad diameter, die attach thickness, and package pitch. In addition, material parameters considered include coefficient of thermal expansion, elastic modulus, and the glass transition temperature for all the package elements in the electronic assembly. Principal component regression in conjunction with stepwise regression has been used to identify the influential variables, remove the multicollinearity between the predictor varia-

Announcements

CAVE3 Team Attends ASME INTERPACK and ICNMM 2015 Conference to Present Research Papers

The following students from Professor Lall's research team visited the ASME InterPACK and ICNMM 2015 Conference in San Franscisco from July 6-9, 2015 to present their research papers:

1. Hao Zhang
2. Yihua Luo
3. Nakul Kothari
4. Vikas Yadav
5. Shantanu Deshpande
6. Junchao Wei
7. Amrit Abrol
8. Peter Sakalaukus

Pictured from Left-to-Right: Hao Zhang, Yihua Luo, Nakul Kothari, Vikas Yadav, Professor Pradeep Lall, Shantanu Deshpande, Junchao Wei, Amrit Abrol, Peter Sakalaukus.

CAVE3 Paper Wins the Best-Poster Paper Award at the ASME INTERPACK and ICNMM 2015

The following CAVE3 papers won the 1st and 2nd place Best-Poster Paper Award at the ASME InterPACK and ICNMM 2015 Conference held in San Francisco, CA on July 6-9, 2015.

1st Place: Lall, P., Deshpande, S., Nguyen, L., Fuming Acid Based Decapsulation Process for Copper-Aluminum Wirebond System Molded with Different EMC's, Paper IPACKICNMM2015-48638; Session 14-2-1, ASME InterPACK, San Francisco, CA, July 6-9, 2015

2nd Place: Ahmed, S., M. Basit, J. C. Suhling, P. Lall, Characterization of Doped SAC Solder Materials and Determination of Anand Parameters, Paper IPACKICNMM2015-48624, 14-2-2, ASME InterPACK, San Francisco, CA, pp. 1-14, July 6-9, 2015

Pictured from Left-to-Right: Pradeep Lall (AU) and Shantanu Deshpande (AU)

LALL SERVES AS THE GENERAL CHAIR OF THE IEEE PHM 2015

Professor Lall will serve as the General Chair of the IEEE PHM 2015 Conference to be held in Austin, TX in June 22-25, 2015. The conference focuses on prognostics health management systems for a broad array of electrical and electronic systems with emphasis on principles, system design, implementation, applications. 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 program 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. Additional information about the conference is available on the conference web site at: phmconf.org.

BEST-OF-CONFERENCE PAPER OF ECTC 2014

The following CAVE3 paper from ECTC 2014 was recognized with the Best-of-Conference Session Paper Award at the ECTC 2015 on May 27, 2015 in San Diego.:

Session 9, Paper 2 (ECTC 2014) Exploration of Aging Induced Evolution of Solder Joints Using Nanoindentation and Microdiffraction, Mohammad Hasnine, Jeffrey C. Suhling, Barton C. Prorok, Michael J. Bozack, and Pradeep Lall, 64th ECTC, pp. 379-394, Orlando, FL, May 27-30, 2014.

AU TO LEAD HARSH ENVIRONMENTS NODE FOR FLEXIBLE ELECTRONICS MANUFACTURING INSTITUTE

Auburn University has been selected to lead a national manufacturing effort on harsh environment electronics as part of a U.S. Department of Defense led flexible hybrid electronics institute.
On Friday, Aug. 28, at NASA's Ames Research Center, Department of Defense Secretary Ashton Carter announced a cooperative agreement to the research consortium FlexTech Alliance to establish and manage a Manufacturing Innovation Institute for Flexible Hybrid Electronics, or FHE MII. FlexTech Alliance, based in San Jose, California, will coordinate the FHE MII, which comprises 96 companies, 11 laboratories and non-profits, 43 universities and 15 state and regional organizations. Auburn University will head the only node in the state of Alabama.

Leading Auburn's node on harsh environments is Pradeep Lall, the John and Anne MacFarlane endowed professor of mechanical engineering and director of Auburn's NSF Center for Advanced Vehicle and Extreme Environment Electronics, or CAVE. "This establishment will provide engineers with the integrated skills and theoretical background for the manufacture of flexible hybrid electronics for extreme environment applications," said Lall. "It will create intellectual property and expenditures on research, education and related activities, as well as catalyze development of technologies which can be manufactured in the state. We have developed strategic partnerships with industry and research labs in Alabama and nationally for development and demonstration of technologies for harsh environment operation."

The institute will be awarded $75 million in federal funding over a five-year period and is being matched by more than $96 million in cost sharing from non-federal sources including private companies, universities, not-for-profit organizations and several states, including Alabama. "The strength of the institute will stem from the strong support and previous work of our partner organizations," said Michael Ciesinski, CEO of FlexTech Alliance. "Auburn University's strong work in utilizing electronics in harsh environments will lend the institute a huge advantage in the special needs for that environment. We look forward to collaborating with the excellent team there and the CAVE facility."

In addition to defense, the institute's activities will benefit a wide range of markets including automotive, communications, consumer electronics, medical devices, health care, transportation and logistics and agriculture.

"I am pleased that Auburn University is a partner in this national organization, and that Dr. Lall is leading the way for its initiatives on harsh environments," said Christopher B. Roberts, dean of the Samuel Ginn College of Engineering. "The institute represents an innovative collaboration between the public and private sectors and has the potential to make a huge impact on our nation as we continue to embrace advanced manufacturing."
The new institute is part of the National Network for Manufacturing Innovation program. The FHE MII is the seventh manufacturing innovation institute announced and the fifth under Department of Defense management. The institutes are intended to bridge the gap between applied research and large-scale product manufacturing, and it is anticipated that Auburn's harsh environment node will create technologies for the benefit of the nation's commercial and national defense interests.

Flexible electronics has been identified as one of the frontier goals by the National Academies of Engineering Reports on Leading Edge Engineering in 2013. In order to make flexible electronics possible, processes must meet the demands of soft, pliant and often easily damaged surfaces. Compatibility with delicate surface often requires low temperature processing. There are no large flexible electronics manufacturing firms in the US engaged in large scale commercial manufacturing of products that integrate flexible and printed electronics technologies. Thirty years ago when large corporate laboratories were prevalent, applied research and practical application of science used to be an area of strength in the United States. However, pricing pressures, commoditization of products, and the migration of manufacturing to the Far East has resulted in the downsizing and many cases elimination of the corporate research laboratories. There is a chasm between the laboratory research and the realization of commercialized products. The global flexible electronics industry is in its infancy as scaled up production for commercial applications exists in only a few niche areas including e-paper, RFID tags and organic light emitting diode screens. An IMI in the area of flexible electronics will fill in the void between lab research and commercial products. The semiconductor manufacturing is highly automated, utilizing complex processes developed by multiple vendors which cannot be readily integrated without coordination between players. The manufacturing challenges exist at multiple levels including raw materials, material handling, fabrication and assembly. Processing at low temperatures on conformal bendable, stretchable and foldable substrates is needed or device assembly integration. Adequate survivability in harsh applications will require development of flexible encapsulation approaches in addition to physical packaging and common interconnects and interfaces. Stretchable electronics will need device designs for mitigating the interconnect failures due to fracture and delamination under large deformation and strain. Innovative thermal management schemes are needed to ensure thermal and thermo-mechanical survivability in the presence of multi-material thin-film interfaces. In parallel with the development of manufacturing protocols, it is envisioned that the development of modeling tools and prediction methods is needed to assess the device design, layout, and fabrication parameters. Accelerated test methods and test conditions which have been developed for rigid electronics will need to be scaled to flexible hybrid electronics. The existence of the prior research expertise in the area of harsh environment electronics for automotive and military environments uniquely positions the AU led thematic node to put together a successful IMI-node in the area of flexible hybrid electronics.

Selected Recent Publications

1. Lall, P., Deshpande, S., Nguyen, L., Fuming Acid Based Decapsulation Process for Copper-Aluminum Wirebond System Molded with Different EMC's, Paper IPACKICNMM2015-48638; Session 14-2-1, ASME InterPACK, San Francisco, CA, pp. 1-13, July 6-9, 2015
2. Lall, P., Sakalaukus, P., Davis, L., An Investigation of Catastrophic Failure in Solid-State Lamps Exposed to Harsh Environment Operational Conditions, Paper IPACKICNMM2015-48257; Session 1-5-1, ASME InterPACK, San Francisco, CA, pp.1- 7, July 6-9, 2015
3. Lall, P., Luo, Y., Nguyen, L., Chlorine Ion Related Corrosion in Cu-Al Wirebond Microelectronic Packages, Paper IPACKICNMM2015-48639; Session 1-3-2, ASME InterPACK, San Francisco, CA, pp. 1-12, July 6-9, 2015
4. Lall, P., Zhang, H., Davis, L., Prognostics Health Management Model For LED Package Failure Under Contaminated Environment, Paper IPACKICNMM2015-48724; Session 1-5-1, ASME InterPACK, San Francisco, CA, pp. 1-9, July 6-9, 2015
5. Lall, P., Wei, J., LED Chip Deformation Measurement During the Operation Using the X-ray CT Digital Volume Correlation, Paper IPACKICNMM2015-48785; Session 14-5-1, ASME InterPACK, San Francisco, CA, pp. 1-6, July 6-9, 2015
6. Lall, P., Abrol, A., Simpson, L., Glover, J., Survivability of MEMS Accelerometer Under Sequential Thermal and High-G Shock Environments, Paper IPACKICNMM2015-48790; Session 3-1-1, ASME InterPACK, San Francisco, CA, pp. 1-11, July 6-9, 2015
7. Lall, P., Yadav, V., Suhling, J., A Study on the Evolution of the High Strain Rate Mechanical Properties of SAC105 Leadfree Alloy at High Operating Temperatures, Paper IPACKICNMM2015-48389; Session 14-2-1, ASME InterPACK, San Francisco, CA, pp. 1-17, July 6-9, 2015
8. Lall, P., Kothari, N., Glover, J., Mechanical Shock Reliability Analysis and Multiphysics Modeling of MEMS Accelerometers in Harsh Environments, Paper IPACKICNMM2015-48457; Session 3-3-2, ASME InterPACK, San Francisco, CA, pp. 1-9, July 6-9, 2015
9. Lall, P., Mirza, K., Suhling, J., DIC Based Investigation into the Effect of Mean Temperature of Thermal Cycle on the Strain State in SnAgCu Solder Joint, Paper IPACKICNMM2015-48727, Session 14-5-1, ASME InterPACK, San Francisco, CA, pp. 1-13, July 6-9, 2015
10. Basit, M., Motalab, M., Suhling, J., Lall, P., Viscoplastic Constitutive Model For Lead-Free Solder Including Effects of Silver Content, Solidificaton Profile, and Severe Aging, Paper IPACKICNMM2015-48619, ASME InterPACK, San Francisco, CA, pp. 1-18, July 6-9, 2015
11. Basit, M., Motalab, M., Suhling, J., Evans, J., Lall, P., FEA Based Reliability Predictions for PBGA Packages Subjected to Isothermal Aging Prior to Thermal Cycling, Paper IPACKICNMM2015-48620, ASME InterPACK, San Francisco, CA, pp. 1-11, July 6-9, 2015
12. Chowdury, P., Chhanda, N., Suhling, J., Lall, P., Experimental Characterization of Underfill Materials Exposed to Moisture Including Preconditioning, Paper IPACKICNMM2015-48622, ASME InterPACK, San Francisco, CA, pp. 1-9, July 6-9, 2015
13. Hasnine, M., Suhling, J., Prorok, B., Bozack, M., Lall, P., Characterization of the Effects of Silver Content on the Aging Resistance of SAC Solder Joints, Paper IPACKICNMM2015-48623, ASME InterPACK, San Francisco, CA, pp. 1-15, July 6-9, 2015
14. Ahmed, S., Basit, M., Suhling, J., Lall, P., Characterization of Doped SAC Solder Materials and Determination of Anand Parameters, Paper IPACKICNMM2015-48624, ASME InterPACK, San Francisco, CA, pp. 1-14, July 6-9, 2015
15. Nguyen, Q., Roberts, J., Suhling, J., Jaeger, R., Lall, P., Measurement and Simulation of Moisture Induced Die Stresses in Flip Chip on Laminate Assemblies, Paper IPACKICNMM2015-48626, ASME InterPACK, San Francisco, CA, pp. 1-13, July 6-9, 2015
16. Prognostication of Solder-Joint Reliability of 0.4mm and 0.5mm Pitch BGAs Subjected to Mechanical Shocks up to 10,000G, Pradeep Lall, Kalyan Dornala, Junchao Wei, Ryan Lowe, Jason Foley, IEEE PHM Conference, Austin, Texas, pp. 1-14, June 22-25, 2015
17. Prognostication of LED Remaining Useful Life and Color Stability in the Presence of Contamination, Pradeep Lall, Hao Zhang, Lynn Davis, IEEE PHM Conference, Austin, Texas, pp. 1-8, June 22-25, 2015
18. Session -37/ Paper -4: Failure Mechanisms and Color Stability in Light-Emitting Diodes during Operations in High-Temperature Environments in Presence of Contamination, Pradeep Lall and Hao Zhang; Lynn Davis; Basit, M.,, 65th ECTC, San Diego, CA, pp.1624-1632, May 26-29, 2015
19. Session -3/ Paper -4: Thermal Cycling Reliability of Aged PBGA Assemblies- Comparison of Weibull Failure Data and Finite Element Model Predictions, Basit, M., Motalab, M., Suhling, J., Hai, Z., Evans, J., Bozack, M., Lall, P.,, 65th ECTC, San Diego, CA, pp. 106- 117, May 26-29, 2015
20. Session -10/ Paper -1: X-Ray Micro- CT and Digital- Volume Correlation Based Three- Dimensional Measurements of Deformation and Strain in Operational Electronics, Lall, P., Wei, J.,, 65th ECTC, San Diego, CA, pp. 406- 416, May 26-29, 2015
21. Session -15/ Paper -2: High Strain Rate Properties of SAC305 Lead Free Solder at High Operating Temperature after Long-Term Storage, Lall, P., Zhang, D., Suhling, J.,, 65th ECTC, San Diego, CA, pp. 640- 651, May 26-29, 2015
22. Session -40/ Paper -8: Principal Components Regression Model for Prediction of Life-Reduction in SAC Lead Free Interconnects During Long-Term High Temperature Storage, Lall, P., Duraisamy, S., Suhling, J., Evans, J.,, 65th ECTC, San Diego, CA, pp. 2040- 2047, May 26-29, 2015
23. Session -24/ Paper -5: Multiphysics- Modeling Corrosion in Copper-Aluminum Interconnects in High Humidity Environments, Lall, P., Luo, Y., Nguyen, L.,, 65th ECTC, San Diego, CA, pp. 1045- 1056, May 26-29, 2015
24. Session -36/ Paper-4: Nanomechanical Characterization of SAC Solder Joints- Reduction of Aging Effects Using Microalloy Additions, Hasnine, M., Suhling, J., Prorok, B., Bozack, M., Lall, P.,, 65th ECTC, San Diego, CA, pp. 1574- 1585, May 26-29, 2015

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