AUBURN UNIVERSITY

SAMUEL GINN
COLLEGE OF ENGINEERING

Fall 2017

$cave^3$ News

NSF-CAVE3 Electronics Research Center

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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

The center kicked-off the NextFlex project on the development of test-protocols jointly with STI Electronics, SRI, and Optomec in May-2017. We have made significant progress on the development of test setups for the testing of flexible substrates and batteries. I had a chance to visit the NextFlex Project Review in Monterrey, CA to present the findings of the project team July 19-23, 2017 to the members of the institute. My appointment to the governing council of the NextFlex institute was announced by Executive Director of the Institute, Dr. Malcolm Thompson, on June 22, 2017. I am deeply honored by the appointment and will continue to serve the Institute in the new role which expands on my prior involvement as member of the Technical Council and Academic Co-lead of the Asset and Situational Awareness Technical Working Group. Auburn University is a founding tier-1 academic member of the institute and a member of the technical council of the institute.

We have been successful in developing a wearable biometric band with a lifesaver smartphone app. The band along with the app is intended for monitoring of remote workers and autonomously triggers call for medical intervention if the health of the worker deteriorates. A number of sensors attached to the band are used for monitoring the health of the remote worker including pulse-oximetry sensor, blood pressure sensor, and electromyography sensor. An app written for the smartphone platform communicates wirelessly with the biometric band through the Bluetooth protocol. The band allows for the measurement of the loss of blood oxygenation resulting from depletion of oxygen in the environment, abrupt changes in the pulse rate resulting from anxiety or claustrophobia, loss of consciousness, myocardial infarction, stroke, bradycardia or aneurysm. Additional sensors can be added if needed to address a broader range of medical conditions. AU has filed a Provisional Patent 62/530,986, Wearable Multi-Sensor Band and Smartphone App for Remote Health Monitoring. The band will be showcased at the NextFlex Innovation Day in September-2017.

We have had a very productive summer with the center-researchers travelling to multiple conferences to present research papers. In all, CAVE3 presented 7-papers at ECTC and 20-papers at ITHERM. Two of the papers received the highest honors at the ITHERM conference. The following paper on SAC-Q solders received the outstanding paper award - P. Lall, V. Yadav, J. Suhling and D. Locker, "High Strain Rate Mechanical Behavior of SAC-Q Solder," in Proceedings of the 16^{th} ITHERM, Orlando, FL, pp. 1447-1455, May 30 - June 2, 2017. The following paper on LED color-shift analysis received the best-paper award - P. Lall, H. Zhang and L. Davis, "Color Shift Analysis and Modeling of High Power pc-LED under High Temperature and High Humidity Environment," in Proceedings of the 16^{th} ITHERM, Orlando, FL, pp. 1161-1177, May 30 - June 2, 2017. CAVE3 Student, Shantanu Deshpande has been awarded the 2017 Student Engineer of The Year Award by ASME Electronics and Photonics Packaging Division. The award honors an active student who has excelled in research and has shown promise to be a strong contributor in the field of electronic and photonic packaging. On September 18, 2017, CAVE3 in conjunction with the SMTA will be hosting the Harsh Environments Symposium in Rosemont, IL. A number of CAVE3 papers will be presented at the conference. The workshop continues in its 14^{th}-year originally established by CAVE3 in 2003 with a SMTA co-sponsored workshop in Detroit, MI.

I am also glad to announce that following companies and federal agencies have joined the center – Harris Corporation, ARDEC Picatinny, and MDA. We look to the future with excitement as the Center builds on a remarkable legacy of technical accomplishments.

- Pradeep Lall,
MacFarlane Endowed Professor & Director

CAVE^3 Consortium Spring-2017 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 7-8, 2017 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:

P14-201:Effects of Moisture on the Mechanical Behavior of Packaging Materials
P13-201: Effects of Moisture on the Reliability of Flip Chip Assemblies
P14-202: Effects of Moisture on the Reliability of Plastic Packaging
P15-201: Improved FEA Modeling of Area Array Assemblies
P15-407: Connector Failure Diagnosis in Communication System
P15-404: Influence of CTE Mismatch on Sn Whiskering
P15-405: Effect of Small Wt% Impurities on Sn Whiskering
P15-403: Capacitance Effects in Fretted Electrical Connectors
P16-101: Test Protocols for Flexible Electronics
P16-102: High-g Survivability and Reliability Modeling of Advanced Interconnects
P16-104: Thermo-mechanical Reliability of Leadfree Electronics under Wide Temperature Extremes
P16-105: Characterization of High Strain-Rate Properties at High and Low Operating Temperatures
P16-106: Reliability Models for SSL Luminaires
P16-107: Harsh Environment Survivability of MEMS Sensors
P16-108: Wirebond Interconnects under High Voltage and High Current
P16-103: Simultaneous Temperature and Vibration Reliability
P12-501a: Reliability of aged lead-free solder for temperature accelerated life testing (TV7)
P12-501b: Special Sponsored Project-Reliability Study on Isothermally Aged Doped Lead- Free Solders for Accelerated Life Testing
P12-501c: Special Sponsored Project 2-Solder Dopant Selection Test: Downselect
P12-501d: Special Sponsored Project 3-Reliability Study on Isothermally Aged Doped Lead- Free Solders for Accelerated Life Testing with Downselect
P14-501: Reliability of Aged Lead- Free Solder Dopants for Temperature Accelerated Life Testing (TV9),
P13-301: Aging Behavior of Solder Joints
P14-301: Anand Model and FEA Predictions for Lead Free Solder Alloys Including Aging Effects
P15-301: Effects of Aging on the Cyclic Fatigue Life of Pb-Free Alloys

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

SPECIAL EVENTS

2017 IEEE International Conference on Prognostics and Health Management

June 19-21, 2017, Dallas, TX

Professor Pradeep Lall served as the member of the organizing committee of the 8th Annual IEEE Reliability Society PHM conference held June 19-21 at Marriott Courtyard in Dallas, TX. The conference brought 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 program included Tutorials, Panel Sessions, and Papers that address the wide-ranging, interdisciplinary topics related to PHM technology and application. There was a special working session on the in-process development of a PHM Standard. The conference included a keynote session on the topics of - Demystifying Big Data and Data Science: Challenges, Opportunities and Path forward for Reliability, Safety and Availability of Deployed Systems; and Fusing Heterogeneous Data for Condition Based Maintenance Decisions. In addition, the program had panel sessions on the topics of Nuclear Power System PHM, and Methods to Improve Li-ion Battery Performance.

SMTA International 2017

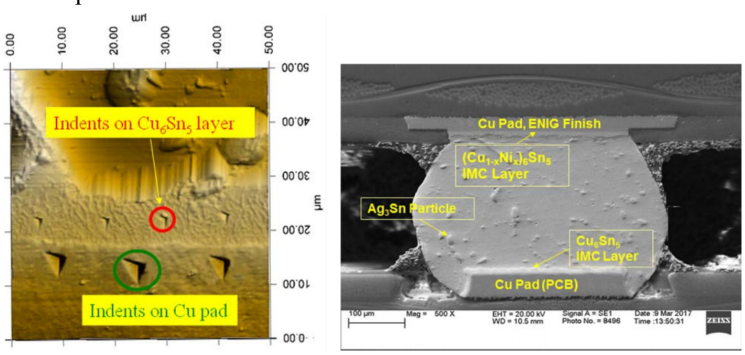
Conference: Sep. 17-21, 2017
Donald Stephens Convention Center
Rosemont, IL

CAVE3/SMTA will be co-hosting the harsh environment electronics workshop at the SMTAI Conference in Rosemont, IL. The workshop this year will include 4-sessions on a range of topics including - predicting component life, impact of chemically corrosive environments, material selection and test methods, and ruggedization of electronics components. The Annual SMTA International Conference will be held at the Donald Stephens Convention Center from Sept 17-21, 2017. The papers will focus on environments including thermal, thermo-mechanical, vibration, mechanical shock, corrosion, and contamination. Session topics include - Advanced Packaging Technology; Flux, Solder, Adhesives; Inspection Technologies; Manufacturing Excellence; and Substrates/PCB Technology, as well as the Harsh Environments Symposium, Technical Innovations Symposium, and the Lead-Free Soldering Technology Symposium. Microsoft Corporation's Rune Jensen will keynote Tuesday morning with his presentation "Experiencing Mixed Reality - using the Microsoft HoloLens." Twenty half-day educational workshops are offered Sunday and Monday from expert instructors on topics including Fan-Out Wafer-Level Packaging and 3D Packaging, DfX, Cleaning, Ball Grid Array (BGA) issues, Flex Circuits, Reliability, Inspection, Temperature Profiling, Reflow Soldering, Stencil Printing, Surface Finishes, Process Troubleshooting. Additional information can be found at: https://www.smta.org/smtai/

Research Highlights

Nanomechanical Characterization of IMCs formed in SAC Solder Joints Subjected to Isothermal Aging

Isothermal aging of lead-free Sn-Ag-Cu (SAC) solder joints leads to growth of intermetallic (IMC) particles in the solder bulk as well as growth of intermetallic layers at the joint interfaces with copper bond pads. Fracturing near the interfacial IMC layers is often found to be the primary reason for failures caused by drop impacts. The IMCs in SAC joints are primarily AgsSn and Cu6Sn5 binary compounds. Cu-Ni-Sn based ternary IMCs can also form at the interface of Ni containing surface finish (i.e. ENIG) and SAC solder. The mechanical properties of these IMCs are very different than those of the Sn rich dendrites and Cu pads. Nanoindentation (NI) techniques are powerful tools to characterize mechanical properties of small particles and thin layers. In this study, the mechanical behaviors of IMC particles and layers in SAC solder joints have been characterized using nanoindentation. SAC bga solder joints were first aged for 6 months at T = 125 °C. Test samples were subsequently prepared by cross-sectioning the aged solder joints, and then molding them in epoxy and polishing them to prepare the joint surfaces for microscopy and nanoindentation. Intermetallics formed in the bulk solder region, copper pad and SAC solder interface, and ENIG plating finish and SAC solder interface were observed and detected using SEM and the energy-dispersive x-ray spectroscopy (EDX) technique.



(a) *(b)*

Figure 1— (a) SPM Images of the Indent (b) SEM Image of Solder Joint

The same intermetallics were then indented to measure their room temperature mechanical properties including the elastic modulus, hardness, and creep strain rate. To ensure the indentation occurred at the desired phase, SPM imaging was done prior and after the indentations. As expected, the measured properties of the IMCs were significantly higher than the Sn-matrix forming the solder joints. The measured elastic modulus and hardness values were 98.1 ± 6.3 and 5.80 ± 0.70 GPa for the Cu6Sn5 layers at the joint and copper bond pad interfaces, 132.5 ± 4.5 and 8.58 ± 1.13 GPa for the Cu1-x Nix)6Sn5 layers at the joint and ENIG plating finish interfaces, and 75.2 ± 4.0 and 3.085 ± 0.50 GPa for the AgsSn IMC particles in the solder joint bulk. These are all much higher than the values of 42.7 ± 2.3 and 0.21 ± 0.12 GPa measured for the β-Sn phase in the solder joint bulk. Creep testing performed at 25 °C revealed that the (Cu1−xNix)6Sn5 IMC layers had the lowest steady state secondary creep rate of 1.088×10^{-3} sec^{-1}, whereas the Cu6Sn5 layers had a creep rate of 1.66×10^{-3} sec^{-1}, and the AgsSn IMC particles had a creep rate of 2.34×10^{-3} s^{-1}. The creep stress exponents were evaluated from log-log plots of the strain rate vs. applied stress data.

Assessment of Reliability of Missile Fuze using MicroCT Data based Finite Element Technique with DVC

Densely packed field extracted electrical assemblies like fuze, subjected to harsh environments may often undergo degradation in terms of material properties and physical structure (geometry), but no signs of damage may be visible from the physical appearance. Quantification of accrued damage may require cross-sectioning and thus sacrificing the sample which may be undesirable as it may not allow for any further investigation. Use of conventional finite element techniques for modeling such assemblies may be prohibitively time consuming. It has been shown earlier that the large number of components and geometric details in such assemblies make the modeling process, time consuming and results may not be accurate because of not modeling the accrued physical damage. In the past, researchers have studied the reliability of such assemblies using failure rates and mean time to failure approach.

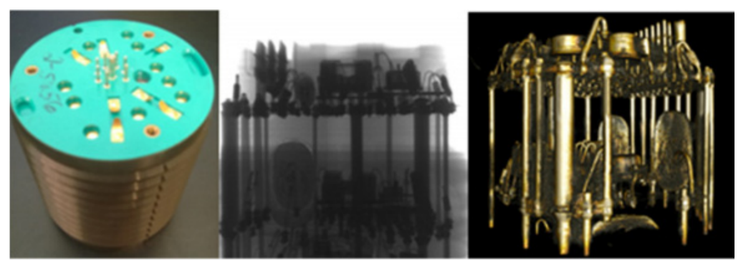


Figure 2—Optical, X-ray, Micro-CT Rendering of Fuze Assembly

Lall, et. al. have used Digital Volume Correlation and micro-CT (Computed Tomography) data based finite element mesh to study remaining useful life of small sized packages like ball grid arrays No literature is found on studying reliability of large, densely packed electronics using micro-CT based non-contact type, full field deformation measurement techniques and finite element models that capture the real 'as is' geometry. In this paper, micro-CT data of the fuze has been used to perform Digital Volume Correlation, to measure deformations when the device is subjected to a thermal load. Young's modulus of the sub-components have been measured using nano-indentation, thus accounting for degradation in the material properties. Micro-CT data of a fuze has been used to create a finite element mesh which has been further used to perform a thermo-mechanical analysis of implicit type. Usage of micro-CT data has ensured the modeling of 'as is' geometry of the components of the fuze assembly, thus accounting for the prior accrued physical damage. The results of the finite element model are compared with the deformations measured using Digital Volume Correlation to analyze the accuracy of the FE method used for modeling fuze device.

Deformation and Warpage of the Double-sided Flexible Printed Circuit Board through Reflow using DIC

Flexible electronics provide new design options not afforded by rigid electronics in a variety of applications including wearable electronics, robotics and automotive systems. However, the processes for the manufacturing of complex electronic assemblies using fine-pitch components are not as well developed as those for rigid electronics. The lack of structural rigidity of flexible printed circuit cards requires the use of fixtures or palletes for component placement and subsequent reflow. In addition, mechanisms are needed to compensate for the deformation and warpage of the flexible substrate and components during assembly. In this paper, two different fixture options have been presented for the manufacture of flexible circuits. The first fixture option includes the use of a pallete with tensioners. The second fixture option includes the use of vacuum fixture during reflow of the flex circuit assembly.

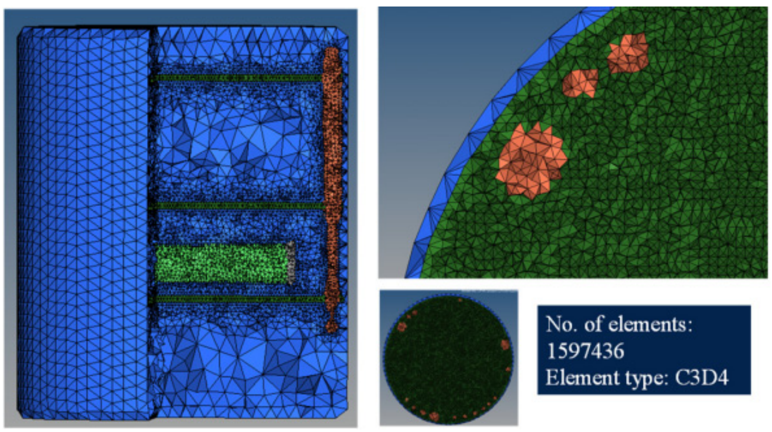


Figure 3— 3D Model of the FUZE assembly from CT Database

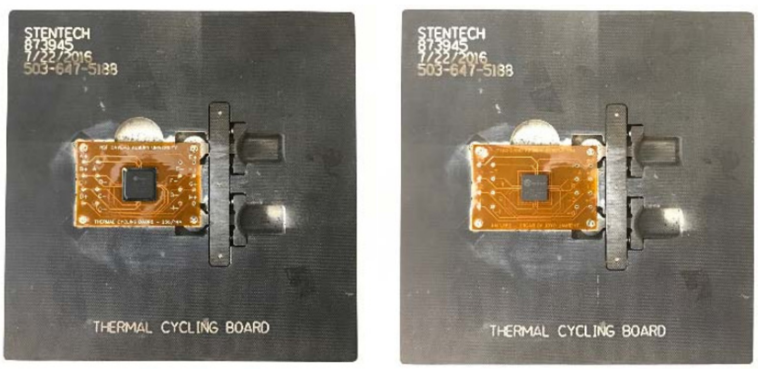


Figure 4— Fabricated Packages on the Palate

The deformation of the flex circuit assemblies during reflow has been studied using a combination of low-speed high-resolution cameras in conjunction with digital image correlation. The double-sided board used for the experiment is of BGA 256-144 combination with dummy components, A-PBGA256-1.0mm17mm and A-CABGA144-1.0mm-13mm. Firstly, warping of the flexible circuit with only PBGA 256 on the front side was studied, then CABGA 144 was placed on the back side using the pick and place machine, and warping was studied again, both using DIC. Two low speed Point Grey Cameras were used to capture many frames of flexible circuit going through every stage in reflow and a DIC software Vic 3D 2007 was used to get the warpage measurements. Both of the warping data has been studied in this project and compared with the results in rigid circuit boards.

Test Protocol for Assessment of Flexible Power Sources Under Stresses of Daily Motion Operation

Emergence of flexible electronics technologies has made tractable the ability to develop solutions for integration of electronics for biometric sensing into wearable fabrics. In wearable applications, electronics may be subjected to stresses of daily motion in addition to exposure to human body temperature, and ambient environments. Existing test standards and protocols are geared towards the assessment of rigid electronics. In this paper, a test-protocol has been developed to impose deformations that mimic the stresses of daily motion on flexible batteries during charge-discharge operation. The test protocol is intended to be used for assessment of the ability of flexible battery to meet the power needs of wearable electronics and provide adequate survivability while being subjected to constant human body or ambient temperature and flexing typical of stresses of daily motion. The changes to the state-of-charge of the battery have been tracked for the development of method to prognosticate prior accrued damage and remaining useful life.

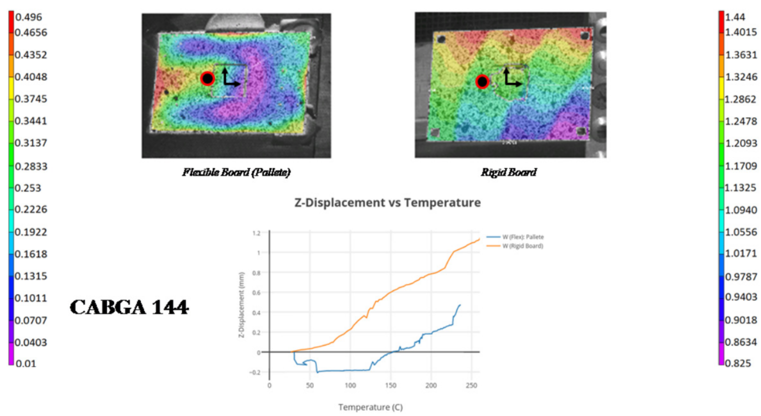
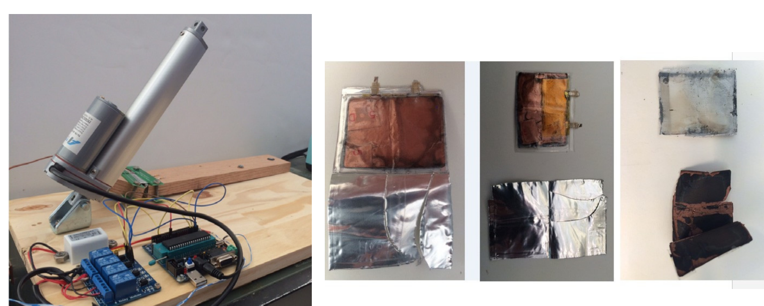


Figure 5— Comparison of Warpage between Rigid and Flexible Boards during Reflow.



(a) (b)

Figure 6— (a) Test Setup for battery bending (b) Internal structure of flexible battery.

Interaction of EMC Formulation with Operating Current and Reliability of Cu-Al Wirebonds in Harsh Environments

The migration of high-reliability applications requiring sustained operation in harsh environments needs a better understanding of the acceleration factors under the stresses of operation. Prolonged exposure of the copper wire to elevated temperatures results in growth of excessive intermetallics and degradation of the interface. Behavior of Copper wirebond under high current-temperature conditions is not yet fully understood. Exposure to high current may induce Joule heating and electromigration, and thus significantly increase the degradation rate in comparison with low current operating conditions. Further, the accelerated test results of unbiased conditions cannot be used for life

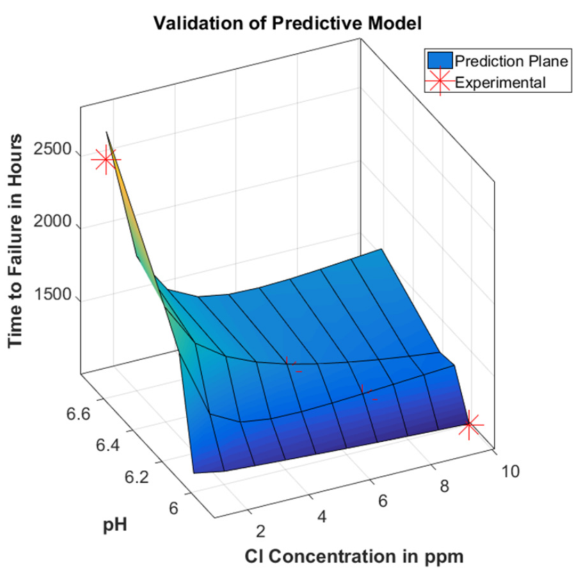


Figure 7— Change in Resistance of the Cu wirebonded Molded packages subjected to various environmental Conditions

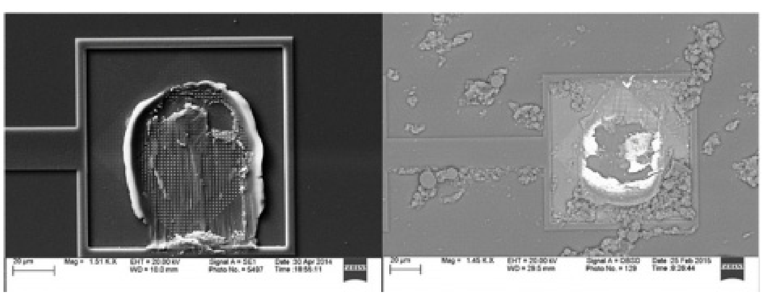


Figure 8—Shear failure modes in Cu wirebonded parts

prediction of such high powered parts. EMCs used for encapsulation of the chip and the interconnects may vary widely in their formulation including pH, porosity, diffusion rates, levels and composition of the contaminants. Selection of different materials, such as EMC used in the molding process plays key role in defining lifetime for wirebond system. There is need for predictive models which can account for the exposure to environmental conditions, operating conditions and the EMC formulation in order to be realistically representative of the expected reliability. In this paper, a set of parts, molded with different EMCs were subjected to high temperature-current environment (temperature range of 150°C-200°C, 0.2A-1A). An artificial neural network (ANN) driven predictive model for estimation of the beta-sensitivities of the input variables has been developed for computation of the acceleration factor for the Cu-Al WB under high voltage and high temperature

Package-Level Multiphysics simulation of Cu-Al WB Corrosion under High Temperature/Humidity

Copper wire has found extensive applications in microelectronics packaging industry due to its low material cost, advanced electrical, mechanical and thermal properties compared to gold wire. Studies have shown that copper wire performs better than gold wire under high temperature operational conditions as there is little or no Kirkendall void formation at Cu-Al wire bond interfacial area. However, when functioning under high humidity conditions, Cu-Al wire bond is more susceptible to bond interfacial corrosion compared to Au-Al wire bond. Experimental results on high humidity reliability of Cu-Al wire bond show that galvanic corrosion at ball bond interface is one of the main causes of failure. Despite reliability performance of wire bond being a constant research subject for decades, there is no time-to-failure model available to describe progression of corrosion. In this paper, a COMSOL multiphysics package level of Cu-Al wire bond corrosion model is developed. The package level model focus on capturing the progression of corrosion as a result of mold compound degradation, chlorine transport and micro-galvanic corrosion. The model is characterized by Nernst -Planck equation and interfacial electrolytic corrosion. Three-electrode electrochemical polarizations are performed to quantify the corrosion rate of wire bond. Diffusion cell experiment and molding compound degradation experiments are performed to quantify the diffusion rate of chlorine and the release rate of chlorine in a particular type of molding compound. Those experimental results are then incorporated into COMSOL multiphysics software to simulate the corrosion process and calculate lifetime of Cu-Al wire bond. The simulation results are then verified by the experimental results.

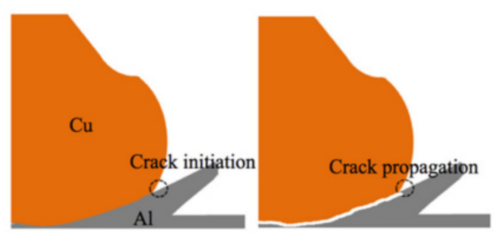


Figure 9—Crack Initiation and Propagation in Cu wirebonds

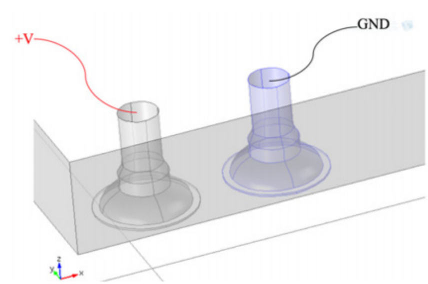


Figure 10—Application of Electric Stresses During Simulation

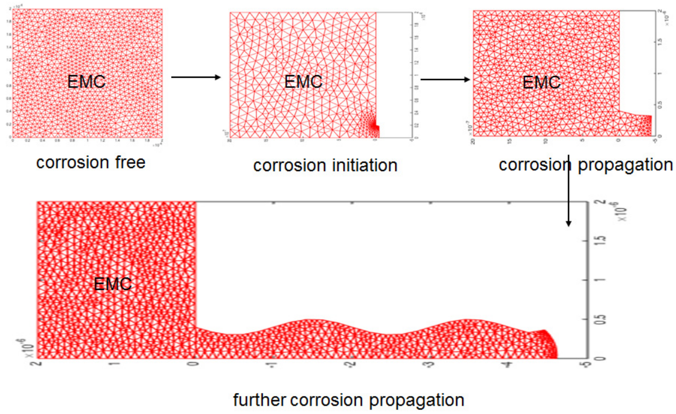


Figure 11 - Corrosion Model Prediction

Improved Finite Element Modeling Strategies with Multipoint Constraints for BGA packages subjected to Thermal Cycling

Finite Element simulations are often used to study the reliability of solder joints subjected to thermal cycling. Packaging configurations are becoming more complex to accommodate better functionality and performance. Increased complexity leads to several challenges for FE models including difficulties modeling thin layers and interfaces, as well as keeping the total numbers of nodes and elements to reasonable levels so that computation times can be practical. To reduce the use of high-density meshes and to relax the restrictions of nodal connections, the technique of Multi-Point Constraints (MPC) is often used in finite element analysis. In the MPC method, constraints are enacted between different degrees of freedom of the model to simply transition between finely and coarsely meshed regions. MPC algorithms require additional DOF constraints on a FE model; and extra contact nodes/ elements are deployed between the interfaces of contacting elements. MPC methods can be implemented with materials having linear or nonlinear mechanical behavior. The accuracy and efficiency of MPC-based finite element simulations for electronic packages have not been evaluated completely in the literature.

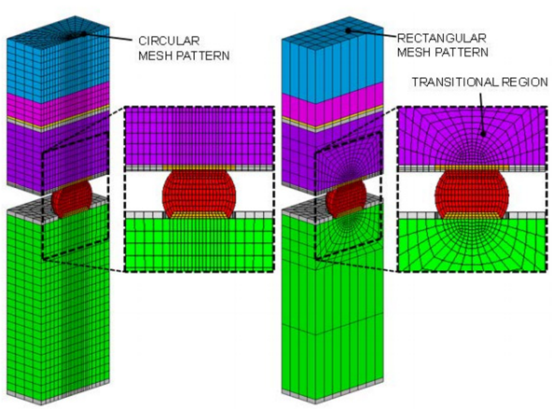


Figure 12— Conventional and transitional models.

In this work, an improved MPC based FE modeling strategy was developed for BGA packages to reduce the total number of elements (including both conventional and MPC elements), and thus reduce the simulation time. In addition, the new method can improve the simulation accuracy relative to models prepared using conventional meshing strategies. The proposed technique allows for different types of mesh patterns (circular pattern from solder joint and rectangular patterns from other component) to be connected in a package assembly while reducing the overall number of elements in the model. The proposed approach works with both symmetric and non-symmetric solder ball arrays, and achieves a good balance between simulation cost and simulation accuracy.

Effectiveness of Potting Methods and underfills on the Survivability of Fine-Pitch Electronics at 25,000g Shock Loads

Electronics in military and aerospace applications may be subjected to high-g. Surface mount BGA solder joints may not survive due to the large strains experienced at high-g accelerations. In order to increase the drop performance of these electronics package reinforcements like underfilling and epoxy potting are used. The epoxy potting absorbs the high-g shock forces and transmits reduced amount onto the package solder joints. Not a lot of research was found in the literature regarding the selection and use of epoxy potting compounds on the reliability of fine pitch electronics under mechanical shock loads. In this paper, a circular PCB with an annular hole assembled with CTBGA and CVBGA components 0.5mm and 0.4mm respectively was studied using underfill and epoxy potting reinforcements under mechanical shock of 25,000g. The test board configuration is similar to JEDEC JESD22B111, face down and constrained via four screws. The survivability and strain distribution is different as JEDEC standard is a rectangular board and tested at 1,500g shock. Three potting compound systems were studied in this work. All the potting configurations have Lord Thermoset ME531 underfill reinforced beneath the packages. The survivability of the components for all the potting configurations is assessed by subjecting to high-g mechanical shock of 25,000g, 0.08ms shock pulse and recording the drops to failure for each component. The transient event was continuously monitored for continuity using high-speed data acquisition system. Two high-speed cameras operating at 8,200fps were used to capture the high-g shock event. 3D digital image correlation (DIC) was employed to characterize the full-field strain distributions of the PCB. The shock survivability of these configurations of the test vehicle was reported. Finite element model predictions were performed to characterize the peak displacement and solder-joint interconnect strains and compared with the experimental results.

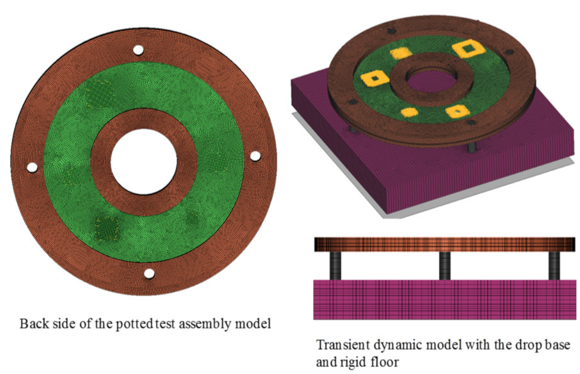
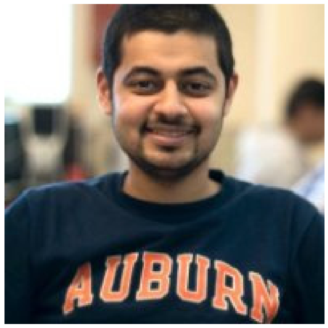


Figure 13— Explicit FE Model of Potted Assembly.

Announcements

CAVE3 Student Wins ASME EPPD 2017 Student Engineer of the Year Award



Shantanu Deshpande has been awarded the 2017 Student Engineer of The Year Award by ASME Electronics and Photonics Packaging Division. The award honors an active student who has excelled in research and has shown promise to be a strong contributor in the field of electronic and photonic packaging. Active participation in EPPD sponsored conferences such as IMECE, ITHERM and InterPACK is one of the requirements of the award. Award was presented at Award Lunchon at the InterPACK 2017 conference held in San-Francisco. Shantanu's research area focuses failures in different wirebond systems subjected to extreme environment applications. His main goal is to develop life prediction models for Cu wirebonds subjected to different environmental conditions. Shantanu is pursuing the Ph.D degree in Mechanical Engineering under direction of Professor Pradeep Lall.

CAVE3 Students Win Best-Paper Awards at ITHERM 2017 Conference in Orlando, FL.

The following CAVE3 papers from ITherm 2017 were recognized as best and outstanding poster papers at the conference. Paper entitled "High Strain Rate Mechanical Behavior of SAC-Q Solder" by Vikas Yadav received outstanding poster award and "Color Shift Analysis and Modeling of High Power Warm White pc-LED under High Temperature and High Humidity Environment" by Hao Zhang received best student poster award. More than 50 graduate students from various universities participated in the poster presentation competition. All posters were peer reviewed prior to the final competition. 3-judges were assigned per student for final competition and posters were judges based on the structure, technical content, significance of the research and the narrative by the author.

Left-to-Right: Vikas Yadav, Pradeep Lall, Hao Zhang at ITHERM-2017 in Orlando, FL.

Both Vikas Yadav and Hao Zhang are pursuing their Ph.D. degrees under the direction of Professor Pradeep Lall. Vikas's topic of research is the measurement of high strain-rate properties of SAC105 and SAC-Q alloys. Hao's topic of research is the reliability model development and failure mechanism characterization of LEDs and SSLs.

CAVE Students Win Various Awards in Graduate Engineering Research Showcase.

Students from NSF-CAVE3 team participated in Graduate Engineering Research Showcase poster competition in September, 2016, conducted by College of Engineering at Auburn University. The competition garnered participation from 142 Graduate Researchers from 10 departments of Samuel Ginn College Engineering each presenting their research via their posters to a committee of 4 randomly selected judges. The participants were judged on the relevance of the research, impact of the research conducted, quality of presentation and the poster itself. Hao Zhang, won the award for Best Poster from Mechanical Engineering Department for his poster titled "Failure Mechanism Analysis and Modeling of High Power automotive LED assemblies Under Harsh Environment". Nakul Kothari, received Honorable Mention for his poster titled "A Novel Micro-CT Data Based Finite Element Modeling Technique to Study Reliability of Densely Packed Fuze Assemblies". His work focused on making Finite Element models of a field extracted electrical assemblies subjected to harsh environments like high temperatures, high and low g mechanical shocks and vibrations in a non-destructive manner, using X-ray micro-CT system. Both Nakul Kothari and Hao Zhang are pursuing the Ph.D. degrees under direction of Professor Pradeep Lall.

Top-Left: Hao Zhang; Top-Right: Nakul Kothari; Bottom-Right: Jeff Suhling, Nakul Kothari, Jeff Fergus.

CAVE3 Director Professor Pradeep Lall wins the NSF-IUCRC Alex Schwarzkopf Prize for Technology Innovation

Professor Pradeep Lall, Director of CAVE3 won the NSF-IUCRC's Alex Schwarzkopf Prize for Technology Innovation. The award was presented at the NSF-IUCRC Biennial Meeting held on July 26 -28, 2017 in Washington, DC. Professor Lall received the award from non-other than Alex Schwarzkopf, NSF-IUCRC program's Founding Director. Lall joined the Auburn faculty in 2002 after a distinguished industry career at Motorola, where he worked on the development and manufacture of wireless products such as cell-phones and two-way radios. "Dr. Lall's recognition with the Alex Schwarzkopf Prize is evidence of the societal and transformational impact that Auburn University is making on automotive and harsh environment technologies in everyday life," said John Mason, Auburn's vice president for research and economic development.

Left Picture: (Left-to-Right) Pradeep Lall (Auburn University) receiving award from Alex Schwarzkopf at NSF-IUCRC Director's Biennial Meeting on July 26, 2017 in Washington, DC.
Right Picture: (Left-to-Right) Bernhard Boser (UC-Berkeley), Alex Schwarzkopf, Pradeep Lall (Auburn University)

"Electronic systems have taken an increasingly important role in automotive design and operation," Lall said. "Traditional automotive electronics at one time consisted of climate control and entertainment systems. Roll the clock forward to the present day and automotive electronics have expanded to include driving assists such as antilock braking systems, traction control systems, adaptive cruise control, lane-departure warning systems and more. Failure of one of these systems is no longer an inconvenience; it may be critical to the safe operation of the vehicle."

Founded in 1999 as the Center for Advanced Vehicle Electronics, CAVE3 has over the years expanded its expertise to include extreme environment electronics. Lall has been the center's director since 2008, following his appointment as associate director in 2004. Lall also directs Auburn's Harsh Environments Node of the NextFlex Manufacturing Institute, part of a national manufacturing effort on harsh environment electronics led by the U.S. Department of Defense. CAVE3 partners with industry, government and academic agencies to address major technological challenges through precompetitive research on automotive and harsh environment electronics. This arrangement gives the center an opportunity to address the challenges before the technologies become commercialized.

The National Science Foundation's cooperative research centers program was established in 1973 by Schwarzkopf to develop long-term research partnerships among industry, academe and government in areas of mutual interest. The Alexander Schwarzkopf Prize for Technological Innovation has been presented annually since 2003 to an individual or team at a member institution whose research makes an exemplary contribution to technology innovation. More than 100 universities and nearly a thousand researchers are members

Lall Elected to NextFlex Institute's Governing Council

Professor Pradeep Lall was elected to the Governing Council of NextFlex Manufacturing Institute. The announcement of the appointment was made by the Executive Director of NextFlex, Dr. Malcolm Thompson at the Governing Council Meeting held on June 22, 2017 in Monterrey, California. Auburn University is the founding tier-1 academic member of the NextFlex Institute and member of the team that wrote the winning proposal for founding the Institute. Professor Pradeep Lall is the PI on a NextFlex program focused on the development of test protocols for flexible hybrid electronics. The test protocols are targeted toward the development of methods for ensuring the survivability of FHE based products in a end use applications with a specific focus on wearables. Professor Lall presently serves as a member of the technical council and the academic co-lead of the Asset and Situational Awareness Technical Working Group. He will continue to retain both roles as he takes on the responsibilities with appointment to the Governing Council.

Selected Recent Publications

1. P. Lall, Y. Luo and L. Nguyen, "Package-level Multiphysics Simulation of Cu-Al WB Corrosion under High Temperature/ humidity Enviornmental Conditions," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1176-1184, May 30 - June 2, 2017 .
2. P. Lall, N. Kothari, J. Deep and R. Lowe, "Assessment of Reliability of Missile Fuze using Micro-CT Data Based Finite Element Technique and Digital Volume Correlation," in *Proceedings of the 16th ITherm*, Orlando, FL,pp. 1131-1138, May 30 - June 2, 2017.
3. P. Lall, H. Zhang and L. Davis, "Color Shift Analysis and Modeling of High Power pc-LED under High Temperature and High Humidity Enviornment," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1161-1177, May 30 - June 2, 2017.
4. P. Chowdhury, J. Suhling and P. Lall, "Experimental Characterization of Underfill Materials Exposed to Different Moisture," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1197-1208, May 30 - June 2, 2017.
5. P. Lall, A. S. Abrol, J. Suhling, L. Simpson, J. Glover and D. Locker, "Effect of Simultaneous High Temperature and Vibration on MEMS based Vibratory," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1214-1228, May 30 - June 2, 2017.
6. M. Alam, J. Suhling and P. Lall, "High Temperature Tensile and Creep Behavior of Lead Free Solders," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1229-1237, May 30 - June 2, 2017.
7. P. Lall and J. Wei, "X-ray Micro-CT and DVC Based Analysis of Strains in Metallization of Flexible Electronics," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1253-1261, May 30 - June 2, 2017.
8. P. Lall, K. Dornala, J. Deep and R. Lowe, "Effectiveness of Potting Methods and Underfills on the Enhancement of Survivability of Fine Pitch Electronics at 25000g Shock Loads," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1262-1274, May 30 - June 2, 2017
9. P. Lall, S. Deshpande and L. Nguyen, "Study of Electromigration in Cu and Ag Wirebonds Operating at High Current in Extreme Environments," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1275-1284, May 30 - June 2, 2017.
10. P. Lall, D. Zhang, J. Suhling and D. Locker, "Evolution of High Strain Rate and High Temperature Mechanical Properties of SAC305 with Long Term Storage up to 1-Year," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1285-1297, May 30 - June 2, 2017.
11. P. Lall and K. Goyal, "Study on the Effect of Fixtures on Deformation and Warpage of the Double-Sided Flexible Printed Circuit Board through Reflow Using DIC," in *Proceedings of the 16th ITherm*, Orlando, Fl, pp. 1306-1314, May 30 - June 2, 2017.
12. P. Lall, S. Deshpande and L. Nguyen, "Effect of EMCs on the High Current Reliability of Cu Wirebonds Operating in Harsh Environments," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1315-1324, May 30 - June 2, 2017.
13. N. Fu, J. Suhling, S. Hamasha and P. Lall, "Long Term Isothermal Aging Effects on the Cyclic Stress-Strain Behavior of Sn-Ag-Cu Solders," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1337-1345, May 30 - June 2, 2017.
14. N. Fu, J. Suhling, S. Hamasha and P. Lall, "Evolution of the Cyclic Stress-Strain and Constitutive Behaviors of SAC305 Lead Free Solder during Fatigue Testing," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1353-1360, May 30 - June 2, 2017.
15. M. Chowdhury, N. Fu, J. Suhling and P. Lall, "Evolution of the Cyclic Stress-Strain Behavior of Doped SAC Solder Materials Subjected to Isothermal Aging," in *Proceedings of the 16th ITherm*, Orlando, FL,pp. 1369-1379, May 30 - June 2, 2017.
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18. P. Lall, V. Yadav, J. Suhling and D. Locker, "Effect of Storage on High Strain Rate Mechanical Properties of SAC105 at Operating Temperature up to 200°C," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1433-1446, May 30 - June 2, 2017.
19. P. Lall, V. Yadav, J. Suhling and D. Locker, "High Strain Rate Mechanical Behavior of SAC-Q Solder," in *Proceedings of the 16th ITherm*, Orlando, FL, pp. 1447-1455, May 30 - June 2, 2017.
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21. N. Fu, S. Ahmed, J. C. Suhling and P. Lall, "Visualization of Microstructural Evolution in Lead Free Solders," in *Proceedings of the 67th ECTC*, Florida, pp. 429-440, May 30 - June 2, 2017.
22. S. Ahmed, M. Hasine, J. C. Suhling and P. Lall, "Mechanical Characterization of SAC Solder Joints at High Temperature Using Nanoindentation," in *Proceedings of the 67th ECTC*, Florida, pp. 1128-1135, May 30 - June 2, 2017.
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24. P. Lall, K. Mirza, J. Suhling and D. Locker, "Effect of Mean Temperature on the Evolution of Strain-Amplitude in SAC Ball -Grid Arrays during Operation under Thermal Aging and Temperature Excursions," in *Proceedings of the 67th ECTC*, Florida, pp. 1027-1038, May 30 - June 2, 2017.
25. P. Lall, S. Deshpande, Y. Luo and L. Nguyen, "Model for Interaction of EMC Formulation with Operating Current and Reliability of Cu-Al Wirebonds Operating in Harsh Enviorments," in *Proceedings of the 67th ECTC*, Florida, pp. 815-826, May 30 - June 2, 2017.
26. P. Lall, N. Kothari, J. Deep, J. Foley and R. Lowe, "Development of FE Models and Measurement of Internal Deformations of Fuze Electronics Using X-Ray MicroCT Data with Digital Volume Correlation," in *Proceedings of the 67th ECTC*, Florida, pp. 497-596, May 30 - June 2, 2017.
27. P. Lall and H. Zhang, "Test Protocol for Assessment of Flexible Power Sources in Foldable Wearable Electronics under Stresses of Daily Motion during Operation," in *Proceedings of the 67th ECTC*, Florida, pp. 804-814, May 30 - June 2, 2017.

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