AUBURN UNIVERSITY
SAMUEL GINN COLLEGE OF ENGINEERING

Spring 2019

cave³ 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

I am glad to report that our presentation of the biometric band at the NextFlex Innovation Day was featured in the Voice-of-America (VOA) News in October 2018. The biometric band is a technology product demonstrator developed at AU to demonstrate the flexible hybrid electronics. The band has a number of biometric sensors for monitoring of patient health and transmission of impending conditions to the paired smart phone through a Bluetooth low-energy interface. The smartphone interface with the biometric band has been entirely developed at AU. It is envisioned that the biometric band will be used for remote worker monitoring for early identification of imminent conditions requiring medical attention.

In January 2019, we have kicked off a new NextFlex project on the development of additive processes for z-axis interconnects. The program focuses on the development of process recipes, which includes the additive printing of metals, additive fabrication of dielectrics, z-axis vias between metallization between two layers, recipes for sintering of metallization using photonic and thermal processes. The process recipes will be used for high-volume scale-up of additively printed multi-layer circuits in production environments. Partners on the program include Optomec and DuPont.

Congressman Bradley Byrnes visited CAVE3 in November-2018 to view the ongoing research projects on the topic of flexible printed electronics, and design of electronics for harsh environment operation. During the visit, Congressman Byrnes had an opportunity to see the work being done at Auburn University in enabling the flexible printed electronics ecosystem, view the technology product demonstrators developed at CAVE3 and view how the research was impacting workforce development through courseware at the university-level and at the high-school level.

Auburn University has partnered with teachers from Auburn City Schools for development of courseware for flexible hybrid electronics. The courseware focuses on additive printed electronics and use of the additive technologies for the fabrication of circuits to allow students understand the potential of a career in electronics manufacturing. The effort is part of the ongoing NextFlex projects, which focus on workforce development as part of the manufacturing ecosystem.

We have had a number of visits to CAVE3 over the last two quarters. These include visit from TE Connectivity to discuss the connector technology, Boeing Research and Technology to discuss additive printed electronics for development of multi-layer printed substrates and test methods, Northrop Grumman for additive printed electronics and harsh environment electronics survivability characterization methods, and Porex for encapsulant materials for MEMS applications in harsh environments.

We presented two papers at the FLEX conference in Monterey, CA in February 2019. The technical presentations focused on our work on the development of additive printed electronics processes and the development of test protocols for flexible power sources. In addition, we also presented an update on our ongoing work related to the development of test protocols for additively printed electronics at the NextFlex Meetings in February 2019. In addition, I attended the NextFlex technical working group meetings, technical council meetings and the governing council meetings.

The CAVE3 center, which has always had a stable membership base, has experienced strong growth. I also want to welcome NSWC, and DEVCOM, Picatinny Arsenal to the Center Spring-Review.

Pradeep Lall,
John and Anne MacFarlane Professor and Director

CAVE3 Consortium Spring 2019 Technical Review Meeting

The Center for Advanced Vehicle and Extreme Environment Electronics (CAVE³) will hold its Spring 2019 Technical Review and Project Planning Meeting on March 6-7, 2019 in Auburn University's Wiggins Hall. All current members of the Consortium are invited to attend. The following projects will be presented at the meeting:

- Capacity Degradation of Flexible Li-Ion Power Sources Subjected to Shallow Discharging
- Print Consistency of Aerosol Jet printed conductive patterns
- Effect of Dielectric Material on the Reliability of 3640 MLCC Capacitors under High-G Shock Loads
- Reliability of Additively Printed Traces on a Polymer Substrate Subjected to Mechanical Stretching
- Factors Influencing the Line Consistency of Commonly Used Geometrics for Additively Printed Electronics
- Method for Assessment of Folding-Reliability of Flexible Electronics in Wearable Applications
- Analysis of Nonlinear Vibration Behavior of a Flexible Electronic Assemblies
- Stress Strain Analysis on Stitch Bond of Cu-Al Wirebonds Using X-ray Micro CT Technique
- Study of the effect of Solder-Joint voiding using X-ray MicroCT data-based FE Models with Experimental Validation
- Mechanical and Electrical Characterization of Electrical Lines Printed with Aerosol Jet Printing based Additive Manufacturing Process
- Effect of Prolonged Storage up to 1-Year on Anand Parameters for SAC105 Leadfree Alloys
- Evolution of Anand Parameters for SAC-Q Solder Alloy After Prolonged Storage up to 1-Year at High Strain Rate at Very High Operating Temperature
- Effect of Storage Temperature on the High Strain Rate Mechanical Properties of SAC305 Solder
- Effect of Sintering temperature on the Fatigue life of Additively Printed Electronics during cyclic bending
- Effect of Use of Parameters on Fatigue-Life of Flexible Substrates under Bending Loads
- Effect of Shock Pulse Variation and Restraint Mechanisms on Surface Mount Electronics under High G Shock
- Effect of Shallow Charging on Flexible Power Source Capacity Subjected to Varying C-Rates and Extreme Temperatures
- Health Monitoring of PCB during 10,000G shock pulses using Strain Measurements
- Failure Modes of Flexible Electronics Under Mechanical Vibration
- Sensitivity of Sensor and Use Conditions on the Detectability of Accrued Damage for PHM under Combined Temperature Vibration
- 3-D Numerical Multiphysics Model for Cu-Al Wire Bond Corrosion
- Effect of Surface Finish on the Reliability of SAC-based Solder Joints
- Air Transportable Rack (ATR) Vapor Compression Refrigeration (VCR) System
- Reliability Analysis of Super Ball Grid Array Packages
- Effect of Surface Finish on the Shear and Fatigue of Lead-Free Doped Solder Joints
- Evolution of the Cyclic Stress-Strain Behavior of Doped SAC Solder Materials Subjected to Isothermal Aging
- Evolution of the Cyclic Stress-Strain and Constitutive Behaviors of Doped Lead Free Solder During Fatigue Testing
- Effects of Mechanical Cycling on the Microstructure of Lead Free Solders
- Mechanical Characterization of SAC Solder Joints at High Temperature Using Nanoindentation
- Nanoindentation Measurements of the Mechanical Properties of Individual Phases Within Lead Free Solder Joints Subjected to Isothermal Aging
- Effects of High Temperature Aging on The Mechanical Behavior of Lead Free Solders
- A Comparative Study of the High Temperature Mechanical Behavior of SAC and SAC+X Lead Free Solders
- Investigation of Aging Induced Evolution of the Microstructure of SAC305 Lead Free Solder
- Evaluation of Aging Induced Microstructural Evolution in Lead Free Solders Using Scanning Probe Microscopy

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SPECIAL EVENTS

SMTA International 2019

Conference: Sept. 22—Sept. 26, 2019
Donald E. Stephens Convention Center, Rosemont, IL

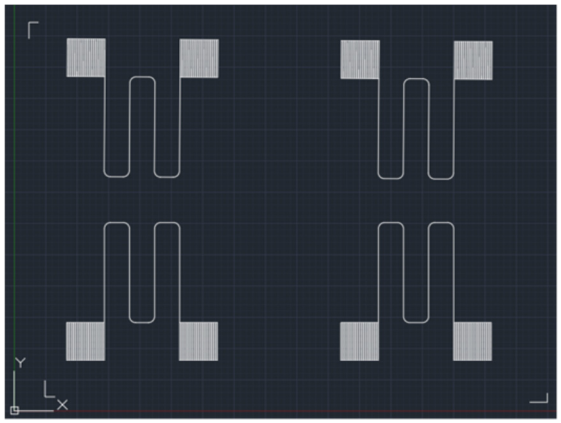
CAVE3 researchers will be heading the Harsh Environment and Advanced Packaging Technologies Tracks at the SMTA International Conference this year. The Harsh Environment Track started as a separate CAVE3/SMTA Harsh Environment Workshop in 2003 and merged with the main SMTA International Conference later after experiencing growth. The annual SMTA International Conference will be held at the Donald E. Stephens Convention Center in Rosemont, Illinois from Sept. 22— Sept. 26, 2019. Dr. Lall is member of the SMTA International Technical Advisory Committee and a track co-chair of the Advanced Packaging Technologies track. Dr. Hamasha is track co-chair of the Harsh Environments Track. The papers will focus on alternate energy, battery prognostics, components and reliability, copper corrosion, COTS, high lead solder replacement, high temperature electronics, lead-free issues, non-destructive inspection, micro-computed tomography, multiphysics modeling, substrates and finishes, thermal management, and tin whiskers. Papers on a variety of topics such as advanced packaging, assembly process and materials, PCB technology, harsh environment, emerging technologies, etc. will be presented during this conference. SMTAI has been recognized as a truly different type of industry event because of the high quality of 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

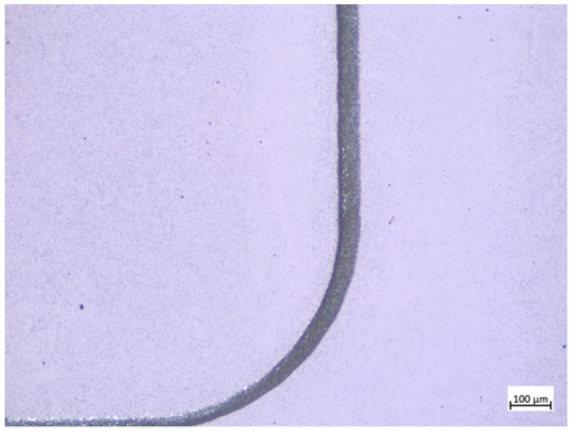
10 hour Print Consistency of Aerosol-Jet Printed Electronics as a Function of Optimized Print Parameters

Recent advancements in the field of additive manufacturing have given rise to a nanomaterial ink based technology known as Aerosol -jet printing (AJP), which enables fabrication of micro scaled printed and flexible electronics. Development of test protocols, refinement of inks, and print process parameters have been demonstrated within the research community largely depending on the empirical observations; however, if AJP is to be utilized at a large scale level for fabrication and manufacturing, then it is of the utmost importance that the print consistency be studied as a function of not only the optimized print parameters, but also as a function of the print-time over a period of 8-10 hours, which is a fair representation of a standard work shift.

Image of AJ Optomec 300 Printer (Credit: TCT Magazine)

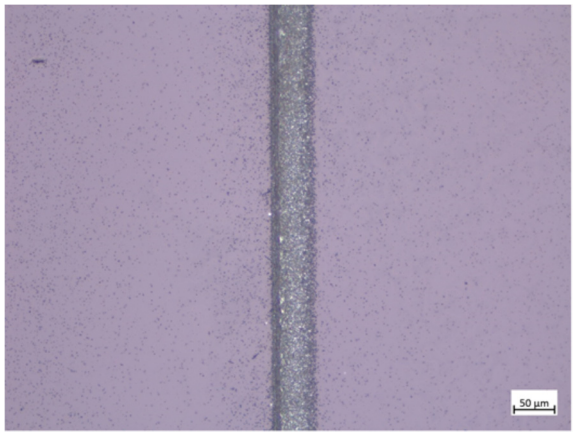


Schematic of the Electronic Pattern (Strain Gage)



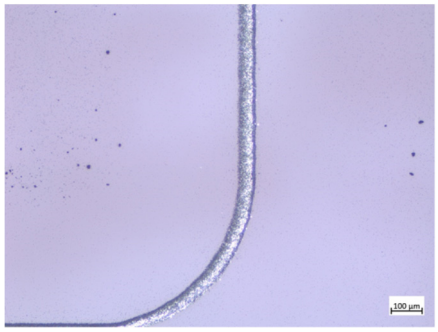
Print Quality of the loop feature from the pattern after 10 hours of printing

Due to the novelty of the AJP technology, there is no known existence of information that addresses issues related to the print consistency of AJP. The goal of this study is to establish a basic understanding which may or may not result in process limitations and provide guidelines for an improved process window and print parameter optimization if need be. In this research study, a 90nm particle sized silver based ink and 70nm particle sized ink have been utilized to study the print consistency of a state-of-the-art Aerosol jet printer, Optomec 300. The print process parameters were optimized by varying the sheath rate, mass flow rate, nozzle size, and chiller temperature. Using these parameters, the numbers of passes were optimized as a function of the least amount of line resistance. With all parameters optimized, the Aerosol jet printer was allowed to print continuously for a duration of 10 hours.



Print Quality of the straight line feature from the pattern after 10 hours of printing

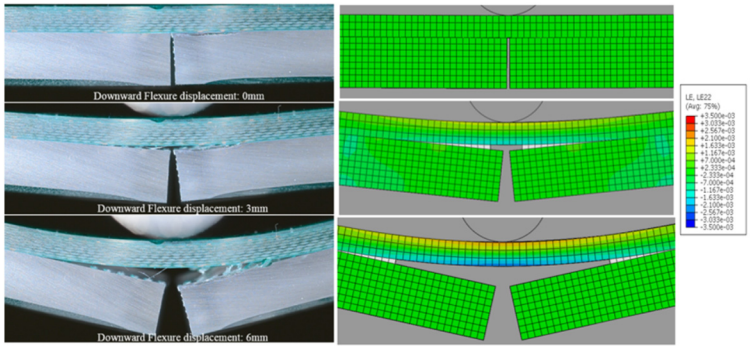
Printing process efficiency has been gauged as a function of process capability index (Cpk) and process capability ratio (Cp). Later, the printed samples were studied offline using optical Profilometry to analyze the consistency within the line width and line height. SEM analysis has also been conducted to verify if or if not the overall profile of the printed samples stays constant over the 10 hour period.



Print Quality of the loop feature from the pattern after 50 minutes of printing

Measurement and Prediction of Interface Crack Growth at the PCB-Epoxy Interfaces under High-G Mechanical Shock

Surface mount electronic components reinforced with underfills and epoxy potting have shown an increase in the survivability expectations under extreme thermo-mechanical loading. Additional structure support and shock damping are provided by potting. Electronic components are also potted to protect sensitive equipment from environmental conditions (such as moisture) as well as to insulate electrical leads in the event that other components fail. Potting of electronics has become one of the most viable and cost-effective solutions to enhance electronic package survivability. At extreme mechanical shock loads, the electronic components undergo tremendous strain, which, in turn, is responsible for solder joint failure in BGA components.

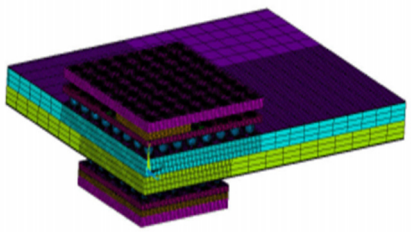


Epoxy-A potting PCB 3-point bend test

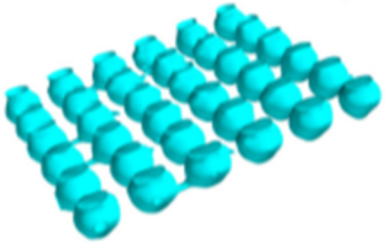
Due to the bulk of material surrounding the PCB, potting and encapsulation resins are commonly two-part systems, which, when mixed together, form a solid and fully-cured material with no by-products. The cured potting materials are prone to interfacial delamination under dynamic shock loading, which can potentially cause failures in the package interconnects. The study of interfacial fracture resistance in PCB/epoxy potting systems under dynamic shock loading is important in mitigating the risk of system failure in mission-critical applications. This research study focused on the mechanics of the interface delamination of the epoxy potted PCB samples. Determination of the fracture parameters, such as fracture toughness and strain energy release rate, is important in selecting and the reliability study of the supplemental restraint systems. Sample specimens of the Epoxy/PCB systems were prepared and subjected to quasi-static three-point bend loading to observe the fracture behavior of the bi-material samples and study the interface delamination mechanisms. The fracture toughness and crack initiation of the PCB/Epoxy bi-material system were compared with the cure schedule and temperature. A cohesive zone model was developed for mode I delamination of PCB/Epoxy specimen under three-point bending. Damage is assumed to occur at interfaces modeled through cohesive zone elements in the material, while the bulk material is assumed to be linear elastic. The fracture parameters obtained from the experiment were used in the finite element fracture model to predict the damage accumulation and compared with the fracture characteristics of the cohesive zone constitutive law.

Thermo-mechanical Deformation in Flexible-Board Assemblies during Reflow and Post-Assembly Usage

Flexible printed circuit boards lack the structural stiffness of their rigid printed circuit counterparts. Thermo-mechanical deformation in flexible printed circuit assemblies may be very different from that in rigid board assemblies. The double-sided board used for this experiment is of BGA 256-144 combination with dummy components, A-PBGA256-1.0mm-17mm and ACABGA144-1.0mm-13mm. The three dimensional measurements of deformation and strain have been visualized on the geometry of the solder joints in the package. The digital volume correlation (DVC) method has been used to find the displacements and strains in interconnects of operational electronics. The x-ray microscopic computed tomography (µCT) system has been used to generate the 16-bit digital volume data. The x-ray detector has the ability to image the x-ray attenuation of x-rays through the object. Reliability testing of SAC 305 solder interconnects has been performed on double-sided flexible circuit board using x-ray µCT by heating the package to 100°C. 3D-finite element models have been developed to ascertain the degree of error in the model prediction from non-destructive experimental measurements in reflow and thermal cycling.



Final 3D model for Printed Circuit Board



Solder Joints Visualization from µ-CT scan for DVC

Announcements

AU Biometric Band Presented at NextFlex Innovation Day 2018 Featured in VOA News

Auburn University's Flexible Biometric Band presented at the NextFlex Innovation Day was featured in VOA News. The intended application is for operators working on the inspection and maintenance of aircraft fuel tanks. The fuel tanks are small, confined spaces in the aircraft, which reside in the fuselage and inside the wings of the aircraft. Inspection and maintenance operations require the operators to climb inside of the confined space of the fuel tanks. Oxygen levels in a confined space may become depleted due to oxidation or depletion by another gas. The typical concentration of oxygen in the environment is 20.9 percent. When oxygen levels drop from 19.5 percent to 12 percent, judgment is impaired and personnel may experience an increased pulse fatigue. If levels drop further, from 12 percent to 6 percent, fatigue, nausea, and vomiting may occur. A dual-use aspect of the technology may include the following applications: 1.) monitoring of vitals of workers in high-heat environments to determine when they need to come out before the effects of heat stress become a physical risk factor and 2.) monitoring of an individual worker in a hazardous environment.

The multi-sensor biomedical band will be worn by the operator working in a confined space and its multiple sensors will measure the loss of blood oxygenation resulting from depletion of oxygen in the fuel tank, abrupt changes in the pulse rate resulting from anxiety or claustrophobia, loss of consciousness, myocardial infraction, stroke, bradycardia or aneurysm. Additional sensors can be added if there is a need to address a broader range of medical conditions. The raw data from the sensors is gathered by the embedded microcontroller on the wearable band through the GPIO and transmitted via the Bluetooth sensor on the USART port of the microcontroller to a paired smartphone. The LifeSaver App installed on the smartphone receives the transmitted data via its Bluetooth module and processes the data in order to check for imminent danger to the operator. If the status is okay, the app continues to monitor silently. However, if the operator is in imminent danger or in need of medical attention, the app autonomously contacts emergency medical services with the GPS location of the operator and details the condition of the operator and nature of the medical condition.

AU-Biometric Band Featured in VOA News, Oct 30, 2018

U.S. Congressman Bradley Byrne Visits CAVE3

Dr. Lall (right) discusses 3D-additive printed flexible electronics at CAVE3 with Congressman Byrne (left)

U.S. Congressman Bradley Byrne, who represents Alabama's 1st District, visited CAVE3 on October 12, 2018 in order to learn more about the Center's ongoing research projects in additive printed flexible-hybrid electronics and harsh environment electronics. Topics discussed included biometric flexible band, testing fuze electronics at high-g shock, non-destructive MicroCT analysis, and the capabilities of LED research as part of a U.S. Department of Energy grant provided to test the reliability of LED light bulbs.

Dr. Lall (left) discusses high-g electronics and light-emitting diodes research at CAVE3 with Congressman Byrne (right)

Announcements

Boeing Research & Technology Visits CAVE3 to Discuss 3D Printing Capabilities

Dr. John Rogers, Senior Electrical Engineer at Boeing, recently visited CAVE3 in order to learn more about and discuss the Center's 3D Aerosol Printing Electronics and printing capabilities. Dr. Rogers was also interested in acquiring more knowledge about various initiatives and practices in the area of Flexible Electronics being utilized by Auburn University. Both Auburn University and Boeing are connected through their Tier 1 membership in NextFlex, a flexible electronics manufacturing company.

Dr. Lall (left) and two Mechanical Engineering Ph.D. students (center) explain CAVE3's research and technological advances in Aerosol Jet Printing to Dr. Roberts (right)

Lall Elected to Board of Governors of the IEEE Electronics Packaging Society

Dr. Lall was recently elected to serve as a Member-at-Large on the IEEE Electronics Packaging Society Board of Governors from 2019 until 2021. The Electronics Packaging Society (EPS) Board of Governors (BoG) includes 18 Members-at-Large who are elected by the full voting membership of the Society. The three-year terms of the Members-at-Large are staggered – so that six Members-at-Large to the Board of Governors are elected annually. Members-at-Large are elected to achieve totals proportionate to the geographic distribution of EPS members. Therefore, any IEEE Region/grouping of Regions determined to have at least 10% of total EPS members will have the proportional number of Member-at-Large Positions designated to it for representation on the BoG. Dr. Lall was chosen from a slate of candidates at the 2018 election to ensure that the resulting total of newly elected Members-at-Large plus continuing Members-at-Large will have the proper portion of representatives from his Region from 2019 until 2021. As a Member-at-Large, Dr. Lall will work on growing the EPS in the areas of Flexible Hybrid Electronics, Harsh Environment Electronics, Prognostics Health Management, and Solder Joint Reliability through publications, conferences, membership development, chapter development, etc.

Purdue University Mechanical Engineering Professor Presents Seminar Focused on Semiconductor Devices

Dr. Subbarayan (second from right) with Dr. Lall (second from left), Dr. Jeffrey Suhling (far left), and Dr. P.K. Raju (far right) after the seminar

Dr. Subbarayan (right) with CAVE3 Students after the seminar

Dr. Ganesh Subbarayan, Professor of Mechanical Engineering at Purdue University, hosted a seminar entitled 'Analysis of Corner Singularities and Cracks in Semiconductor Devices' in the Department of Mechanical Engineering on November 16, 2018. During his seminar, he explained that modern semiconductor chips contain layers of alternating brittle dielectric materials and metal signal planes. The arrangement of these "Back-End-of-Line" (BEOL) structures naturally introduces multi-material corners that are sources of high stress. In the drive towards improved performance, the dielectric materials are made more porous with every new technological node, exacerbating the stress concentration in BEOL structures. Dr. Subbarayan also presented computational modeling strategies as well as specialized computational tools for analyzing corner singularities, crack initiation, and crack propagation in semiconductor devices.

Announcements

Lall Elected Fellow of NextFlex Manufacturing Institute

Pictured here (L to R) are: ACI CEO Dana Hankey who accepted the award on behalf of Mike Mastropietro, VP Engineering, ACI Materials; Pradeep Lall, Ph.D., John and Anne MacFarlane Endowed Professor and Director, Auburn University; Nancy Stoffel, Ph.D., Senior Engineering Professional/Project Manager, GE Global Research; Chris Stoessel, Ph.D., Sr. Manager, Process Development, Eastman Chemical; Malcolm Thompson, NextFlex Executive Director; John Williams Ph.D., Associate Technical Fellow, Boeing Research and Technology; Jeff Stuart, Ph.D., Emerging Technology External Portfolio Lead, Lockheed Martin, and Bruce Hughes, Lead FHE Engineer, AMRDEC. Not pictured: Scott Anderson, Ph.D., Research Scientist Senior Staff, Lockheed Martin and Craig Herndon, Director, Critical Technologies Innovation Center, Naval Surface Warfare Center, Crane Division. (Photo: Business Wire)

NextFlex, America's Flexible Hybrid Electronics Manufacturing Institute, recently recognized Pradeep Lall, the MacFarlane Endowed Professor in the Department of Mechanical Engineering, as an individual who has accelerated the flexible hybrid electronics industry's growth. NextFlex acknowledged nine individuals who have made remarkable contributions to advancing the flexible hybrid electronics ecosystem and industrializing the FHE manufacturing process at this year's FLEX conference, during the third annual presentation of the NextFlex Fellow Award. The winners received the Fellow Award for their work in accelerating the development of FHE in emerging technologies, manufacturing, defense, aerospace, and medical applications, as well as workforce development. Lall is a member of the founding proposal team for the NextFlex Manufacturing Institute. Lall's research in NextFlex focuses on the development of processes for additive manufacturing of flexible electronics and the development of test protocols for the reliability assurance of flexible electronics. Auburn University is a Tier-1 Founding Member of the NextFlex Manufacturing Institute. Lall serves on the technical council and the governing council of NextFlex Manufacturing Institute.

TE Connectivity Presents Seminar Visits CAVE3

Dr. Rod Martens, Senior Principal Engineer at TE Connectivity, conducted a seminar focused on 'Electrical Contact Finish Systems' in the Department of Mechanical Engineering on August 16, 2018. He has been the recipient of both the IEEE Holm Conference Erle Shobert Prize Paper Award and the IEEE Holm Armington Recognition Award. Dr. Martens' discussion went in to detail about the separable interfaces of electrical connectors. He explained that, to reliably pass electrical power or signals across an interface, it must be engineered as a system to optimize its performance and cost. The basics of contact resistance are reviewed, followed by a description of how the properties of the bulk conductor, underplate and contact finish interact to enhance the properties of the interface. Following the seminar, he provided Mechanical Engineering graduate students with insights into the type of work and environment they would encounter if they were to pursue employment in his field.

Dr. Rod Martens (1st from Left), TE Connectivity with Dr. Lall (right) after Seminar at CAVE3

Graduate Students with Dr. Martens following the seminar

Announcements

Dr. Lall Presents Dr. Luu Nguyen with Member of Technical Distinction Award at 2018 SMTA International Conference

Dr. Lall (left) presents Dr. Nguyen (right) with his award at the 2018 SMTA International Conference in Rosemont, IL

Dr. Lall presented Dr. Luu Nguyen, Fellow at Texas Instruments in Santa Clara, CA, with the SMTA Member of Technical Distinction Award at the 2018 SMTA International Conference in Rosemont, IL during the week of October 14-18. While at Texas Instruments, Dr. Nguyen has been leading a company-wide initiative evaluating the applicability of printed electronics to a number of packaging applications for enhanced performance. He also has been the coordinator of packaging university research for the past 10 years during which he has worked with over 20 stateside and overseas universities on different topics to meet TI's critical needs. Additionally, Dr. Nguyen has a significant array of other professional and academic achievements. These include: 140 invited talks; 80 patents and invention disclosures; and the publication of 2 books, among multiple others. He also has been selected to serve on multiple editorial boards. Some of Dr. Nguyen's most notable honors and awards include those from IEEE, the European Electronics Industry Awards, National Semiconductor Hall of Fame, and Fulbright Scholarship Program in Helsinki, Finland.

Lall receives AU Advisory Board's Advancement of Research and Scholarship Achievement Award

At its Spring 2018 meeting, Auburn University's Research and Economic Development Advisory Board selected Dr. Pradeep Lall, the MacFarlane Endowed Professor in Auburn's Department of Mechanical Engineering, as the 2018 recipient of its Advancement of Research and Scholarship Achievement Award. The award recognized him for his research achievements in the fields of harsh-environment electronics and flexible electronics. The advisory board is made up of more than 40 industry professionals from across the country who actively support Auburn's research efforts. The recipient of the annual award receives a $25,000 grant to further his or her research.

Dr. Lall (left) receives the Research and Economic Development Advisory Board Advancement of Research and Scholarship Achievement Award from Dr. Jennifer Kerpelman, Interim Vice-President for Research (right), at the Faculty Awards Ceremony on November 13, 2018

Dr. Lall, Director of Auburn's NSF Center for Advanced Vehicle and Extreme Environment Electronics, is the author or co-author of two books, 14 book chapters and more than 500 journal and conference papers in the field of electronics reliability, safety, energy efficiency, and survivability. He serves on the NextFlex Institute's technical council and governing council. He has spearheaded research efforts in flexible electronics and led Auburn's proposal team for the NextFlex Flexible Hybrid Electronics Manufacturing Institute. A fellow of the Institute of Electrical and Electronics Engineers, or IEEE, Dr. Lall has received numerous awards for his research. He was the recipient of the IEEE Sustained Outstanding Technical Contributions Award in 2018 and the National Science Foundation Schwarzkopf Award for Technology Innovation in 2016. With significant funding from public-private partnerships, his work has proven beneficial to the aerospace and automotive industries and in military vehicles and defense systems.

"The Research and Economic Advisory Board has made a great choice in honoring Dr. Lall with this award," said Dr. Jennifer Kerpelman, Auburn's Interim Vice-President for Research. "He is a very accomplished researcher with a strong track record, and his work is a great asset to Auburn University," she added.

Lall's research focuses on the development of methods for assuring survivability of electronics to high shock forces, vibration and extreme temperatures. He is best known for his research in the areas of reliability and prognostics for electronic systems operating in harsh environments, such as: combined exposure to temperature and vibration under the hood of an automobile for electronics mounted on-engine or on-transmission; extreme cold or extreme hot environmental temperatures for prolonged periods of time experienced in military and defense applications; high-g forces experienced by electronics inside missiles; and corrosive attack of salt fog for electronics operating on ships at sea. "Electronics systems have taken an increasingly important role in automotive design and operation," Dr. 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."

Selected Recent Publications

1. Chen, C., Suhling, J.C., and Lall, P., "Improved Approaches for FEA Analyses of PBGA Packages Subjected to Thermal Cycling", *Proceedings of the ASME INTERPACK,* San Francisco, CA, USA, August 27-30, 2018.
2. Chowdhury, P.R., Suhling, J.C., and Lall, P., "The Effects of Curing Profile, Temperature, and Aging on the Mechanical Behavior of Solder Mask Materials", *Proceedings of the ASME INTERPACK,* San Francisco, CA, USA, August 27-30, 2018.
3. Fahim, A., Ahmed, S., Suhling, J.C., and Lall, P., "Nanoindentation Measurements of the Mechanical Properties of Individual Phases within Lead Free Solder Joints Subjected to Isothermal Aging", *Proceedings of the ASME INTERPACK,* San Francisco, CA, USA, August 27-30, 2018.
4. Hassan, K.R., Alam, M.S., Basit, M., Suhling, J.C., and Lall, P., The Effects of Temperature, Strain Rate, and Aging on the Poisson's Ratio of SAC Lead Free Solders", *Proceedings of the ASME INTERPACK,* San Francisco, CA, USA, August 27-30, 2018.
5. Chowdhury, M.M.R., Hoque, M.A., Fahim, A., Suhling, J.C., Hamasha, S., and Lall, P., "Microstructural Evolution in SAC305 and SAC-Bi Solders Subjected to Mechanical Cycling", *Proceedings of the ASME INTERPACK,* San Francisco, CA, August 27-30, 2018.
6. Alam, M.S., Hassan, K.R., Suhling, J.C., and Lall, P., "Investigation of the Effects of High Temperature Aging on the Mechanical Behavior of Lead Free Solders", *Proceedings of the ASME INTERPACK,* San Francisco, CA, USA, August 27-30, 2018.
7. Lall, P., Yadav, V., Suhling, J.C., Locker, D., "Viscoplastic Constitutive Model for High Strain Rate Mechanical Properties of SAC-Q Leadfree Solder after High-Temperature Prolonged Storage", *Proceedings of the ASME INTERPACK,* San Francisco, CA, USA, August 27-30, 2018.
8. Lall, P., and Thomas, T., "Assessment of Damage Progression in Automotive Electronics Assemblies Subjected to Temperature and Vibration", *Proceedings of the ASME INTERPACK,* San Francisco, CA, USA, August 27-30, 2018.
9. Lall, P., Deshpande, S., and Nguyen, L., "Copper, Silver, and PCC Wirebonds Reliability in Automotive Underhood Environments", *Proceedings of the SMTA INTERPACK,* San Francisco, CA, USA, August 27-30, 2018.
10. Lall, P., Deshpande, S., and Nguyen, L., "Comparison of Reliability of Copper, Gold, Silver, and PCC Wirebonds under Sustained Operation at 200°C", *Proceedings of SMTA International***,** Rosemont, IL, USA, October 14-18, 2018.
11. Akkara, F.J., Zhao, C., Abueed, M., Su, S., Hamasha, S., Suhling, J., and Lall, P., "Effects of Mixing Solder Sphere Alloys with Bismuth-Based Pastes on The Component Reliability in Harsh Thermal Cycling", *Proceedings of SMTA International*, Rosemont, IL, USA, October 14-18, 2018.
12. Su, S., Jian, M., Akkara, F.J., Hamasha, S., Suhling, J., and Lall, P., "Fatigue and Shear Properties of Highly Reliable Solder Joints for Harsh Applications", *Proceedings of SMTA International,* Rosemont, IL, USA, October 14-18, 2018.
13. Lall, P., Goyal, K., Leever, B., and Marsh, J., "Warpage of Flexible-Board Assemblies with BGAs during Reflow and Post-Assembly Usage, *Proceedings of SMTA International,* Rosemont, IL, USA, October 14-18.

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