The 23rd Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems

ITherm

DENVER, CO

2024

Gaylord Rockies Resort & Convention Center
Denver, CO
May 28 – 31, 2024

IEEE Advancing Technology for Humanity

IEEE ELECTRONICS PACKAGING SOCIETY

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WELCOME LETTER

On behalf of the organizing committee, it is a great pleasure to welcome you to ITherm 2024, the leading international conference for the scientific and engineering exploration of thermal, thermo-mechanical, and emerging technology issues associated with electronic devices, packages, and systems. ITherm is once again being held along with the Electronic Components and Technology Conference (ECTC), a premier electronic packaging conference.

ITherm 2024 is packed with many activities, including over 220 Technical Papers across 4 Technical Tracks, 3 Keynote Talks addressing the topics of overing the areas of CHIPS NAPMP and Metrology Programs; Multiscale thermal modeling of electric vehicle batteries; and challenges and opportunities for liquid cooled data centers for AI compute. ITherm 2024 also has an Invited Presentation by the recipient of the Richard Chu ITherm Award for Excellence; 5 Technical Panel Sessions for a highly interactive engagement with experts; 5 Technology Talk Sessions providing deep dive talks on high profile topics; a Federal Funding Landscape Panel workshop which provides a platform to engage with program managers of different government agencies; over 50 Student Posters with an engaging networking session; presentations from the finalist of the 2024 ASME/K-16 and IEEE/EPS Student Heat Sink Design Competition; 16 Professional Development Course; and several must visit Vendor Exhibits. ITherm 2024 attendees are also highly encouraged to take advantage of networking opportunities with our ECTC colleagues. Several exciting joint ITherm and ECTC events will be held starting Tuesday. On Wednesday evening, ITherm and ECTC will jointly host the 2024 Diversity and Career Growth Panel and Reception, where distinguished panelists will speak on challenges related to recruitment, inclusion and retention of diverse talents, and the development of initiatives, policies and programs to increase the workforce.

We have sought sponsorships to support expanded student participation with opportunities to present their work in oral and poster presentations, as well as other activities at ITherm. This year we have had unbelievable sponsorship support from both industry and academia. Our thanks go out to each of this year's sponsors for the critical role their sponsorship provides to ITherm. Please visit their exhibition booths, benefit from the exchange of information, and we thank them for their sponsorship.

Thank you for participating in the ITherm 2024 conference. Building upon the previous ITherm conferences, and growing momentum in our area, we expect attendance at ITherm 2024 to exceed record 400 professionals. ITherm continues to find innovative ways to grow and serve our community. Many thanks go to everyone who has contributed to the success of ITherm 2024. We would like to thank our track chairs and co-chairs, session chairs/co-chairs, panel/technology talk organizers, all reviewers, and many others. Finally, the support of our Executive Committee is highly appreciated. A complete list of key contributors is listed later in this program.

Whether this is your first time attending or if you have attended before, we hope that you will feel energized by the interaction with your fellow attendees. For our first-time attendees, we hope you take advantage of all the networking opportunities to continue to grow your careers. ITherm 2025 will be held in Dallas, Texas, USA on May 27 – May 30, 2025, and we hope that you mark your calendars to be there as well. Please join us for the ITherm 2025 Program Planning meeting (open to all) to volunteer on Thursday 7-8pm. We appreciate the dedication of this community and are eager to see you all again.

Ashish Gupta, Ph.D.
General Chair

Amy Marconnet, Ph.D.
Program Chair

Milnes David, Ph.D.
Vice Program Chair

Jack Maddox, Ph.D.
Communications Chair

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CONFERENCE DESCRIPTION

Sponsored by the IEEE's Electronics Packaging Society (EPS), ITherm 2024 is the leading international conference for the scientific and engineering exploration of thermal, thermomechanical and emerging technology issues associated with electronic devices, packages and systems. ITherm 2024 will be held along with the 74th Electronic Components and Technology Conference (ECTC 2024 - http://www.ectc.net), a premier electronics packaging conference at the Gaylord Rockies Resort & Convention Center (Denver, CO).

CONFERENCE SUMMARY

- **Over 220 Technical Papers and presentations** organized across four Technical Tracks: Component-Level Thermal Management (TI), System-Level Thermal Management (TII), Mechanics & Reliability (M), and Emerging Technologies & Fundamentals (E)
- **3 Keynote Talks** covering the areas of challenges and opportunities for liquid cooled data centers for AI/accelerated compute; multiscale thermal modeling of electric vehicle batteries; and an the history and future of electronics packaging.
- **Richard Chu ITherm Award and Seminar**
- **5 Technology Talks** providing deep-dive talks on high-profile topics
- **5 Panels** discussing the latest industry challenges and trends.
- **50 Student Posters** showcasing the latest research in an interactive networking environment
- **Federal Funding Landscape Panel** with representatives from government funding agencies.
- **Student Heat Sink Design Challenge Presentations**
- **ECTC/ITHERM Diversity and Career Growth Panel and Reception**
- **16 Professional Development Courses** offered as a collaboration with ECTC
- **Heterogeneous Integration Roadmap (HIR) All-Day Sessions** consisting of 4 technical sessions on Tuesday, May 28, 2024.

GENERAL INFORMATION

REGISTRATION

Location: Colorado Pre-Function

Opening Hours:
Tuesday, May 28: 3:30 PM – 5:30 PM
Wednesday, May 29: 6:30 AM – 5:30 PM
Thursday, May 30: 7:00 AM – 5:30 PM
Friday, May 31: 7:00 AM – 12:00 PM

Conference Registration Includes:
- Admission to All Conference Sessions
- Breakfast and Luncheons (Wednesday, Thursday, and Friday)
- Digital Conference Proceedings

Fees (Onsite Registration)	IEEE Member	Non-Member	Student Member	Student Non-Member
Joint ITherm/ECTC Registration	$1665	$1995		
ITherm Registration	$900	$1050	$500	$600
One-Day Registration	$750	$900		

GENERAL EMERGENCY INFORMATION

If an accident or illness of a guest, visitor or employee occurs in your area, you should immediately:
- Call Hotel Security at extension 4444, and provide your name, location and accident or illness.
- Do not move the injured or ill person. Jennie Brahams is our Event Manager and can be reached at M (720) 498-1354 or F (720) 574-1621. For police, fire, and ambulance, call 911.

COMMITTEE MEETINGS

ITHERM EXECUTIVE COMMITTEE

Thursday, May 30, 5:00 to 6:00 PM.
Homestead 4
By invitation only.

ASME K-16 COMMITTEE AND JOURNAL OF ELECTRONIC PACKAGING

Wednesday, May 29, 7:45 to 9:00 PM.
Red Rock 10-11
Open to all interested in becoming involved with K-16 and the Journal of Electronic Packaging

ITHERM 2025 PROGRAM PLANNING

Thursday, May 30, 7:00 to 8:00 PM.
Red Rock 10-11
Open to all current and future contributors.

ITHERM 2024 ORGANIZERS' DINNER

Thursday, May 30, 8:00 to 10:00 PM.
By invitation only.

ITHERM MOBILE APP

1. To get started, Download the Ex Ordo app on your phone from either the App Store (iOS) or the Google Play Store (Android). You can also go directly to the appstore and search for the "Ex Ordo" app. The app is free and the ITherm guide will be downloaded from within this app.
2. The installation process will take a few minutes. Once the app is installed, click the Ex Ordo icon that now appears on your phone screen.
3. Once you have downloaded the app, go to "Find Guides" at the bottom right of the screen. Then to find the ITherm2024 guide, tap on "Have a passphrase" and add the passphrase. Then tap "Download Guide" (above the map) to add the ITherm2024 guide to your app and begin using it.

Passphrase (case-sensitive)
itherm2024

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CONFERENCE EXECUTIVE COMMITTEE

The Executive Committee is made up of past ITherm General Chairs who are willing to assist the conference. It provides the leadership and continuity needed to carry forward the thrust of our Inter Society Conference.

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Prof. Ronald Warzoha, US Naval Academy, USA

LAST YEAR'S BEST PAPERS (ITHERM 2023)

COMPONENT-LEVEL THERMAL MANAGEMENT TRACK

PROF. AVRAM BAR-COHEN BEST PAPER

DIRECT SOLAR-THERMAL FORMATION OF GRAPHITIC HEAT SPREADERS ON ORGANIC SUBSTRATES

Min Jong Kil, Eythan Lam, Mostafa Abuseada, James F. Buckwalter, and Timothy S. Fisher

DOI: 10.1109/ITherm55368.2023.10177667

BEST PAPER – RUNNER UP

MICRO-SCALE JET COOLING: A NUMERICAL STUDY ON IMPROVEMENT OPTIONS

G. Elsinger, H. Oprins, V. Cherman, G. Van der Plas, E. Beyne, and I. De Wolf

DOI: 10.1109/ITherm55368.2023.10177556

SYSTEM-LEVEL THERMAL MANAGEMENT TRACK

PROF. AVRAM BAR-COHEN BEST PAPER

THERMAL AWARE FLOORPLAN OPTIMIZATION OF SOC IN MOBILE PHONE

Youngsang Cho, Heonwoo Kim, Kyoungmin Lee, Yunhyeok Im, Heeseok Lee, & Minkyu Kim

DOI: 10.1109/ITherm55368.2023.10177572

BEST PAPER – RUNNER UP

BI-MODAL THERMAL DESIGN OF A SPACEBORNE ROTORCRAFT AVIONICS UNIT

Christopher D. Kim, Allison M. Orr, and Amelia A. Cherian

DOI: 10.1109/ITherm55368.2023.10177603

EMERGING TECHNOLOGIES AND FUNDAMENTALS TRACK

PROF. AVRAM BAR-COHEN BEST PAPER

EXPERIMENTAL INVESTIGATION OF ULTRA-THIN MICROCHANNEL OSCILLATING HEAT PIPES WITH SUBMILLIMETER-SCALE THICKNESS

Qian Qian, Xin Zhang, Shurong Tian, Justin A. Weibel, and Liang Pan

DOI: 10.1109/ITherm55368.2023.10177622

BEST PAPER – RUNNER UP

THE DESIGN AND DEVELOPMENT OF A SMART MULTILAYER COATING WITH VARIABLE EMISSIVITY CAPABILITY FOR SPACE VEHICLE THERMAL CONTROL SYSTEMS

Juvani Downer, Mehdi Kabir, & Jiajun Xu

DOI: 10.1109/ITherm55368.2023.10177535

MECHANICS AND RELIABILITY TRACK

PROF. AVRAM BAR-COHEN BEST PAPER

INFLUENCE OF THERMAL CYCLING ON DEGRADATION BEHAVIOR OF THERMAL GREASES

Pranay P. Nagrani, Ritwik V. Kulkarni, & Amy M. Marconnet

DOI: 10.1109/ITherm55368.2023.10177495

BEST PAPER – RUNNER UP

MULTISCALE, NON-INTRUSIVE COMPUTATIONAL FRAMEWORK FOR ANALYZING RATE-DEPENDENT DEFORMATION OF SOLDER JOINTS

Sai Sanjit Ganti and Ganesh Subbarayan

DOI: 10.1109/ITherm55368.2023.10177531

KEYNOTES

Keynote Chairs: Justin Weibel (Purdue University) and John Thome (JJ Cooling Innovation SARL)

K-1: CHIPS NAPMP AND CHIPS METROLOGY PROGRAMS

WEDNESDAY, MAY 29, 9:30 AM – 10:30 AM, COLORADO BALLROOM B

David A. LaVan
Program Manager

National Advanced Packaging
Manufacturing Program (NAPMP)

Packaging is evolving from primarily protecting the chip, to complex integration of heterogeneous chiplets. An important aspect of this integration is miniaturization. Substrate feature sizes are shrinking to approach monolithic wiring pitches, the last level via pitches and IP block spacings. Simultaneously, the number and variety of chiplets in the package is increasing to improve performance and functionality. Besides the technology and processes needed to scale down and scale out substrates, there are other difficult issues that need to be addressed: these include power delivery and thermal dissipation, high bandwidth, and potentially active wired, wireless, and photonic connectors to the external world or between subsystems. Finally, to make this vision a reality a chiplet ecosystem needs to be developed with standards that ensure interoperability and cost-effective reuse. Similarly, a comprehensive EDA approach needs to be developed that goes well beyond the electrical abstraction of the system and includes, among other things, thermal and thermomechanical considerations, power delivery, test methodology, metrology, failure analysis, and reliability. The CHIPS NAPMP is developing programs to address these challenges to continue the trend set by Moore's law through advanced packaging and system integration. As devices become more complex, smaller, and multi-layered, the ability to measure, monitor, predict, and ensure quality in manufacturing becomes much more difficult and uncertain. As greater demands are put on semiconductor device performance and material requirements, these challenges will continue to intensify; the CHIPS Metrology Program is developing research programs to address the highest-priority metrology challenges.

Bio: David A. LaVan is a Program Manager in the CHIPS National Advanced Packaging Manufacturing Program (NAPMP). Before joining CHIPS, he was a group leader in the Material Measurement Laboratory at NIST and has worked on the measurement of thermal and mechanical properties of thin films and devices for almost 30 years. He received his B.S. in Materials Science and Engineering from the University of Florida and his Ph.D. in Mechanical Engineering from the Johns Hopkins University; he was a Postdoctoral Fellow at Sandia National Labs and then in the joint MIT and Harvard HST Program. He was a Co-Chair for the 2018 Fall MRS Meeting and Chair for the 2023 NATAS Meeting. He was named to the National Academies Frontiers of Engineering in 2006 and awarded a Department of Commerce Bronze Medal in 2018.

K-2: Multiscale Thermal Modeling of Electric Vehicle Batteries from Nanoscale Electrodes to Battery Pack Cooling Systems: Illustration of DeepEDH Neural Network-based Optimization of Battery Cold Plates

THURSDAY, MAY 30, 9:30 AM – 10:30 AM, COLORADO BALLROOM B

Cristina Amon
Alumni Distinguished Professor and Dean Emerita of the Faculty of Applied Science and Engineering

University of Toronto

This presentation will focus on thermal-related issues of Lithium-ion batteries in electric vehicles (EV), beginning with a brief overview of current thermal challenges. We will describe our group's research activities of multiscale multiphysics thermal modeling from electrodes to cells, modules and battery packs, spanning up to six orders of magnitude, including temperature effects on electrode and cell degradation, thermophysical cell characterization, and thermal runaway. This keynote will also present our surrogate modeling methodology based on modular deep convolutional encoder-decoder hierarchical (DeepEDH) neural network architectures for computationally intensive conjugate heat transfer. We will illustrate the DeepEDH methodology for analyzing and optimizing EV battery thermal management pin-fin cold plate systems.

Bio: Cristina Amon is Professor, Alumni Distinguished Professor and Dean Emerita of the Faculty of Applied Science and Engineering at the University of Toronto (UofT). She is the Scientific Director of the UofT's Electrification Hub and Director of the ATOMS Laboratory. Prior to joining UofT in 2006, she was the Raymond J. Lane Distinguished Professor and Director of the Institute for Complex Engineered at Carnegie Mellon University. She has pioneered the field of Computational Fluid Dynamics and the development of multidisciplinary multiscale hierarchical modelling, concurrent design and optimization methodologies for thermo-fluid transport phenomena, with applications to renewable energy, biomedical devices, and thermal management of electronics and electric vehicles.

Professor Amon was appointed to the Order of Canada and inducted into the Canadian Academy of Engineering, Royal Society of Canada, Hispanic Engineer Hall of Fame, Spanish Royal Academy and National Academy of Engineering. She is a fellow of all the technical societies in her field, including AAAS, ASME, ASEE, and IEEE, was recognized with the 2021 Richard Chu ITherm Award for excellence in Thermal and Thermo-Mechanical Management of Electronics, and received the highest honor for Engineers in Canada (2020 Engineers Canada Gold Medal) and Ontario (2015 PEO Gold Medal) for outstanding engineering public service, technical excellence and professional leadership.

Cristina Amon is the founding chair of the Global Engineering Deans Council and has served in numerous editorial and technical conference leadership roles, advisory and review boards in North America and abroad. She was the ITherm General Chair in 2002 and has been the co-organizer and founding chair of the ECTC-ITherm Diversity Panel since its inception in 2017. She received her Mechanical Engineering degree from Simon Bolivar University in Venezuela, and her M.S. and Sc.D. from the Massachusetts Institute of Technology.

K-3: How Generative AI and Accelerated Compute is Creating the Next generation Liquid Cooled Data Centers with focus on Challenges, Opportunities and the Road Ahead

FRIDAY, MAY 31, 9:30 AM – 10:30 AM, COLORADO BALLROOM B

Ali Heydari
Distinguished Engineer and
Data Center Technologist

NVIDIA

As NVIDIA continues to push the boundaries of high-performance computing, managing escalating power densities in data centers has become a crucial challenge. This keynote addresses the significant shift towards racks with power densities approaching 100 kW and the critical role of advanced liquid cooling systems in sustaining these high-density environments. We will delve into the implementation of both single-phase liquid and two-phase pumped refrigeration cooling techniques, examining their effectiveness in optimizing Power Usage Effectiveness (PUE) and reducing Total Cost of Ownership (TCO). The presentation will highlight the transformative impact these cooling solutions have on enhancing energy efficiency and operational sustainability in modern data centers. Attendees will gain insight into the challenges and innovations shaping the future of data center infrastructure, poised to support the intensive requirements of high-performance computing. Additionally, the talk will delve into the role of NVIDIA Omniverse in creating physics-informed digital twins of data centers. This platform facilitates accurate simulations and real-time analytics, enabling data center operators to predictively model and optimize energy consumption and cooling efficiency across their facilities. By leveraging Omniverse, NVIDIA is setting a new standard in data center design and management, marrying high computational performance with environmental sustainability. Attendees will gain valuable insights into the strategic implementations that are shaping the future infrastructure of data centers, poised to meet the demanding requirements of next-generation technologies.

Bio: Ali Heydari is a Distinguished Engineer and Data Center Technologist at Nvidia in charge of all data center cooling technology development at Nvidia. He has 20+ years of experience in the design and deployment of high-performance servers and DCs, including some of the largest in existence, involving hardware, software, infrastructure, efficiency, reliability, manufacturing, and deployment. He has extensive experience with customized high-performance systems as well as the deployment of energy efficiency measures in low, medium, and high-volume operations.

RICHARD CHU ITHERM AWARD FOR EXCELLENCE

REACTION-DIFFUSION PROBLEMS IN ADVANCED PACKAGING

AWARD LUNCHEON TALK, WEDNESDAY, MAY 29, 12:30 PM – 2:00 PM, COLORADO BALLROOM C-D

2024 Richard Chu ITherm Awardee

Prof. Ganesh Subbarayan
James G. Dwyer Professor of Mechanical Engineering

Purdue University

Reaction-diffusion phenomena such as electromigration, intermetallic compound (IMC) formation, phase segregation, and corrosion can significantly impact the reliability of interconnects in 2.5D and 3D packages. As the interconnects approach micron length scales, surface diffusion becomes a critical mechanism contributing to the observed failure phenomena in these structures. Therefore, it is essential to develop length scale appropriate governing theories, experimental techniques, and simulation methodologies that can capture the complex multiphysics interactions including surface diffusion. This presentation will provide an overview of recent work by the senior author and co-workers on these topics. We will describe a general continuum thermodynamics theory governing interfacial phenomena, and its specialization for reaction-diffusion problems. This will then be followed by Blech-inspired test structures to characterize the capping layer influence on electromigration void growth rate in circuit lines, as well as its extension to In-Line test structures for characterizing electromigration caused voiding and phase segregation in solder microbumps. We connect the theory with the electromigration experiments for the inverse calculation of adhesion energies of circuit lines to capping layers as well as for estimating diffusivities of Bi in SnBi solder joints. We will follow the experimental observations with an overview of phase field and Enriched Isogeometric Analysis (EIGA) simulation methodologies to solve the governing equations on complex geometrical domains. The experimental observations are explained using the simulation results. Finally, potential areas for future research in interconnect reliability modeling and characterization are discussed.

Bio: Ganesh Subbarayan is the James G. Dwyer Professor of Mechanical Engineering at Purdue University and the Co-Director of the Purdue-Binghamton SRC Center for Heterogeneous Integration Research in Packaging (CHIRP). He also serves as the Director of the recently created Atalla Institute for Advanced System Integration and Packaging (ASIP) at Purdue University. He began his professional career at IBM Corporation (1990-1993). He holds a B.Tech degree in Mechanical Engineering (1985) from the Indian Institute of Technology, Madras and a Direct Ph. D. (1991) in Mechanical Engineering from Cornell University. Dr. Subbarayan's research is broadly concerned with modeling and experimentally characterizing failure in microelectronic devices and assemblies. He was a pioneer in using geometric models directly for analysis, popularly referred to as Isogeometric Analysis. Among others, Dr. Subbarayan received the 2022 SRC Technical Excellence Award, 2005 Excellence in Mechanics Award from the ASME Electronics and Photonics Packaging Division and the NSF CAREER award. He is a Fellow of ASME as well as IEEE, and he served as the Editor-in-Chief of IEEE Transactions on Advanced Packaging during 2002-2010.

PROFESSIONAL DEVELOPMENT COURSES

A set of 16 Professional Development Courses (PDCs) are being offered as a collaboration between ITherm and ECTC conferences. Each of these courses are presented by world-class experts, enabling participants to broaden their technical knowledge base. All PDC courses will be held on Tuesday, May 28, 2024, the first day of the ITherm and ECTC conferences. A separate registration fee is required to attend these courses, and the PDC course registration can be performed at the ECTC registration website: https://www.ectc.net/registration/ or at the ECTC registration desk.

MORNING COURSES 8:00 AM – 12:00 PM

1. High Reliability Soldering in Semiconductor Packaging
COURSE LEADER: NING-CHENG LEE – SHINEPURE HI-TECH

2. Photonic Technologies for Communication, Sensing, and Displays
COURSE LEADER: TORSTEN WIPIEJEWSKI, Huawei Technologies

3. From Wafer to Panel Level Packaging
COURSE LEADERS: TANJA BRAUN AND PIOTR MACKOWIAK – FRAUNHOFER IZM

4. Eliminating Failure Mechanisms in Advanced Packages
COURSE LEADER: DARVIN EDWARDS – EDWARDS ENTERPRISES

5. Navigating Thermal and Reliability Challenges in Chip Components for Automotive High-Performance Compute Systems
COURSE LEADER: FEN CHEN -- AUTOMOTIVE RELIABILITY/VALIDATION CONSULTATION SERVICES

6. Polymers for Advanced Packaging
COURSE LEADER: JEFFREY GOTRO –INNOCENTRIX, LLC

7. Flip Chip Technologies
COURSE LEADER: SHENGMIN WEN – HAISEMI, INC.

8. Reliable Integrated Thermal Packaging for Power Electronics
COURSE LEADER: PATRICK MCCLUSKEY – UNIVERSITY OF MARYLAND

AFTERNOON COURSES 1:30 PM – 5:30 PM

9. Additive Flexible Hybrid Electronics – Manufacturing and Reliability
COURSE LEADER: PRADEEP LALL – AUBURN UNIVERSITY

10. Fundamentals of RF Design and Fabrication Processes of Fan-Out Wafer/Panel Level and Advanced RF Packages
COURSE LEADERS: IVAN NDIP – FRAUNHOFER IZM/BRANDENBURG UNIVERSITY OF TECHNOLOGY AND MARKUS WÖHRMANN – FRAUNHOFER IZM

11. Advanced Packaging – Fan-Out, Chiplet, and Heterogeneous Integration
COURSE LEADER: JOHN LAU – UNIMICRON

12. Analysis of Fracture and Delamination in Microelectronic Packages
COURSE LEADER: ANDREW TAY - NATIONAL UNIVERSITY OF SINGAPORE

13. Advanced Packaging for MEMS and Sensors
COURSE LEADER: HORST THEUSS – INFINEON TECHNOLOGIES AG

14. Nano Materials and Polymer Composites for Electronic Packaging
COURSE LEADERS: C.P. WONG – GEORGIA TECH AND DANIEL LU – HENKEL CORPORATION

15. Design-On-Simulation for Advanced Packaging Reliability and Life Prediction
COURSE LEADERS: KUO-NING CHIANG – NATIONAL TSING HUA UNIVERSITY AND XUEJUN FAN – LAMAR UNIVERSITY

16. Thermal Spreading and Contact Resistance
COURSE LEADERS: YURI MUZYCHKA – MEMORIAL UNIVERSITY OF NEWFOUNDLAND AND MARC HODES – TUFTS UNIVERSITY

HETEROGENEOUS INTEGRATION ROADMAP (HIR) SPECIAL SESSIONS

TUESDAY, MAY 28, 8:00 AM – 5:30PM, AURORA D (ECTC, LEVEL 2)

Chairs: Ravi Mahajan (Intel Corporation) and **William Chen (ASE)**

- Engineering Chiplets for the AI Era
- Challenges and Innovations in Thermal Engineering from Fan-out to 2.5D and 3D Stacking
- Packaging Challenges and Innovation for Future Communication Systems
- CHIPS Act Roundtable Chat

YOUNG PROFESSIONALS NETWORKING PANEL

TUESDAY, MAY 28, 7:00 – 7:45 PM, AURORA D (ECTC LEVEL 2)

Chairs: Aakrati Jain (IBM), Rui Chen (Eastern Michigan University) and Zhangming Zhou (Auburn)

Join us for an invaluable opportunity to connect with industry leaders and fellow emerging talents! Tailored specifically for young professionals, including current graduate students, this event is crafted with your needs in mind. Engage in dynamic interactions with senior EPS members and professionals through a series of active and engaging activities. Seize the chance to delve deeper into packaging-related topics, pose career questions, and connect with industry professionals for a valuable learning experience

ECTC/ITHERM DIVERSITY & CAREER GROWTH PANEL AND RECEPTION

EFFECTIVE PRACTICES TO ATTRACT, PROMOTE AND RETAIN A DIVERSE WORKFORCE

WEDNESDAY, MAY 29, 6:30 – 7:30 PM, AURORA A (ECTC, LEVEL 2)

Chairs: Cristina Amon (University of Toronto) and **Vidya Jarayam (Intel Corporation)**

Semiconductor, electronic packaging and energy-related companies are planning to grow their workforces to meet the current and expected demands due to policy incentives and domestic investments, including the CHIPS Act. To achieve business and economic success, we will need to attract a broader group of students to the relevant fields and expand beyond the traditional pool of candidates to include women and underrepresented minorities from rural candidates to veterans and mid-career retrainees. This panel will focus on how best practices in Diversity, Equity and Inclusion have been implemented and can be used to attract students and hire, develop, promote and retain employees within organizations to meet their goals.

The panelists will introduce some of the challenges faced by women, minorities, and underrepresented groups, as well as share their organization's strategies for professional development, promotion, retention, and success. This will be followed by an interactive Q&A with the audience. After the panel session, a social and networking reception will be held. All ECTC and ITherm attendees are invited to join in on this engaging discussion and the reception afterwards.

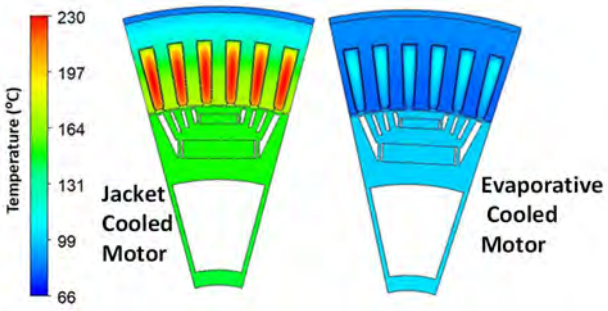
Panelists:

Kylie Patterson NIST-CHIPS Program Office	**Allyson Stewart** Marvell Inc.	**Al Ortega** Villanova University
Tina Herrera NREL	**Margaret Kindling** SEMI Foundation	**Ravi Mahajan** Intel Corporation

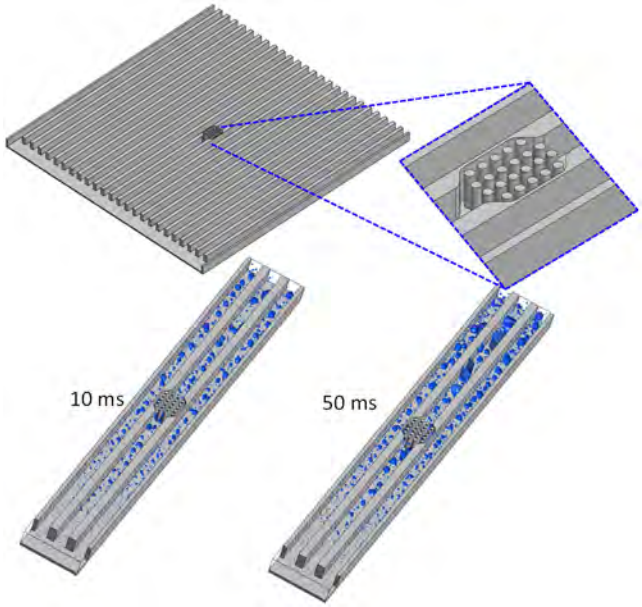
Georgia Tech College of Engineering
George W. Woodruff School of Mechanical Engineering

Micro Nano Devices and Systems Lab (MiNDS)

https://sites.gatech.edu/minds/



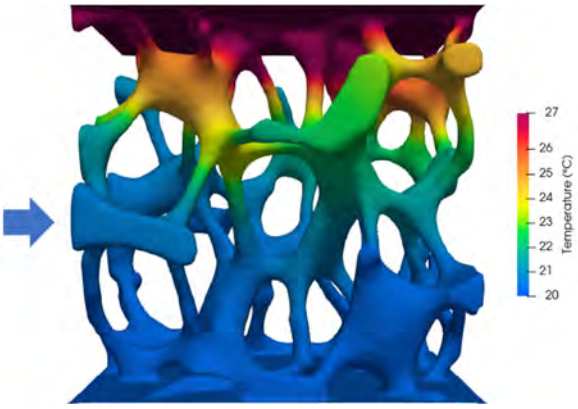
Electro-thermal co-design of electric motors.



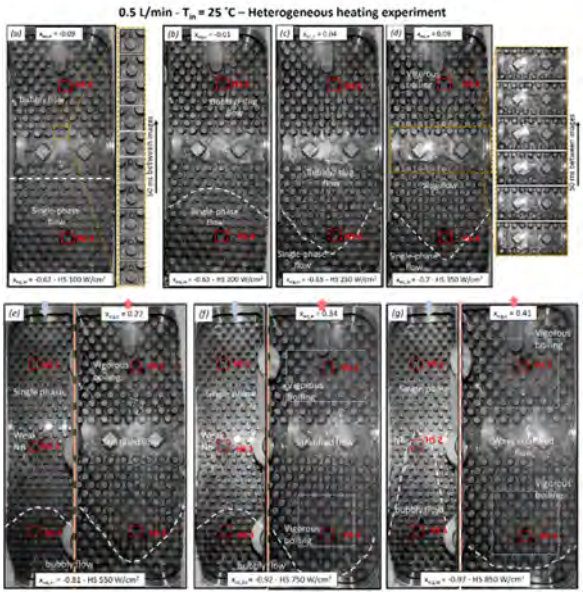
Top: Hybrid microchannel pin-fin heat sink. Bottom: Spatial vapor distribution at different time instants from CFD simulations. Flowrate: 0.06 L/min, and hot spot heat flux: 120 W/cm^2.

Microelectronics and Emerging Technologies Thermal Lab (METTL)

https://mettl.gatech.edu/



Temperature distribution on a ε = 0.879 porosity metal foam exposed to a constant heat flux.



Visualization of the two-phase flow regimes at a 8.3 cm^3/s (0.5 L/min) flowrate, (a) 100 W/cm^2, (b) 200W/cm^2, (c) 250W/cm^2, (d) 350 W/cm^2, (e) 550 W/cm^2, (f) 750 W/cm^2, and (g) 850W/cm^2.

STUDENT HEAT SINK DESIGN CHALLENGE

WEDNESDAY, MAY 29, 5:30 – 6:30 PM, HOMESTEAD 2

The Student Heat Sink Design Challenge is a team competition in which students design, analyze, and optimize an additively manufactured, stainless steel heat sink to cool a constant heat flux power electronics module subject to natural convection. The design from each student team is then evaluated based on a series of design and manufacturing criteria. The teams having the most effective and creative designs had the opportunity to test their design using the additive manufacturing facilities at GE and using state-of-the-art test equipment at the University of Southern Denmark in the lab of Prof. Joe Alexandersen.

Event Sponsorship provided by: TOYOTA

Additive Manufacturing supported by:

SCALE

Scalable Asymmetric Lifecycle Engagement

Developing the U.S. Defense Microelectronics Workforce

Scalable Asymmetric Lifestyle Engagement (SCALE) is the preeminent U.S. program for semiconductor workforce development in the defense sector. The Department of Defense and Naval Surface Warfare Center – Crane Division (NSWC Crane), in partnership with leading colleges and universities have joined forces to offer a program to train highly skilled microelectronics engineers, hardware designers, and manufacturing experts who will help ensure our national security for years to come.

Technical Areas

SCALE students gain expertise and hands-on experience with current and future technology demands, ensuring U.S. prowess in building the domestic semiconductor industrial base and the critical infrastructure and national defense applications it supports.

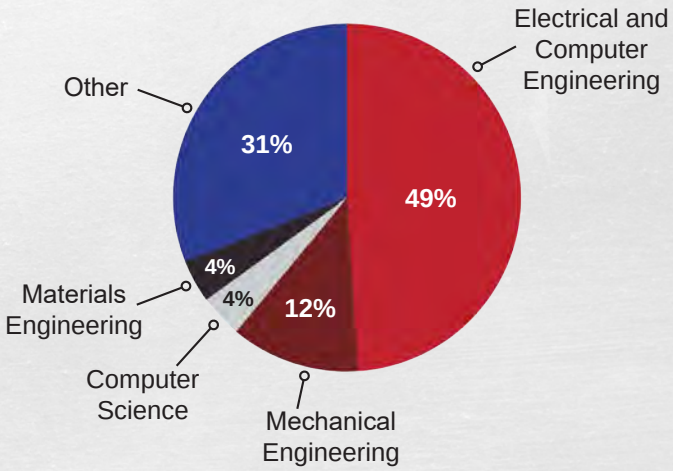
- Radiation-Hardening (RH)
- Radiofrequency and Optoelectronics (RFOE)
- Supply Chain Awareness (SCA)
- Trusted Artificial Intelligence (TAI)
- Heterogeneous Integration Advanced Packaging (HIAP)
- System on a Chip (SOC)

For questions on HIAP, reach out to Prof. Amy Marconnet, co-director of the HIAP thrust, at Marconnet@purdue.edu

Stats

- 500+ active students currently enrolled in the SCALE Program
- 250 SCALE alumni
- 21 universities partners
- 33 industrial partners
- 15 government partners

Nearly 50% of SCALE students are studying **electrical and computer engineering** due to SCALE's microelectronics focus, however the other 50% of students come from a **broad range of over 15 majors**, highlighting the opportunity SCALE provides STEM students across a wide range of fields.



To learn more about SCALE, visit www.nanohub.org/groups/scale or email SCALE@purdue.edu

FEDERAL FUNDING LANDSCAPE PANEL

THURSDAY, MAY 30, 4:00 – 5:30PM, RED ROCK 10-11

Session Chairs: Patrick Shamberger (Texas A&M University), Sreekant Narumanchi (NREL), and **Satish Kumar (Georgia Tech)**

The federal funding landscape panel provides a platform to engage with program managers of different government agencies and learn better about their programs. In this workshop, program managers will describe their programs and the successes that have come out of them, as well as directions moving forwards.

ARPA-E FUNDING MOONSHOT ENERGY TECHNOLOGIES

Peter de Bock & Zachary Berquist
ARPA-E

Abstract: The Advanced Research Projects Agency – Energy was founded to support high-risk/high-reward technologies that could lead to transformational impact in the energy space. The ARPA-E COOLERCHIPS program supports $42M in research to advance the efficiency and capability of cooling systems for future AI and high power chipsets targeting over transformational reduction in cooling energy use. A variety of technical approaches are explored to achieve this mission.

Bio: Dr. Peter de Bock currently serves as Program Director at the Advanced Research Projects Agency-Energy (ARPA-E) for the US Department of Energy. At ARPA-E Dr. de Bock developed the COOLERCHIPS program focused on making a transformational leap in efficiency of cooling of Data Centers. In addition, Dr. de Bock leads and developed the ASCEND and PRE-TRAILS programs to realize a future of sustainable aviation. Prior to joining ARPA-E, Dr. de Bock worked at GE Research as Principal Engineer ThermoSciences. Dr. de Bock is the former chair of ASME K-16 committee on Heat Transfer in Electronics equipment, ASME Fellow, AIAA member and holds 50+ patents and publications. Dr. de Bock received his Ph.D. in Mechanical Engineering from the University of Cincinnati and holds MSc degrees from University of Twente in the Netherlands, and University of Warwick in the United Kingdom.

Bio: Dr. Zachary Berquist currently serves as an ARPA-E Fellow. His interests include carbon removal, industrial heat decarbonization, thermal management, and next-generation battery technologies. Dr. Berquist received his Ph.D. in Chemical Engineering from the University of Michigan in September 2022. His doctoral thesis focused on the development of high-temperature aerogels as transparent insulation for concentrating solar thermal. Dr. Berquist also holds a B.S. in Chemical Engineering from the Pennsylvania State University where he researched the hydrothermal liquefaction of food waste as a source of renewable fuel. During his Ph.D., Dr. Berquist interned at Sandia National Laboratories in the summer of 2021 where he worked at the National Solar Thermal Testing Facility on thermochemical air separation. Prior to joining ARPA-E, he worked as a postdoctoral researcher at the National Renewable Energy Laboratory where he analyzed lithium battery interfaces with X-ray photoelectron spectroscopy.

MICROSYSTEMS THERMAL MANAGEMENT AND MODELING INITIATIVES AT DARPA

Yogendra Joshi
DARPA

Abstract: DARPA has supported advances in thermal management technologies for more than three decades. Current efforts in three-dimensional heterogeneous integration, and radio-frequency devices thermal management will be summarized. Continued path of Moore's Law is resulting in deeply scaled Complementary Metal-Oxide-Semiconductor transistors, with nanometer sized features. Thermal transport prediction in these remains a key challenge, and ongoing efforts on this topic will be summarized.

Bio: Dr. Yogendra Joshi Dr. Yogendra Joshi joined DARPA in July 2022 as a program manager in the Microsystems Technology Office (MTO). He is a professor and the John M. McKenney and Warren D. Shiver Distinguished Chair at Georgia Institute of Technology's G.W. Woodruff School of Mechanical Engineering. In addition, he has a courtesy appointment at Georgia Tech's School of Electrical and Computer Engineering. His research interests are in multi-scale thermal management. Joshi is the author or co-author of more than 450 publications in this area, including more than 225 journal articles. He received his Bachelor of Technology in mechanical engineering from the Indian Institute of Technology (Kanpur) in 1979, Master of Science in mechanical engineering from the State University of New York at Buffalo in 1981, and doctorate in mechanical engineering and applied mechanics from the University of Pennsylvania in 1984. He has served as the principal investigator for multiple DARPA programs and for the Office of Naval Research-led Consortium for Optimally Resource-Secure Outposts. He also previously was site director for the National Science Foundation Industry/University Cooperative Research Center on Energy Efficient Electronic Systems. Joshi is an elected fellow of the American Society of Mechanical Engineers (ASME), the American Association for the Advancement of Science, and IEEE. He's been recognized for his contributions through several awards, including the Inventor Recognition Award from the Semiconductor Research Corporation (2001), the IBM Faculty Award (2008), the IIT Kanpur Distinguished Alumnus Award (2011), the AIChE Donald Q. Kern Award (2018), and multiple honors from IEEE and ASME.

NATIONAL SCIENCE FOUNDATION: "TO LEAD THE WORLD IN SCIENCE AND ENGINEERING RESEARCH AND INNOVATION…"

Sumanta Acharya
NSF

Abstract: National Science Foundation (NSF) invests in basic research and people to create knowledge and transform the future in diverse areas such as national health, industrial and manufacturing economy, national defense and others. The Thermal Transport Processes (TTP) program is housed in the Chemical, Bioengineering, Environmental and Transport Division in the Engineering Directorate. The TTP program supports use-inspired research that contributes to fundamental understanding of thermal transport phenomena, and innovations in enhancing heat transport and properties across all scales (from atomistic to macro). Proposed research should contribute to basic scientific understanding via experiments, theoretical developments, and computational discovery. Priority is given to insightful and innovative investigations of fundamental thermal transport problems with clearly defined end-use applications.

Bio: Dr. Sumanta Acharya currently serves as the Program Director of the Thermal Transport Processes (TTP) program where he manages the proposal submission and research supported by NSF in the area of thermal sciences. He is also a Professor in the Mechanical, Materials and Aerospace Engineering (MMAE) Department at the Illinois Institute of Technology (IIT) in Chicago where he previously served as the Department Chair from 2016-2022. His primary areas of research include gas turbine heat transfer and combustion, and thermal management of heat-exchange systems in the power-plant and electronic industries. He has published/presented nearly 500 technical articles in archival journals and refereed conferences. In recognition of his research, he was awarded the ASME Heat Transfer Memorial Award in the Science category, the AIChE Donald Q Kern Award for achievements in heat transfer, and the AIAA Thermophysics Award. He was previously the Chair of the ASME Heat Transfer Division. He is a Fellow of the ASME (American Society of Mechanical Engineers) and ASTFE (American Society of Thermal and Fluids Engineers).

DOE\AMMTO Funding Landscape and Future Needs

Tina Kaarsberg
AMMTO

Abstract: In this federal funding panel, Dr. Kaarsberg will provide an overview of the U.S. Department of Energy's new—since Fall 2022—Advanced Materials and Manufacturing Technologies Office (AMMTO). She will begin by describing the myriad AMMTO program areas that are relevant to this conference. In AMMTO, electronics are considered key platform technologies—along with battery manufacturing technologies-- for the Clean Energy Transition. They also are the key to near term deployment needed to prevent potentially unsustainable increases in electricity use. Dr. Kaarsberg then will present on three roadmap/strategy efforts that involved numerous other DOE offices as well as external partners—including the IEEE. The oldest is DOE's Conductivity enhanced materials for Affordable Breakthrough Leapfrog Electric and thermal applications (CABLE) which—though originally conceived for bulk applications on the grid and in transport—has had numerous proposals for electronics applications for advanced packaging and thermal management. Next is DOE's microelectronics Energy Efficiency Scaling for 2 Decades (EES2) initiative, which IEEE formally joined in January 2024. Version 1.0 of the EES2 R&D Roadmap—expected to be released at end of May 2024 for public comment—includes a chapter on Advanced Packaging and Heterogeneous Integration and its Power and Control electronics includes discussion of on-chip power. She also will present on AMMTO's Power Electronics Roadmap which has an expected July 2024 release. She also hoping to learn more about thermomechanical phenomena for which materials and manufacturing research is needed and also to recruit more industry, academic and professional society partners for CABLE, EES2 and AMMTO Power Electronic innovation ecosystems and to discuss potential new partnerships in the micro-manufacturing space that is relevant to electronics and other CET platform materials and manufacturing technologies.

Bio: Dr. Kaarsberg is a physicist and an experienced R&D manager, as well as an R&D, climate and energy efficiency policy expert. As technology manager at the Department of Energy's (DOE) advanced materials and manufacturing technologies office (AMMTO), she is the lead for the semiconductors (microelectronics and power electronics). In this capacity, she leads DOE's microelectronics Energy Efficiency Scaling (EES2) initiative that has enlisted 49 organizations to date to sign the EES2 pledge and participate in the EES2 RD&D Roadmap. She has more than 20 years of experience across DOE in facilitating technology commercialization through its small business programs and in overseeing projects in the power sector, distributed Power, and in the geothermal, buildings and manufacturing technology offices. Dr. Kaarsberg has published or contributed to more than 50 technical papers and book chapters including Nature publication, technical reports, roadmaps, and government documents. Tina has an undergraduate degree from Yale University, an MA in physics from Cornell, and a PhD from Stony Brook University.

STUDENT POSTER SESSION

THURSDAY, MAY 30, 5:30 – 7:00 PM, COLORADO BALLROOM B

Students get the opportunity to present their research and interact with other conference attendees from industry and academia during the Student Poster and Networking Session. They can also distribute resumes and get connected to industrial representatives. Outstanding posters will be selected for awards and will be judged based on technical merit, clarity and self-sufficiency of the content, novelty and originality of the work, overall impact of the poster display, and oral presentation at the poster session.

LIST OF STUDENT POSTERS

COMPONENT-LEVEL THERMAL MANAGEMENT

Poster	Student Name	School	Paper	Paper Title
1	Shanmukhi Sripada	Purdue University	14	Thermal Characterization of Contemporary Electrical Insulation Materials
2	Akshat Patel	Purdue university	51	Heat Transfer Enhancement for Direct-on-Chip Microscale Impingement Jet Cooling with Alternating Feeding and Draining Jets using Variable Micro Pin Fins
3	Zhengda Yao	University of Maryland	69	Hydraulic Performance Analysis of an Additively Manufactured Multipass Microchannel Heat Exchanger
4	Amitav Tikadar	Georgia Institute of Technology	74	Performance Assessment of Hybrid Microchannel-Pin Fin Heat Sink for Hotspot Thermal Management Under Flow Boiling Conditions
5	Georg Elsinger	KU Leuven	102	Enhancement of Direct Liquid Jet Impingement Cooling through Laser-Fabricated Micro Pin-Fins on the Chip-Backside
6	G.Keerthi Sree Gnanavel	Anna University	125	Thermal behavior of lattice structured heat sink for electronic cooling applications

7	Zekun Wu	Purdue University	149	Modeling of Backside Power Delivery and Thermal Management in Semiconductor Die Packages
8	Ryan Regan	Purdue University	317	Thermal Characterization of Two-Phase Cooling using Embedded Microchannels in a High Current Density Electric Motor

SYSTEM-LEVEL THERMAL MANAGEMENT

Poster	Student Name	School	Paper	Paper Title
9	Mingeun Choi	Georgia Institute of Technology	53	Thermal Analysis of High Current Vertical Power Delivery Network with Embedded Microchannel Cooling
10	Mason Pratt	University of Utah	110	Thermal Management of Omnimagnet for Space Debris Mitigation
11	Demetrius Gulewicz	Purdue University	132	Closed-loop Analysis of Thermal Energy Storage Device Arrangement in a Thermal Management System
12	Meghavin Bhatasana	Purdue University	412	Design and Characterization of a Thermal Test Vehicle with Embedded Phase Change Material
13	Maharshi Shukla	Rochester Institute of Technology	414	Novel Subcooled Boiling Chamber With Submerged Condensation for High Heat Flux Removal for Data Center Application

MECHANICS & RELIABILITY

Poster	Student Name	School	Paper	Paper Title
14	Qais Qasaimeh	Auburn University	21	Interpretable Machine Learning Models Can Outperform Statistical Models in Solder Joint Reliability
15	Pranay Nagrani	Purdue University	48	Accelerated Testing to Study Thermal Grease Degradation Behavior
16	Sergio Bolanos	Auburn University	130	The Effect of Bi Content and Strain Rate on Tensile Properties of SnAgCu-Bi Alloys
17	Waad Tarman	Auburn University	148	Evaluating Shear Properties of Individual Solder Joints in Ball Grid Arrays: The Impact of Ag and Bi Content
18	Palash Vyas	Auburn University	168	Drop Shock Testing of BGA Test Vehicles at Elevated Temperature
19	Shaheen Pouya	Auburn University	177	Shear Strength Analysis of Aging SAC-Bi Solder Joints with Different Solder Paste Volumes

20	Kaiying Jiang	Stanford University	186	Pool Boiling Reliability Tests and Degradation Mechanisms of Microporous Copper Inverse (CuIOs) Structures
21	Abdallah Alakayleh	Auburn University	192	Microhardness Analysis of Reflowed Solder Joints: Effect of Paste Alloy and Paste Volume
22	Saddam Daradkeh	Auburn University	196	Aging Effect on Drop-Shock Reliability of SnAgCu305 Solder Alloy
23	Seyed Soroosh Alavi	Auburn University	219	Evaluating the Efficiency of Machine Learning Approaches for Predicting Solder Joint Characteristic Life under Isothermal Aging and Thermal Cycling Test Conditions
24	Whit Vinson	University of Arkansas	309	Altering Electromigration Response in Aluminum Wire Bonds through Heat Treatment
25	Aathi Raja Ram Pandurangan	Auburn University	320	Prediction of Failure at FCBGA Interfaces under Thermo-Mechanical Loads Using a Competing Risk Cohesive Zone Model
26	Madhu Kasturi	Auburn University	329	Thermal Conductivity and Interface Strength Evolution of TIM-Copper with Temperature and Humidity Conditioning
27	Padmanava Choudhury	Auburn University	349	Development and Performance Evaluation of Thermoformed In-Mold Gravure Offset Printed Band-Pass Filters due to Thermal Cycling
28	Mahbub Alam Maruf	Auburn University	354	Effects of Combined Isothermal Aging and Mechanical Cycling Exposures on the Mechanical Behavior of Lead-Free Solder Alloys
29	Vishal Arvindbhai Mehta	Auburn University	365	Investigation of the Effects of Sustained High-Temperature on the Reliability of Lead-Free Solder Joint Assemblies in Vibration
30	Yunli Zhang	Auburn University	366	Investigation of Fatigue performance for Bulk EMCs in sustained high temperature environment up to 1 year aging
31	Debabrata Mondal	Auburn University	373	Prediction of the Mechanical Responses of Single Grain Lead-Free Solder Joints Using Machine Learning
32	Golam Rakib Mazumder	Auburn University	379	Characterization of the Mechanical Response and Microstructure of iSAC Lead-Free Solder
33	Souvik Chakraborty	Auburn University	388	Modeling of the Temperature Cycling Performance of BGA Packages with Hybrid SAC/LTS Joints and Various Bi Concentration Gradients

EMERGING TECHNOLOGIES & FUNDAMENTALS

Poster	Student Name	School	Paper	Paper Title
34	Alexander Ceperley	Purdue University	40	Characterization of Enhanced Two-Phase Jet Impingement on Femtosecond Laser Surface Processed (FLSP) Aluminum Surfaces
35	Feifan Xie	Purdue University	64	Direct-On-Chip Hot Spot Targeted Microjet Cooling for 2.5D Interposer-Based Packaging with Groq Language Processing Unit (LPU) and HBM for Ultra-fast Inference at Scale
36	Trevor Whitaker	University of Utah	79	Modification of Flow Boiling Regimes and Mechanisms in Near-Critical Flows
37	Yujui Lin	Stanford University	82	The Impact of Liquid Supply Packaging Solution on the Thermal Performance of a Capillary-based Two-phase Copper Microchannel Cooler for High Heat Flux Power Electronics Cooling Applications
38	Suhas Tamvada	University of Florida	120	Unveiling the Dual Limits of Critical Heat Flux and Implications for Immersion Cooling
39	Qian Qian	Purdue University	128	An unsteady homogeneous two-phase flow model for microchannel oscillating heat pipes
40	Angie Rojas Cardenas	Purdue University	165	Liquid Metal Concentration Effects on Thermal and Mechanical Properties in Elastomers
41	Geeta Pokhrel	Purdue University	166	Industrially relevant processing of thermoplastic elastomer composites for thermal interface materials
42	Md. Jubayer Hossain	Georgia Institute of Technology	206	Investigation of Flow and Thermal Performance in a Non-uniform Channel Pulsating Heat Pipe Additively Manufactured from High-temperature Resin
43	FNU Gutta Prudhvi Reddy	University of California - Davis	294	Assessment of bubble pump model for fluid directional motion from asymmetric heated ratchets
44	Jacek Nazdrowicz	Lodz University of Technology	299	Important factors in the design of systems containing a MEMS sensor and ASIC in relation to a variable temperature environment.
45	Daniel Karakitie	Auburn University	323	Repairability Of Additively Printed Circuits Using Sustainable Aqueous-Based Silver Nanoparticle Ink on Polyimide Substrates
46	Hyesoo Jang	Auburn University	326	Development Of In-Mold Integration Of Eda Sensors Via Additive Production In Wearables
47	Shriram Kulkarni	Auburn University	345	Screen-Printed Thermoformed Circuits Performance and Reliability under Sustained High Temperatures for In-Mold Electronics
48	Fatahi Musa	Auburn University	347	Impact of Thermal Cycling on In-Mold Flexible Substrates Fabricated via Direct-Write Printing

49	Sabina Bimali	Auburn University	351	Advancing Sustainability in Printed Electronics: Low-Temperature Interconnects and Water-Based Ink Performance
50	MD Golam Sarwar	Auburn University	356	Reliability of Additively Printed In-Mold Electronics Using ECA in Sustained High-Temperature Operation
51	Ved Soni	Auburn University	357	Performance Stability and Reliability of Gravure Offset Printed Thermoformed IME Circuits Subjected to Sustained High Temperature Storage

ELECTRONIC POSTER REVIEWERS

Aakrati Jain	Hitoshi Sakamoto	Leslie Hwang	Shiva Farzinazar
Abdellah Salahouelhadj	Jack Maddox	Lon Stevens	Shreyas Bindiganavale
Alapati Ramakrishna	Jagadeesh Radhakrishnan	Mehdi Asheghi	Sreya Sarkar
Angie Qian	Jinesh Narangaparambil	Meiying Su	Subramanya Sadasiva
Arjang Shahriari	John Ditri	Min Park	Uday Manda
Awni Qasaimeh	John Wilson	Ming-Cheng Cheng	Vaibhav Agrawal
Carlos Da Silva	Joseph Hanson Vazquez	Nitin Karwa	Vibin Shalom Simon
Casey Carte	Joseph Thalakkottor	Ram G. V. Ramaraju	Vinod Chippalkatti
Daewhan Kim	Karthekeyan Sridhar	Rinaldo Miorini	
Fahri Erinc HIZIR	Khan Mohammad Rabbi	Sara Estevez	
Georges Pavlidis	Khashayar Ebrahimi	Seok Pil Jang	

LAST YEAR'S BEST POSTERS (ITHERM 2023)

COMPONENT-LEVEL THERMAL MANAGEMENT TRACK

BEST POSTER	OUTSTANDING POSTER
DYNAMIC MODELING OF A REFRIGERANT-BASED CROSS-FLOW HEAT EXCHANGER FOR CLOSE-COUPLED HYBRID COOLED DATA CENTERS Carol Caceres (Villanova University)	**MICRO-SCALE JET COOLING: A NUMERICAL STUDY ON IMPROVEMENT OPTIONS** Georg Elsinger (KU Leuven)

SYSTEM-LEVEL THERMAL MANAGEMENT TRACK

BEST POSTER	OUTSTANDING POSTER
CONTROL CO-DESIGN OF A THERMAL MANAGEMENT SYSTEM WITH INTEGRATED LATENT THERMAL ENERGY STORAGE AND A LOGIC-BASED CONTROLLER Falak Mandali (Purdue University)	**IMPLEMENTATION OF A TOPOLOGICALLY OPTIMIZED HEAT SINK FOR NON-UNIFORM HEAT FLUXES IN AN EV FAST-CHARGER** Joshua Palumbo (University of Toronto)

EMERGING TECHNOLOGIES AND FUNDAMENTALS TRACK

BEST POSTER	OUTSTANDING POSTER
TEMPERATURE DEPENDENT THERMAL PROPERTIES OF THIN FILM HAFNIUM OXIDE Diego Vaca (Georgia Institute of Technology)	**FEASIBILITY ASSESSMENT OF METROLOGIES FOR THERMAL RESISTANCE CHARACTERIZATION OF DEEPLY BURIED INTERFACES BETWEEN BONDED SILICON LAYERS** Aalok Gaitonde (Purdue University)

MECHANICS AND RELIABILITY TRACK

BEST POSTER	OUTSTANDING POSTER
INFLUENCE OF THERMAL CYCLING ON DEGRADATION BEHAVIOR OF THERMAL GREASES Pranay P. Nagrani (Purdue University)	**IN SITU OPTICAL OBSERVATIONS OF DEGRADATION OF THERMAL GREASES WITH THERMAL CYCLING** Ritwik Vijaykumar Kulkarni (Purdue University)

Smart and Small Thermal Systems Laboratory

PI: Prof. Michael M. Ohadi; University of Maryland

If you can imagine it, we can deliver it!

Contact:
Prof. Michael Ohadi: ohadi@umd.edu; Or
Prof. Amir Shooshtari: amir@umd.edu; Or
Dr. Andres Sarmiento: apsc@umd.edu
Ms.Shwe Htet Htet Aung: shwehtet@umd.edu

Who We Are

S2TS Laboratory at the University of Maryland, College Park, utilizes innovative design/optimization, materials, and manufacturing techniques to introduce next-generation thermal management systems. S2TS R&D areas of focus:

- Advanced heat exchangers for diverse energy conversion applications
- Electronics cooling
- Micro/Nano Systems for process intensification and optimization
- Energy audit and system efficiency and resiliency analysis

Our Recent Projects

Thermal management of 3D Heterogeneous Integration of chips

- Development of highly-efficient manifold micro-channels heat sinks
- Single-phase embedded cooling for high-heat flux electronics

Highly Compact Metallic Heat Exchangers for Extreme Environments

- Development of HX for extreme environments (T = 800 °C and P = 80 bar)
- Highly compact HX enabled by additive manufacturing techniques

Thermal Management of Advanced Electric Propulsion Systems for the Next Generation of Electric Aircraft

- Manifold mini-channels are air-cooled and are highly efficient heat sinks
- Co-designed heat sink into the motor structure

Low Cost and High-Performance Modular Thermal Energy Storage for Building Equipment

- Heatpump-integrated cross-media thermal energy storage system
- Load shifting during peak demand periods for reduction of energy demand

Prefab Modular Liquid Cooled Micro Data Center

- Back of the chip embedded cooling for high heat flux electronics
- Innovative 3D-printed polymer HX with high effective thermal conductivity.

Thermal Management of High Flux Surfaces using Film Evaporation with an Enhanced Fluid Delivery System (FEEDS)

- Development of highly-efficient manifold micro-channels intra-chip heat sinks
- Two-phase embedded cooling for high-heat flux electronics

ML-Enabled Rapid Energy Auditing for Building Clusters

- Custom-developed ML software for performing fast, reliable, and efficient Virtual Energy Audits for Building Cluster.
- Calculates energy use intensity (EUI) and on-site GHG emissions by performing energy benchmarking

Contact Us

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TECHNOLOGY TALKS

TT-1 DATA CENTERS IN 2035

WEDNESDAY, MAY 29, 8:15 – 9:15 AM, RED ROCK 10-11

Session Chair: Naveenan Thiagarajan (GE) and Qian Han (Sorrento Solution)

NREL SUSTAINABLE HPC/DATA CENTER EFFORTS: PAST, PRESENT, AND FUTURE

David Sickinger
NREL

Abstract: The National Renewable Energy Laboratory (NREL) made the move in 2012 to use liquid cooling technologies such as cold plate and immersion in its high-performance computing (HPC) data center. A paradigm-shift mentality has kept NREL's researchers pushing the boundaries of computing – with major objectives involving the responsible stewardship of energy, water, and waste products. Data center heat reuse within the campus, and an innovative thermosyphon cooling system that has saved over 6.5 million gallons of water since 2016 are illustrations of that. Algorithmic energy consumption improvements and measurements, data center efficiency, and the waste cycle of computers and materials are currently being explored. The talk will share a vision on sustainable HPC/data centers of the future.

Bio: David Sickinger is a researcher in the Advanced Computing Operations Group within the Computational Science Center at the National Renewable Energy Laboratory (NREL) located in Golden, Colorado. Since 2012, he has been involved with the operation of the mechanical systems supporting NREL's High Performance Computing data center that currently house the Eagle and Kestrel supercomputers. His research focus is on energy-/water- efficient data center facilities and liquid-cooling technologies. He has a MS degree in mechanical engineering from the University of Arizona. David is a Certified Energy Manager (CEM - from the Association of Energy Engineers) and a Data Center Energy Practitioner – HVAC Specialist (DCEP - from the U.S. Department of Energy).

DATA CENTERS IN 2035 AND BEYOND: DEFUSING JEVON'S PARADOX

Daniel Bizo
Uptime Institute

Abstract: Data center infrastructure presents a multi-layered conundrum. While underpinning disruptive services, they're surprisingly resistant to forces of change themselves; they also remain wasteful with capacity and energy, but performance improvements contribute to even higher resource consumption, also known as Jevon's paradox. Further optimizations of power, cooling and IT systems will unlikely change this trajectory — rather, as the explosive demand for large generative AI models shows, will only accelerate the strain on the environment and supply chains. As growing energy, water and land use will prove to be untenable with the public and policymakers, the data center industry will be forced to radically change its ways. This presentation offers a draft image of what the future of data centers may look like.

Bio: Daniel Bizo, Research Director, Uptime Intelligence, an Uptime Institute Unit. Daniel serves as Research Director at Uptime Institute. Over the past 20 years, he has covered the business and technology of enterprise IT and infrastructure in various roles, the past 13 years as an industry analyst and advisor. His research primarily focuses on data center energy performance, including thermal operation guidelines, liquid cooling and heat rejection, and IT thermal and power management.

DATA CENTER COOLING TECHNOLOGY FOR A SUSTAINABLE FUTURE- ELIMINATION OF WATER USAGE WITH AN END-TO-END PUMPED-2-PHASE (P2P) REFRIGERANT CLOSED LOOP ECOSYSTEM COOLING ARCHITECTURE

Herman Chu
Celestica

Abstract: As data center deployments growing exponentially and increasing power demand of the servers and networking equipment, it is an enormous strain on municipal water supply. The talk will highlight Celestica's efforts in transforming today's single-phase liquid (mainly some form of water mixture) cooling to refrigerant based cooling that can eliminate the complete usage of water in the data center for cooling purposes. We are developing P2P cooling systems to take the heat directly from the chip all the way out to the environment with refrigerant. The talk will highlight the overall architecture, thermal performance advantage and supply base landscape to go to P2P cooling technology, and new refrigerants from being developed for reduced global warming potential.

Bio: Herman Chu is a senior principal engineer at Celestica and manages the thermal engineering team in North America. His passion, since the early 2000, has been in energy efficiency and sustainability for telco space and data centers. He established rack level power density design targets for networking equipment design based upon different parameters, such as global energy consumption and data center cooling performance and efficiency, before the term "Green" was coined for sustainability. He was an early participant in the Telecom industry in defining the metrics for measuring energy efficiency for telco equipment.
Throughout his career, he has been an industry leader in pioneering efforts developing and deploying high performance thermal solutions, such as high-fin density folded/zipper fin heat sink, heat pipe, vapor chamber and pumped-2-phase liquid cooling for commercial computing/networking equipment.

TT-3 QUANTUM COMPUTING - PACKAGING AND THERMAL CONSIDERATIONS

WEDNESDAY, MAY 29, 2:00 – 3:30 PM, RED ROCK 10-11

Session Chair: Georges Pavlidis (University of Connecticut) and Naveenan Thiagarajan (GE)

CHALLENGES AND OPPORTUNITIES IN MK SYSTEM THERMAL MANAGEMENT

Christopher Barrow
Northrup Grumman

Abstract: As interest in and the maturity of superconductive electronics systems grows, more engineering effort is pouring into chip, package, and cryo-system design. Although, the on-chip circuits in these systems are superconducting and dissipate little power, the supporting hardware can be a source of active power dissipation as well as passive heat load from high temperature stages. The extremely low temperature (10s of mK) of operation necessarily implies that relevant thermal conductivities will be reduced by many orders of magnitude, such that mismanagement of even a few uW could cause unacceptable thermal profiles. We review important design considerations for these systems, which include electron-phonon decoupling, superconductivity, phononic thermal transport, interfacial thermal resistance, low-temperature material (bulk & thin-film) properties, and the challenges of verification through low-temperature metrology.

Bio: Christopher is a Principle Thermal Engineer at Northrop Grumman Microelectronics Center, developing thermal models for the next generation of computing. He is completing his Doctorate at the University of Kentucky under Dr. Jack Maddox.

THERMAL AND PACKAGING CONSIDERATIONS FOR TRAPPED ION QUANTUM COMPUTING

Daniel Slichter
National Institute of Standards and Technology (NIST)

Abstract: Atomic ions trapped in ultra-high vacuum are a leading platform for a variety of applications, including quantum computing. The ions are confined by a combination of static and oscillating electric potentials applied to complex electrode structures, which are often microfabricated on chips. Such surface-electrode ion traps can enable scaling to large numbers of trapped ion qubits, as require for quantum computing applications. In addition to the electrodes used to confine and spatially reconfigure the ions, the trap chips can also integrate elements used to control and read out the states of trapped ion qubits, such as current-carrying wires, photonic waveguides, photon detectors, and active electronics such as digital-to-analog converters. Scaling up surface-electrode ion traps, especially those with additional integrated elements, to hold increasing numbers of ion qubits comes with a corresponding increase in dissipated power on chip due to the confining potentials and the control signals, as well as an increase in the number of electrical and optical signals that must be routed to the chip. The trap chip itself is in ultra high vacuum, typically in a cryogenic environment at temperatures near 4 K. In this presentation, I will endeavor to describe the thermal, electrical, and optical packaging challenges that present themselves for larger-scale trapped-ion quantum computing systems.

Bio: Daniel Slichter is a physicist in the Ion Storage Group at NIST in Boulder, Colorado. His research focuses on quantum information experiments with trapped atomic ions, with an emphasis on developing new paradigms for scalable trapped ion quantum computing and creating long-distance quantum networks with trapped ion memory and computation nodes. He received his A.B. in physics (2004) from Harvard University, and his M.A. (2007) and Ph.D. (2011) in physics from the University of California, Berkeley. His Ph.D. research was in the field of superconducting quantum information, where he demonstrated the first continuous high-fidelity measurement of a superconducting qubit, and studied quantum feedback, measurement backaction, and near-quantum-limited parametric amplification. He was the recipient of a Hertz Foundation Fellowship (2006–2011), the Hertz Foundation Thesis Prize (2012), an NRC Postdoctoral Fellowship (2012–2014), a Kavli Fellowship (2016), and the NIST Jacob Rabinow Applied Research Award (2023). He has also served as an Associate Editor for IEEE Transactions on Quantum Engineering (2020-2023). He is a Senior Member of IEEE.

THERMAL BUDGET FOR CRYOGENIC SIGNAL DELIVERY IN SUPERCONDUCTING QUANTUM COMPUTING

Florent Lecocq
National Institute of Standards and Technology (NIST)

Abstract: As superconducting quantum computers steadily increase in complexity, they are outgrowing the cryogenic environment in which they are housed. This realization has sparked brute-force engineering projects aiming at building larger cryostats with higher density wiring. It also motivated the idea of using photonic links to enable the massive delivery of classical signals to ultracryogenic temperatures, or even quantum-coherent links to build a network of processors living in separate cryostats. Here I will review the state-of-the-art, focusing on the delicate balance between wiring heat load and cryostat cooling power.

Bio: Florent Lecocq is a research scientist at the National Institute of Standards and Technology (NIST) in Boulder, in the Advanced Microwave Photonics group. The group focuses on developing technologies for quantum measurements and quantum information science using superconducting circuits. This includes the development of high-speed parametric qubit gates, nonreciprocal parametric amplifiers, microwave opto-mechanical devices and microwave-to-optical interconnects. Florent received his PhD in physics from the University of Grenoble and the Néel Institute before joining NIST in 2011.

IBM Quantum - System Thermal Design

Milnes P. David
IBM

Abstract: Beginning in 2016, IBM has continued to innovate in and develop qubit chip design, quantum system design and scaling, and quantum software, for research and commercial use. This work resulted in Quantum System One, which was unveiled as the first commercial circuit-based quantum system in January 2019. Since that beginning, there are now over 10 utility-scale quantum systems deployed worldwide, two global quantum data centers, and the upcoming unveiling of Quantum System Two, a modular quantum computer architecture enabling quantum-centric supercomputing.

This tech-talk will provide an overview of the cryogenic cooling used in IBM Quantum System One to maintain the qubits at the necessary millikelvin temperatures, and then delve into other important factors in thermal management of the quantum system. This includes the thermal design to cool the extensive room temperature electronics that interface the qubits to the outside world and how this design intersects with acoustic and industrial needs. We will also provide a brief overview of the upcoming Quantum System Two hardware.

Bio: Dr. Milnes P. David is the zSystems Thermal Architect with IBM Corporation in the Infrastructure Power Packaging and Cooling Group. He is responsible for managing the thermal technology roadmap and leading the overall design, analyses and development of cooling hardware and solutions used in the IBM zSeries Mainframes. He also leads the exploration and enablement of new thermal technologies to improve thermal management and energy efficiency of IBM hardware. Milnes also provides system-level thermal design, analysis and deployment support for IBM Quantum. He is also an IBM Master Inventor with over 100 patents and is an author on over 30 publications. Before joining IBM, Milnes received his doctoral degree in Mechanical Engineering from Stanford University where he studied Two-Phase Flows in Microstructures with Prof. Ken Goodson.

TT-5 Innovations in Industrial Systems

THURSDAY, MAY 30, 8:15 – 9:15AM, RED ROCK 10-11

Session Chair: Naveenan Thiagarajan (GE) and Qian Han (Sorrento Solution)

Thermal and Energy Management Enabling Next Generation Industrial Systems for the Energy Transition

Bill Gerstler
GE Vernova Advanced Research

Abstract: The energy transition requires simultaneously electrifying and decarbonizing the world. The U.S. Energy Information Administration (EIA) projects a 33-75% increase in global electrical demand by 2050 in their 2023 International Energy Outlook (IEO) while COP28 (Conference of the Parties) in 2023 maintained a goal of worldwide net zero carbon dioxide emissions by 2050 to limit global warming to 1.5C by 2100. Carbon Capture, including Direct Air Capture (DAC) is a key technology that supports net zero goals. Concurrently, the availability and management of water is increasingly challenging – from industrial & military needs, building heating ventilation and air conditioning (HVAC), and worldwide

availability of clean drinking water. Atmospheric Water Extraction (AWE) plays a role to meet the challenge. Thermal and energy management are intimately integrated in both DAC and AWE. Modeling and analysis show thermal integration is a key aspect to meet operating and capital cost goals that enable DAC. Similarly, thermal and energy integration in AWE enables technology to operate in environmental conditions impossible for existing technologies while using less energy. Lessons learned from thermal and energy management of DAC and AWE can be applied to other key industries that are part of the energy transition including Data Centers and HVAC.

Bio: Bill Gerstler is a Senior Principal Engineer in the Carbon Capture organization at GE Vernova Advanced Research in Niskayuna NY. During his 23-year career at GE, his research has concentrated in thermal management of applications including power turbines, generators, motors, power electronics, aircraft systems, and aircraft engines. Current interests include thermal and energy management, system design & testing, and applications for carbon capture and atmospheric water extraction technologies. Bill has 38 conference and journal publications. He also has 69 U.S. patents granted. He is a Fellow of ASHRAE.

Advanced Power Electronics and Electric Machines Packaging, Thermal Management, and Reliability for Electric-Drive Mobility Applications

Sreekant Narumanchi
NREL

Abstract: Electronics, power electronics, and electric machines are becoming important for an array of mobility/transportation, renewable energy, and energy efficiency applications. In this presentation, I will introduce NREL and my group. Then, I will describe some challenges and opportunities for power electronics, electric machines, and electric traction drive systems for mobility applications. After that, I will give an overview of my group's recent research activities in power electronics, electric machines and integrated (electric) traction drive systems with focus on thermal management and packaging.

Bio: Sreekant Narumanchi is a Distinguished Member of Research Staff, and the Group Manager of the Advanced Power Electronics and Electric Machines (APEEM) Group within the Center of Integrated Mobility Sciences at the National Renewable Energy Laboratory, in Golden, CO, U.S.A., where he is currently in his 20th year. He leads a Group of 15 researchers focused on electro-thermal, thermal-fluids, thermo-mechanical and reliability aspects of power electronics and electric machines for electric-drive vehicles and several energy efficiency and renewable energy applications. Over the years, his group has collaborated with over 80 institutions cutting across industry, universities, national labs, federal agencies, and other research institutions.

Sreekant is an American Society of Mechanical Engineers (ASME) Fellow, and an Institute of Electrical and Electronics Engineers (IEEE) Senior Member. He has published over 115 peer-reviewed journal and conference papers and book chapters. Professionally, he is active in leadership roles on multiple committees, advisory boards, conferences, and journals – including those under IEEE and ASME. Some of the external awards Sreekant has received include the 2023 ASME Avram Bar-Cohen Memorial Medal, and the 2022 THERMI Award. Sreekant received a Ph.D. from Carnegie Mellon University (2003), M.S. from Washington State University (1999), and B. Tech. from Indian Institute of Technology Kanpur (1997), all in Mechanical Engineering.

TT-7 Novel Structures and Surfaces for Enhanced Heat Transfer

THURSDAY, MAY 30, 2:00 – 3:30PM, RED ROCK 10-11

Session Chair: Naveenan Thiagarajan (GE) and Georges Pavlidis (University of Connecticut)

Phase-Change Cooling of Electronics in Microgravity

Sushil H. Bhavnani
Auburn University / ECS Tech

Abstract: Manned space missions to neighboring planetary destinations have risen to the top of NASA's priorities. Advances in control and communication technologies drive the need for higher heat fluxes in on-board electronics. Phase-change cooling is once-again an ongoing area of interest. Under microgravity conditions, the absence of buoyancy forces disrupts bubble dynamics preventing bubbles from detaching from surfaces. This leads to the formation of a large vapor mass attached to the surface that leads to a large rise in surface temperature. This Tech Talk features the exploration of a meso-scale engineered surface in the form of saw-toothed structures that causes favorable changes in the interfacial radius of curvature of the vapor slug in the immediate vicinity of the surface, producing a net force that can propel the vapor mass away from the heat source in a lateral direction. The surface is built with intentional nucleation sites to allow this motion to occur in a designed direction. Following terrestrial studies on a variety of surface morphologies and process conditions, experiments were conducted on-board zero-gravity aircraft and the International Space Station. The test chambers were in the form of square cross-sectioned glass ampoules, with deposited thin film heaters. The flight test and instrumentation hardware; ASCENT (Asymmetric Sawtooth and Cavity-Enhanced Nucleation-driven Transport) was developed in concert with a NASA implementation partner to conform to stringent flight requirements. The Tech Talk will include both quantitative data and imagery obtained by orthogonal high-speed cameras, for several geometric and process variables. The microstructured surface offers the promise of enhanced thermal management solutions for electronics in suppressed buoyancy conditions without the complexity of flow loops.

Bio: Sushil H. Bhavnani is Burt Professor Emeritus at Auburn University. His current affiliation is with ECS Tech in Fairfax, Virginia, supporting DARPA Programs. His primary research area is in liquid cooling of high-powered microprocessors. He is a past recipient of the ASME Electrical and Electronics Packaging Division's Clock Award for sustained contributions to the area of electronics packaging. He has served as the General Chair of the Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems (ITherm). He has authored 180 refereed journal and conference publications resulting from research sponsored by agencies such as NASA, the National Science Foundation, Southern Company, the U. S. Department of Energy, and the U. S. Department of Defense. While at Auburn, he was recognized with several teaching excellence awards, including the Mortar Board Award, the Walker Award, the Birdsong Award, the Pumphrey Award, and the Leischuck Presidential Award for Excellence in Teaching. He is a Fellow of the American Society of Mechanical Engineers.

ENHANCED HEAT TRANSFER WITH FEMTOSECOND LASER SURFACE PROCESSING (FLSP)

Craig Zuhlke & George Gogos
University of Nebraska – Lincoln

Abstract: Surface functionalization with micro- and nano-scale features has been shown to lead to enhanced heat transfer for thermal management, anti-icing surfaces, anti-microbial surfaces, drag reducing surfaces, and enhanced solar absorption to name a few. There are two major issues that have limited the widespread application of surface functionalization: (1) lack of permanency in terms of maintaining unique properties, and (2) inability to scale the functionalization techniques to large areas for real-world applications.

Profs. Craig Zuhlke and George Gogos from the Center for Electro-optics and Functionalized Surfaces (CEFS) at the University of Nebraska-Lincoln will present on multidisciplinary research efforts to develop a new, transformative approach to functionalize surfaces using finely controlled laser-matter interactions in femtosecond laser surface processing (FLSP). With FLSP, surface properties of a material are modified directly and permanently by producing quasi-periodic hierarchical micro- and nano-scale surface features along with surface and subsurface microstructure and chemical changes. A major advantage of FLSP over other surface modification technologies is the ability to produce micro- and nano-structured surfaces on metals in a single processing step, without adding coatings, and without affecting the properties of the bulk material. Additionally, the dynamics of the ablation process allow for controlled chemical alteration of the surface and alteration of subsurface grain structure during processing, resulting in a fully functionalized surface that can be adapted to specific applications. FLSP has a plethora of applications due to the ability to impart unique properties. Some of the applications of FLSP that CEFS has investigated include, enhanced two-phase heat transfer for thermal management of electronic and optical devices; anti-microbial surfaces; anti-icing surfaces; drag-reducing surfaces; broadband absorbing/emitting surfaces for applications in solar and thermal management through radiative heat transfer; and surfaces for enhanced electrolysis. Prof. Zuhlke will present an overview of the FLSP research program, fundamental research on FLSP, and an overview of applications being investigated by CEFS. Prof. Gogos will present research on the application of FLSP surfaces to enhance two-phase heat transfer.

Bio: Prof. Craig Zuhlke is an Associate Professor in Electrical and Computer Engineering at the University of Nebraska-Lincoln (UNL) and Co-Director of the Center for Electro-optics and Functionalized Surfaces (CEFS). Prof. Zuhlke received B.S. and Ph.D. degrees in Electrical Engineering from UNL. He conducts research utilizing the unique interaction between ultrashort laser pulses and matter to achieve new modalities of manufacturing. Dr. Zuhlke has worked to develop femtosecond laser surface processing (FLSP) techniques for functionalizing surfaces for a wide range of applications. He has led several federally- and industry-funded multidisciplinary research projects related to FLSP and its applications, including research on the fundamental physics of FLSP, and applications of the FLSP. Some of the applications of FLSP that CEFS has investigated include, enhanced two-phase heat transfer for thermal management of electronic and optical devices, anti-microbial surfaces, anti-icing surfaces, drag-reducing surfaces, broadband absorbing/emitting surfaces for applications in solar and thermal management through radiative heat transfer, and surfaces to enhance catalysis.

Bio: Prof. George Gogos holds a B.S. degree in Mechanical Engineering from the Massachusetts Institute of Technology (1980) and an M.S. (1982) and PhD (1986) degrees in Mechanical Engineering and Applied Mechanics from the University of Pennsylvania. After he completed his studies, he joined Rutgers University as an Assistant Professor and in 1993 moved to the University of Nebraska – Lincoln as an Associate professor where he is currently the Wilmer J. and Sally L. Hergenrader Professor of Mechanical & Materials Engineering, Director of the Nebraska Center for Energy Sciences Research (NCESR), and Co-Director of the Center for Electro-optics and Functionalized Surfaces (CEFS). Over the past fifteen years, his research emphasis is on two interdisciplinary research areas: a) thermal/fluids

applications of metallic, ceramic and silicon surfaces that are functionalized with femtosecond lasers, and b) propane flaming for weed control in agronomic crops. The second one has led to a successful startup (Agricultural Flaming Innovations (AFI), website: agflame.com). He has also conducted research in fuel combustion, with emphasis on droplet combustion, droplet vaporization at elevated pressures and microgravity combustion, as well as in a number of interdisciplinary areas that required his expertise in the thermal/fluids sciences, such as rapid DNA multiplication for detection of biological agents (rapid PCR development), blast wave mitigation and rotational molding. His research funding sources include NSF, NASA, DARPA, NIH, ARO, ONR, USDA, Boeing and other industries. He has co-authored more than 150 technical papers in archival Journals and Conference Proceedings and holds 5 patents. He teaches undergraduate and graduate courses in heat and mass transfer processes, fluid mechanics, thermodynamics, computational heat transfer and fluid flow and in combustion.

SINGLE PHASE POWER ELECTRONICS COLD PLATES FOR MODERN DEVICE TECHNOLOGIES

Yogendra Joshi
Georgia Tech

Abstract: Emerging applications of power converters for ground vehicle and aircraft electrification are pushing for dramatically higher power densities in compact, and light-weight form factors. Another quiet revolution is underway in device technologies migration from Si to SiC and GaN, to achieve higher efficiencies at these power densities. Cold plate architectures for these applications have seen significant changes in the past decade, enabled through advances in additive manufacturing. In this talk, two studies will be summarized. The first will focus on the application of jet impingement over structured surfaces to achieve dramatic enhancement in heat transfer, using the current state-of-the-art direct-bonded-copper (DBC) packaging technology. The second will describe an approach for a radical departure from DBC, to a multi-functional architecture to enable both power delivery and heat spreading. Through the use of additive manufacturing, new topologies such as triply-periodic minimal surfaces can be utilized to fabricate heat transfer enhancement structures to achieve superior thermal performance.

Bio: Dr. Yogendra Joshi joined DARPA in July 2022 as a Program Manager in the Microsystems Technology Office (MTO). He is a professor and the John M. McKenney and Warren D. Shiver Distinguished Chair at Georgia Institute of Technology's G.W. Woodruff School of Mechanical Engineering. In addition, he has a courtesy appointment at Georgia Tech/s School of Electrical and Computer Engineering. His research interests are in multi-scale thermal management. Joshi is the author or co-author of more than 450 publications in this area, including more than 225 journal articles. He received his Bachelor of Technology in mechanical engineering from the Indian Institute of Technology (Kanpur) in 1979, Master of Science in mechanical engineering from the State University of New York at Buffalo in 1981, and doctorate in mechanical engineering and applied mechanics from the University of Pennsylvania in 1984. Joshi is an elected fellow of the American Society of Mechanical Engineers (ASME), the American Association for the Advancement of Science, IEEE, and American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). He's been recognized for his contributions through several awards, including the Inventor Recognition Award from the Semiconductor Research Corporation (2001), the IBM Faculty Award (2008), the IIT Kanpur Distinguished Alumnus Award (2011), the AIChE Donald Q. Kern Award (2018), and multiple honors from IEEE and ASME (including the Heat Transfer Memorial Award in 2013).

TT-9 Coolants for High Performance Computing and Industrial Systems – Challenges and Advances

FRIDAY, MAY 31, 8:15 – 9:15AM, RED ROCK 10-11

Session Chair: Georges Pavlidis (University of Connecticut) and Qian Han (Sorrento Solution)

Unlocking Potential: Navigating Challenges and Seizing Opportunities in Two-Phase Liquid Immersion Cooling

Jimil Shah
Stealth Startup

Abstract: Two-Phase Liquid Immersion Technology is gaining traction in today's market as a means of combatting compounding data center concerns related to energy and resource consumption. Nowhere are such issues perhaps better revealed than in the current contentious debate about water usage requirements for data center facilities in draught-stricken western states. The two-phase liquid immersion approach to cooling computing equipment is being recognized for the many opportunities that are made available such as higher processing density, more densely packed DIMMs, the possibility for overclocking, and faster server refresh rates, as well as increased energy efficiency. The presentation will include a high-level comparison of Single- and Two-phase immersion cooling as well as a further discussion of special technical topics related to two-phase immersion cooling of data centers. As is always true with any burgeoning technology, challenges to the implementation of two-phase liquid immersion cooling are legitimate; concerns about fluid loss, fluid selection, limited power density, material compatibility, safety, and environmental impact are real and must be addressed for this technology to succeed. This presentation will address these issues and debate mitigation strategies for these challenges as well as opportunities with respect to the widespread adoption of this technology. The path forward for Two-Phase Liquid Immersion Technology requires an honest evaluation of the challenges, a comprehensive review, and debate regarding mitigation strategies for those challenges, and an accurate assessment of this technology that is unencumbered by entrenched interests.

Bio: Jimil M. Shah, Ph.D. is an Immersion Cooling Staff Engineer in a Stealth Startup. He is contributing to developing a cutting-edge two-phase immersion cooling system for a hyperscale data center for Artificial intelligence applications, contributing to enhanced energy efficiency and reduced operational costs. He is working on the Thermal and reliability aspects of the immersion cooling technology leading towards the operating procedures for the data centers. Previously, Dr. Shah held the position of Senior Director of Thermal Sciences at TMGcore. Before joining TMGcore, he was an Application Development Engineer for Server Liquid Cooling of Data Centers at 3M Company. His research in advanced cooling solutions for data center thermal management focuses on single- and two-phase direct-to-chip as well as immersion cooling using dielectric fluids. Before joining 3M, Dr. Shah was a Post-Doctoral Research Associate at the University of Texas at Arlington. Dr. Shah received his doctorate in Mechanical Engineering from the University of Texas at Arlington in 2018. He holds senior membership status in IEEE and is a professional member of ASHRAE TC9.9, ASME, and OpenCompute. Notably, at InterPACK 2018, Dr. Shah was honored with the "ASME Electronic and Photonic Packaging Division (EPPD) Student Engineer of The Year Award." With a prolific record, he has submitted over 40 patent applications and holds 5 issued/allowed patents. Furthermore, Dr. Shah has contributed to 36 journal and conference papers, with an additional article currently under review.

RECENT DEVELOPMENTS IN TWO-PHASE LIQUID COOLING USING LOWER-GWP HEAT TRANSFER FLUIDS

Gustavo Pottker
Chemours

Abstract: The exponential rise in computing power and big data, the ongoing electrification of traditional mechanical systems and the growing focus on sustainability are driving the need for more effective and energy efficient cooling technologies in applications from data centers, to electric vehicles and power electronics. Liquid cooling technologies, which for years were considered niche, are now becoming mainstream. Heat transfer fluids are a central piece in liquid cooling and while water- and oil- based fluids can meet cooling requirements in many applications, they have limitations that can only be overcome by two-phase heat transfer using fluorinated fluids, or “F-Gases”, with lower boiling points. The presentation will discuss the key attributes and requirements of different two-phase fluids used in thermal management, with particular focus on a low Global Warming Potential (GWP) class called Hydrofluoroolefins (HFOs). Recent developments in the application of HFOs in two-phase direct-to-chip and immersion cooling in data centers and other applications will be shared, together with a critical assessment of advantages, challenges, and opportunities. Finally, we will examine typical HFOs atmospheric chemistry and the impact of environmental regulations.

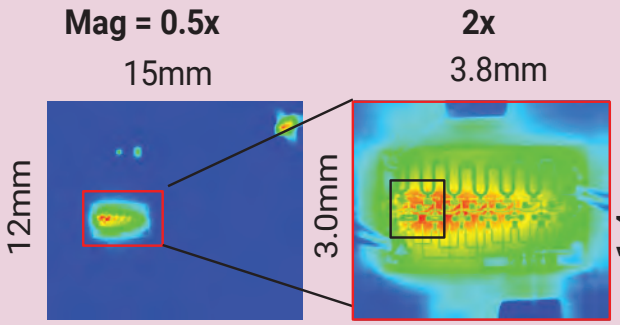
Bio: Gustavo Pottker is a Senior Principal Engineer at the Thermal and Specialized Solutions Division of the Chemours Company. His research life started at 18 year’s old as an undergrad research assistant at the Federal University of Santa Catarina in Brazil, where he also obtained his Master’s degree in Mechanical Engineering in 2006. He has combined more than 20 years of industry and academic experience in the Air conditioning, Refrigeration and Thermal Management areas, including a variety of R&D roles. Gustavo also holds a PhD in Mechanical Engineering from the University of Illinois at Urbana-Champaign. He is the author of dozens of patents, conference, and journal publications while also an active member of industry organizations. At Chemours, Gustavo currently leads the application development of heat transfer fluids for thermal management applications, with primary focus on two-phase immersion cooling.

microsanJ

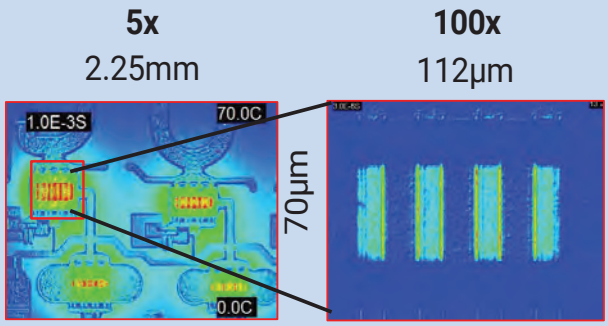
SanjSCOPE™

GaN MMIC Thermal Analysis

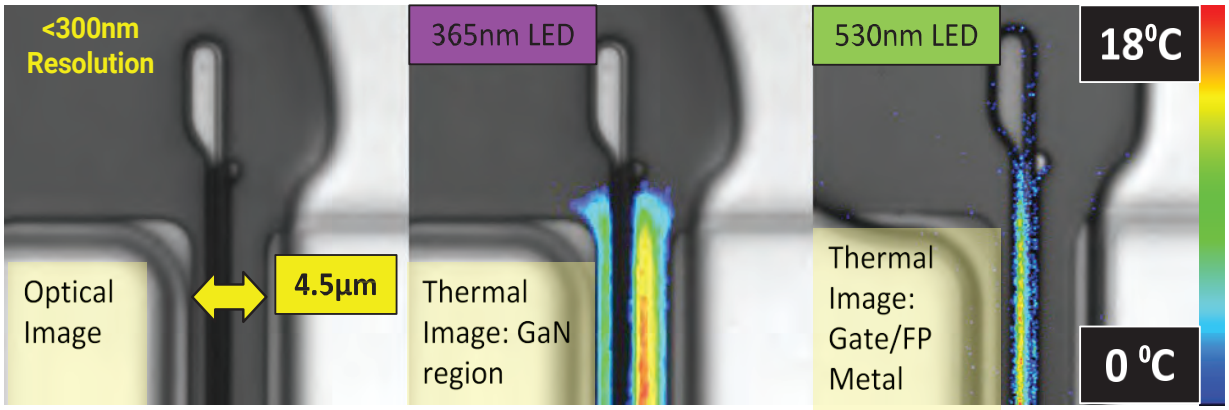
IR MODE for Package-Level



TR MODE for Junction-Level



Thermal Analysis of GaN Region & Gate Metal



Full Spectrum Thermal Imaging
Near Ultraviolet to Infrared

- NUV to IR - Thermoreflectance + IR Emission
- Integrated Dual Mode solution
- High sensitivity macro-analysis with IR
- High spatial resolution micro-analysis with TR
- NUV for GaN & other WIDE BAND-GAP devices
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PANELS

P-2: Opportunities at the Intersection of Artificial Intelligence (AI) and Thermal Management

WEDNESDAY, MAY 29, 11:00 AM – 12:30 PM, RED ROCK 10-11

Moderators: Vaibhav Bahadur (The University of Texas at Austin) and Luca Amalfi (Seguente)

Panelists: Hemanth Dhavaleswarapu (AMD), John Kim (Seguente), Yoonjin Won (UC Irvine), Dursetti Chidambarrao (IBM), and Sumanta Acharya (IIT)

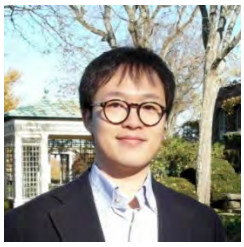
Thermal management is becoming essential to ensure performance and reliability of AI-related hardware (e.g., GPUs) that is critical to realizing the benefits of AI in many areas. Synergistically, AI can also enable the advancement of thermal management solutions in multiple ways (materials discovery, optimization, digital twinning, etc.). A panel of distinguished professionals from industry and academia will discuss these aspects and share their vision on the future of AI as it relates to thermal management.

The Next Generation of AI Architectures

Hemanth Dhavleswarapu
Principal Member of Technical Staff
AMD

Abstract: Supercomputer and AI performance has been on an exponential improvement trend line. The talk will focus on trends of compute, AMDs perf/W advantage and future challenges for large AI data centers.

Bio: Dr. Hemanth Dhavaleswarapu is a Packaging Architect in Advanced Packaging group at AMD contributing to development of Elevated Fanout Bridge (EFB) and 3.5D Hybrid Bonded architectures. He has previously led their Computational Modeling group. Before joining AMD, he spent 12 years at Intel Corporation as a Packaging Technologist contributing to development of EMIB, CoEMIB and other technologies. He has a PhD from Purdue University and Bachelor's from IIT Madras. He has authored over 23 publications and has 20 patents in the field.



Analytics for Thermal Management of Data Centers

John Kim
Co-founder and Chief Innovation Officer
SEGUENTE

Abstract: The exponential growth of data centers in recent years are driven primarily by the increasing demand on digital technologies reshaping our society. Data center energy consumption is a significant concern due to the massive amounts of power required to operate and cool servers. High operational efficiency could be achieved through the adoption of innovative cooling technology coupled with analytics and intelligent resource allocation.

Bio: Dr. John Kim is the Chief Innovation Officer and Co-Founder of SEGUENTE Inc., where he leads the commercialization effort of innovative products, including IoT features and backend software services for advanced thermal management solutions. He also oversees the development of IP and Trade Secrets, covering both hardware and software aspects. Prior to his role at SEGUENTE, he was the department head in the Artificial Intelligence (AI) organization at Nokia Bell Labs, where he led numerous projects with a multi-disciplinary team of engineers and scientists to create novel devices coupled with back-end AI analytics for applications in industrial automation. He received his Chemistry Ph.D. from Rutgers University and had international working experience as a research fellow at Korea Advanced Institute of Science and Technology (KAIST), where he applied computational techniques to study infectious diseases and gene editing techniques. He has authored numerous papers in high profile peer-reviewed journals, and conferences, and has received numerous prestigious fellowships and awards.

FUNDAMENTALS OF MACHINE LEARNING FOR PHASE CHANGE HEAT TRANSFER

Prof. Yoonjin Won
UC Irvine

Abstract: Multiphase phenomena are observed in our everyday life in nature and many industrial applications, ranging from dew condensation on insects, water harvesting, electronics cooling, climatology prediction, hydrogen generations, and manufacturing. While the fundamentals of multiphase processes have been studied for over a century, key scientific questions remain regarding the fundamental mechanisms governing complex phenomena. In this talk, I will showcase key approaches developed by my group that reveal previously undefined features and hidden mechanisms and will introduce examples illustrating how AI technologies enable learning, understanding, and prediction of the dynamic nature of multiphase phenomena. In conclusion, this talk will briefly discuss potential game-changing innovations for thermofluidic domain.

Bio: Yoonjin Won received a B.S. degree in Mechanical and Aerospace Engineering from Seoul National University, and M.S. and Ph.D. degrees in Mechanical Engineering from Stanford University. She is currently an Associate Professor of Mechanical and Aerospace Engineering at the University of California, Irvine. She has courtesy appointments in Electrical Engineering and Computer Science and Materials Science Engineering. Dr. Won's overarching research goal is to gain fundamental insights into multiphase thermal science, centering on keywords—AI for science, graphic-driven physics, and materials design. She is a recipient of the National Science Foundation CAREER Award, the ASME Electronic & Photonic Packaging Division Early Career Award, the ASME Electronic & Photonic Packaging Division Women Engineer Award, the ASME ICNMM Outstanding Leadership Award, the Emerging Innovation/Early Career Innovator from UCI Beall Innovation Center, Faculty Excellence in Research Awards, Mid-Career from UCI. Additional details for Dr. Won’s qualifications and research group are available online (won.eng.uci.edu).

PERSPECTIVES ON THE APPLICATION OF ARTIFICIAL INTELLIGENCE FOR THERMAL MANAGEMENT - SOME OBSERVATIONS FROM NSF

Sumanta Acharya
Program Manager
NSF

Abstract: National Science Foundation (NSF) invests in basic research and people to create knowledge and transform the future in diverse areas such as national health, industrial and manufacturing economy, national defense and others. The Thermal Transport Processes (TTP) program is housed in the Chemical, Bioengineering, Environmental and Transport Division in the Engineering Directorate. The TTP program supports use-inspired research that contributes to fundamental understanding of thermal transport phenomena, and innovations in enhancing heat transport and properties across all scales (from atomistic to macro). Applications of Artificial Intelligence (AI) have now become ubiquitous in thermal science research. Examples include material discovery for improved thermal transport properties, correlating surface and fluid properties to boiling and condensation patterns and heat transfer, and optimization and control of thermal processes and systems. In this presentation, examples of NSF funded ongoing research on AI use in thermal science is presented, and specific areas of priority for the community to explore are discussed. Feedback is solicited from the thermal science community, prior, during or after the presentation.

Bio: Dr. Sumanta Acharya currently serves as the Program Director of the Thermal Transport Processes (TTP) program where he manages the proposal submission and research supported by NSF in the area of thermal sciences. He is also a Professor in the Mechanical, Materials and Aerospace Engineering (MMAE) Department at the Illinois Institute of Technology (IIT) in Chicago where he previously served as the Department Chair from 2016-2022. His primary areas of research include gas turbine heat transfer and combustion, thermal management of heat-exchange systems in power plants and electronic industries. He has published/presented nearly 500 technical articles in archival journals and refereed conferences. In recognition of his research, he was awarded the ASME Heat Transfer Memorial Award in the Science category, the AIChE Donald Q Kern Award for achievements in heat transfer, and the AIAA Thermophysics Award. He was previously the Chair of the ASME Heat Transfer Division. He is a Fellow of ASME (American Society of Mechanical Engineers) and ASTFE (American Society of Thermal and Fluids Engineers).

CAN WE USE AI EFFECTIVELY TO PROVIDE THERMAL MANAGEMENT SOLUTIONS FOR AI?

Dr. Chidambarrao Dursetti
Senior Technical Staff Member
IBM Research

Abstract: When you throw thermal management into the mix, the massive compute and power requirements for advanced AI may soon drive the need for Co-Optimization across the whole stack from the data center to system architecture to 3D advanced packaging down to chiplet designs. New materials, new holistic modeling approaches, new STCO methodologies, new advanced digital twinning techniques, etc. are required. This begs the self-referential question – can we use AI effectively to provide thermal management solutions for AI?

Bio: Dursetti (Chidu) Chidambarrao is a recognized expert in Modeling, semiconductor R&D, DFM, and DTCO. Chidu is currently a Senior Technical Staff Member at IBM Research where he leads cross-functional teams in Thermal Solutions for Chiplets and Advance Packaging and device architecture components of the 2nm program. Before joining IBM Research, Chidu worked at IBM Infrastructure where he led the Product-Technology-Interactions team to help deliver P/Z chips for IBM's mainframes for the 14, 7, and 5nm technology nodes. He developed his deep process, device, and DTCO expertise while at the IBM Semiconductor R&D Center working on the 90nm through 22nm CMOS nodes. Chidu's technical accomplishments have been recognized with multiple awards internally at IBM, including a Corporate Award in 2022, IBM's highest technical recognition. Chidu has over 225 US patents, is an IBM Master Inventor for 15 years, and has 65 publications.

P-4: Mechanics and Co-Design Opportunities

WEDNESDAY, MAY 29, 4:00 – 5:30 PM, RED ROCK 10-11

Moderators: Hemanth Dhavaleswarapu (AMD) and Abhijit Dasgupta (University of Maryland)

Panelists: Ganesh Subbarayan (Purdue), Hesham Taha (Teramount), Luke Garner (Intel Corporation), Keith Newman (AMD), Alexander Janta-Polczynski (IBM)

Heterogeneous Integration (HI) for next-generation chiplet-based systems requires a systematic and sophisticated co-design approach that can simultaneously account for electrical performance (digital, analog, RF and power), thermal performance, mechanical performance and long-term degradation/reliability. The experts in this panel will share their insights about the mechanics challenges and solution roadmaps, in the context of this codesign ecosystem. The panel will consist of 3 HI experts from industry at various levels of the microelectronics/photonics supply-chain, and 3 mechanics experts from academic R&D Centers.

Challenges of System Co-Design: Are Machine Learning Models Useful?

Prof. Ganesh Subbarayan
Purdue University

Abstract: Design exploration of complex Heterogeneously Integrated microsystems rely on behavioral models. Physical behaviors are inherently expensive to analyze. Furthermore, the behavioral models need to span several orders of magnitude in length scale and must trade-off electrical-thermal-mechanical behavior during design exploration. Machine learning (ML) models are often proposed as a surrogate to enable fast analysis during design. We will explore the advantages and disadvantages of ML models in this talk.

Bio: Ganesh Subbarayan is the James G. Dwyer Professor of Mechanical Engineering at Purdue University and the Co-Director of the Purdue-Binghamton SRC Center for Heterogeneous Integration Research in Packaging (CHIRP). He also serves as the Director of the recently created Atalla Institute for Advanced System Integration and Packaging (ASIP) at Purdue University. He began his professional career at IBM Corporation (1990-1993). He holds a B.Tech degree in Mechanical Engineering (1985) from the Indian Institute of Technology, Madras and a Direct Ph. D. (1991) in Mechanical Engineering from Cornell University. Dr. Subbarayan's research is broadly concerned with modeling and experimentally characterizing failure in microelectronic devices and assemblies. He was a pioneer in using geometric models directly for analysis, popularly referred to as Isogeometric Analysis. Among others, Dr. Subbarayan received the 2022 SRC Technical Excellence Award, 2005 Excellence in Mechanics Award from the ASME Electronics and Photonics Packaging Division and the NSF CAREER award. He is a Fellow of ASME as well as IEEE, and he served as the Editor-in-Chief of IEEE Transactions on Advanced Packaging during 2002-2010.

Enhancing Yield and Reliability in Silicon Photonics Packaging Through Detachable Fiber Connectivity

Hesham Taha
CEO and Co-founder
Teramount

Abstract: The demand for high-speed optical connectivity in AI, data centers, and other high-performance systems necessitates scalable packaging solutions that ensure seamless integration between photonics and semiconductor processes, including manufacturing, packaging, and testing. In this session, Teramount will introduce its pioneering Universal Photonic Coupler solution, designed to significantly improve packaging yield and reliability. Leveraging wafer-level optics, wide-band surface coupling, a design tailored for testing, and detachable fiber connectivity, this approach addresses the critical challenges in photonic packaging. Furthermore, Teramount will share its view for achieving scalable photonic packaging by fostering alignment among key ecosystem players, such as foundries and outsourced semiconductor assembly and test (OSAT) vendors.

Bio: Hesham Taha is CEO and co-founder of Teramount Ltd. Hesham has a PhD in Applied Physics from the Hebrew University of Jerusalem with focus on photonics, nano-microscopy and nano-lithography. Hesham leads the development and productization processes of fiber assembly technology for silicon photonics at Teramount.

Challenges for Mechanics of Advancing AI Packages

Luke Garner
Intel Corporation

Abstract: In the advancing world of AI, singular solutions struggle to meet every need. Packages will increasing employee multiple fab nodes with multiple interconnect strategies in ever larger complexes to fulfil the rising computational demands. This heterogenous integration will drive greater challenges for testing and certifying the mechanical reliability with mixed technologies.

Bio: Luke Garner joined Intel's Assembly Test Technology Development in 1999 as a mechanical stress analyst. He is the sponsor of multiple industry standards on warpage and mechanical reliability. He has been the program manager for multiple generations of advanced server packages, and currently is the director of Advanced Package Customer Engineering in Intel's foundry Services group.

Challenges and Opportunities for the Future of High-Performance Compute

Keith Newman
AMD

Abstract: Advanced packaging enabled chiplet architectures are increasingly adopted to drive performance and cost improvements. New heterogeneous architectures like 2.5D Fanout, 3D and 3.5D Hybrid bonded architectures driving AMD's industry leading advanced technology roadmap will be shared. Other topics include chiplets for AI, challenges and solutions for large chiplet modules, etc.

Bio: Keith Newman is presently employed at AMD as a director of package reliability. He received a BSME from Stanford University, and has been an engineer and engineering manager for numerous years in the semiconductor, computer and materials science industries. Previous employers include HP, Sun Microsystems, LSI Logic and Raychem. Keith is a technical committee member for ECTC, IRPS, and EPTC, industry standards contributor for JEDEC and IPC, publishes frequently, and has multiple US patents.

ADVANCE PACKAGING TECHNOLOGIES FOR CHIPLETS

Alexander Janta-Polczynski
IBM

Abstract: Packaging remains the key aspect to enable chiplet technologies interconnection and integration. Chiplets are small modular and specialized chips that combined and connected together creates a complex integrated circuit. By combining different chiplets a custom solutions can be tailored for specific needs, furthermore this approach enables enhanced dies yield form wafers compared to monolithic larger chip. Chiplet-based technology will revolutionize how electronic components are designed and manufactured, for more efficient and cost-effective processes to enable customized and specialized products. This strategy creates a clear path for heterogenous integration of various dies specializations, functionalities and nodes technologies to support high-compute applications like AI/ML, memories, signal processing, data flow management, and eventually photonics. Furthermore, reuse of existing chiplets reduce the design and production cost, and spread the yield over different process technology nodes, which improve significantly the overall risk, compared to a large area single chip confined on the most advanced process node. Chiplets requires advanced connections between the dies to enable the application functionalities, and they are different medium and methods to perform those connections, such as flip-chip of several dies on a high-density interposer, the use of silicon bridge between dies, or reconstruct the dies and use redistribution layer for the wiring. IBM is a leading provider of advanced semiconductor technologies and is actively working on chiplet technology integration and the required advanced packaging. It has developed a chiplet-based architecture and advanced packaging process for the interconnections, notably for its processors, and is researching the use of chiplets in broad applications, and manufacturing reality regarding cost and performance.

Bio: Alexander Janta-Polczynski is a Senior Advisory Engineer at IBM Canada, Bromont. His work focuses on advanced semiconductor packaging technologies involving heterogeneous integration, chiplets and photonics, for high reliability packaging with thermal solutions and state of the art signal integrity / power delivery sciences.

P-6 THERMAL CHALLENGES AND OPPORTUNITIES FOR CONSUMER ELECTRONICS/MOBILE/IOT/AUTO/HIGH POWER COMPUTE

THURSDAY, MAY 30, 11:00 AM – 12:30 PM, RED ROCK 10-11

Moderator: Victor Chirac (GCTG)

Panelists: Eric Bert (Exentis AG USA), Amy Marconnet (Purdue), Raj Pendse (META), Shlomo Novotny (Seguente), Ravi Mahajan (Intel Corporation), and Mike Ohadi (UMD)

The digital world requires higher performance, more data and faster processors. Heterogeneous Computing involves the central processing units (CPUs), the graphics processing units (GPUs), high speed interconnects and other elements that push forward the computing industry. The emergence of 5G/6G leads to significant rise in mobile communication, IoT, automotive, AI and high-power computing devices, providing the infrastructure needed to carry large amounts of data, allowing for a smarter and more connected world – enabling Smart Cities, connected roads, Self-driving cars, AR/VR, AI robotics, Digital healthcare. A panel of experts will share their vision on the future of small to large electronics thermal management and other advanced system level thermal challenges and solutions.

ADDITIVE SCREEN PRINTING: INDUSTRIALIZED AM TECHNOLOGY FOR PRODUCTION OF PARTS WITH ULTRA-FINE FEATURES AND STRUCTURES USING A WIDE RANGE OF MATERIALS

Eric Bert
President
Exentis AG USA

Abstract: Additive Screen Printing is a new approach to sinter based additive manufacturing for volume mass production of industrial parts. Using conventional screen-printing techniques combined with high-speed precision optics and industrial handling automation, Exentis has introduced a new, unique technology platform that enables cost-effective, mass production of industrial parts with ultra-fine features and structures using a wide range of metals, ceramics, and other materials. This presentation will outline how the technology works, its capabilities compared to conventional production technologies like; PM, MIM/CIM, and other additive techniques, as well outline serval thermal management cooling structure part applications where Exentis' capability to produce very small holes, thin walls, and clean, complex micro-channels, using highly thermally conductive materials, delivered successful results. More information on Exentis can be found at www.exentis-group.com.

Bio: Eric Bert holds a BSME from UMass-Amherst and has a 30+ year track record in disruptive manufacturing technology introduction and management. Eric currently serves as President of Exentis North America and is responsible for building a North American beachhead for Switzerland based Exentis Group AG. Prior roles in Additive Manufacturing included; SVP Commercial at Inkbit, COO at 3DMEDiTech, SVP Global Sales at ARCAM (a GE Additive company), and SVP at Stratasys North America during its high growth period. Earlier, Eric held technology and management positions in the high-volume printed circuit and electronics assembly sector. He further completed expat assignments in Thailand and Australia starting-up, building, and operating large-scale manufacturing operations.

HYBRID PASSIVE AND ACTIVE COOLING STRATEGIES

Amy Marconnet
Purdue University

Abstract: To meet the increasing demands in electronic devices across a range of applications, hybrid cooling solutions that combine passive thermal energy storage elements (using phase change materials (PCMs)) with active liquid or air cooling for heat dissipation are promising. Specifically, this approach enables higher peak power levels to be dealt with through melting of the PCM, while active cooling provides for continuous dissipation at the average heat dissipation level. Such approaches can be scaled for use in systems from mobile electronics to power electronics such as in electric vehicles. However, it is critical to understand the transient power usage/heat dissipation levels to understand when PCMs combined with active cooling can provide benefits in a system.

Bio: Professor Amy Marconnet is an associate professor of Mechanical Engineering and associate professor of Materials Engineering (by Courtesy), as well as a Perry Academic Excellence Scholar, at Purdue University. She received a B.S. in Mechanical Engineering from the University of Wisconsin – Madison in 2007, and an M.S. and a PhD in Mechanical Engineering at Stanford University in 2009 and 2012, respectively. Her dissertation focused on thermal phenomena in nanostructured materials. She then worked briefly as a postdoctoral associate at the Massachusetts Institute of Technology, before joining the faculty at Purdue University in August 2013. Her work has won outstanding paper awards at ITherm 2012, InterPACK 2017, ITherm 2019, and ITherm 2023. In 2017, she won the Woman in Engineering Award from the ASME Electronics & Photonics Packaging Division (EPPD). In 2020, she

won the Bergles-Rohsenow Young Investigator Award in Heat Transfer and the Outstanding Graduate Student Mentor from the Official Mechanical Engineering Graduate Association (OMEGA) and the College of Engineering. She recently won a Humboldt Fellowship for Experienced Researchers and conducted research at Karlsruhe Institute of Technology in the 2021-22 academic year.

THERMAL CONSIDERATIONS IN WEARABLE COMPUTING

Rajendra (Raj) Pendse
Director
META

Abstract: Wearable computing for AR/VR devices presents unique challenges that combine high performance processing with constrained form factors and the inevitable need for distributed computing with Edge/AI architectures. We will share a simple case study of Edge/AI for an imaging application. This serves as a proxy for thermal implications of the broader case of Edge/AI and distributed computing in Wearable electronics.

Bio: Dr. Raj Pendse is Director of Si Packaging at Facebook Reality Labs (FRL) and leads the development of advanced Si/Packaging solutions for AR/VR hardware. Raj was previously Vice President of Package Engineering at Qualcomm and played various leadership roles in Package development at STATS ChipPAC, Hewlett-Packard Labs and National Semiconductor. Raj's work spans from packaging of microprocessors, ASIC's and GPU's for High Performance Computing to low-cost packaging solutions for logic and analog devices that find use in Mobile platforms and Consumer Electronics. His most recent focus has been on 3D and Wafer Level Packaging for AR/VR hardware. Raj completed his BS in Materials Science from IIT Bombay with Top in Class honors and his Doctorate in Materials Science from UC Berkeley.

THE TRANSITION TO LIQUID COOLING: WHAT'S, WHY'S AND HOW'S

Shlomo Novotny
VP Business Development
SEGUENTE

Abstract: Contemporary high-performance and AI servers, which utilize the latest CPUs and GPUs available in the market that enable the explosive growth in IT apps and data centers are driven to utilize liquid cooling for performance, energy conservation, sustainability, and reliability. This presentation would clarify the technology and market trends leading to the transition from traditional air cooling to direct to chip liquid cooling.

Bio: Mr. Shlomo Novotny is the Vice President of Business Development & Product solutions of Seguente Inc. responsible for the company's business growth and strategic partnerships. His experience spans over 25 years, as a leader of multi-discipline international development teams delivering cutting edge products with Aavid Thermalloy, Sun Microsystems, DEC, Codex, Magnavox, and Bell Labs. Previously, he was the director of technology and business development for Chilldyne, Nortek Air Solutions and the CTO of Vette Corp. While CTO of Vette Corp., he founded the Coolcentric division, a data center liquid cooling solutions provider, leading it to profitability within its first three years and building the division's name recognition. He is a co-founder of the ASHRAE TC 9.9 committee whose mission is to create industry standards for data center cooling and was an influential member of the PCI and InfiniBand industry committees that defined new interconnect bus architecture standards. He holds

22 patents to date. He is the author of several publications across the industry. He is an ASME Fellow, IEEE senior member, Data Center iMasons and ASHRAE TC9.9 member. He has earned Master's and Bachelor of Science degrees in Mechanical Engineering from the Polytechnic Institute of New York.

THERMAL MANAGEMENT: CHALLENGES AND OPPORTUNITIES FOR HETEROGENEOUS INTEGRATION

Ravi Mahajan
Intel Fellow – Assembly and Packaging Technology
Intel Corporation

Abstract: There is considerable interest today in heterogeneous integration using advanced packaging architectures to create compact high-performance platforms. This presentation will describe some of current and anticipated thermal challenges in these packaging architectures and make a case for continued innovation to meet these challenges.

Bio: Ravi Mahajan is an Intel Fellow responsible for Assembly and Packaging Technology Pathfinding for future silicon nodes. Ravi joined Intel in 1992 after earning Ph.D. in Mechanical Engineering from Lehigh University. He holds the original patents for silicon bridges that became the foundation for Intel's EMIB technology. His early insights have also led to high-performance, cost-effective cooling solutions for high-end microprocessors and the proliferation of photo-mechanics techniques used for thermo-mechanical stress model validation. His contributions during his Intel career have earned him numerous industry honors, including the SRC's 2015 Mahboob Khan Outstanding Industry Liaison Award, the 2016 THERMI Award from SEMITHERM, the 2016 Allan Kraus Thermal Management Medal & the 2018 InterPACK Achievement award from ASME, the 2019 "Outstanding Service and Leadership to the IEEE" Awards from IEEE Phoenix Section & Region 6 and most recently the 2020 Richard Chu ITherm Award For Excellence. He is one of the founding editors for the Intel Assembly and Test Technology Journal (IATTJ) and currently VP of Publications & Managing Editor-in-Chief of the IEEE Transactions of the CPMT. He has been long associated with ASME's InterPACK conference and was Conference Co-Chair of the 2017 Conference. Ravi is a Fellow of two leading societies, ASME and IEEE.

SINGLE PHASE AND PHASE-CHANGE IMMERSION COOLING OF ELECTRONICS

Michael Ohadi
University of Maryland

Abstract: Immersion cooling of high flux electronics through the utilization of appropriate dielectric fluids that offer a high heat capacity while meeting other requirements offers several advantages such as cooling efficiency, energy savings, and space optimization. However, it also presents challenges that need to be addressed for immersion cooling to become an increasingly attractive option for cooling electronics seeking to maximize cooling efficiency while minimizing operational costs. Both single-phase and phase-change immersion cooling and the respective opportunities and challenges will be discussed.

Bio: MICHAEL OHADI is a Minta Martin Professor of Mechanical Engineering and a co-founder of the Center for Environmental Energy Engineering (CEEE) at the University of Maryland, College Park.

Ohadi's research has focused on enhancing heat/mass transfer utilizing multi-scale design optimization, materials, and manufacturing techniques. From 2016 to 2020, Ohadi served as Program Director (PD) at the U.S. Department of Energy, Advanced Research Project Agency-energy (ARPAE), where he led the development of programs in thermal management and energy conversion systems. Ohadi received his Ph.D. in mechanical engineering from the University of Minnesota and joined the University of Maryland in 1990. He is a fellow member of both ASME and ASHRAE. He has published more than 300 peer-reviewed technical articles in his fields of expertise. He received the 2021 ASME Heat Transfer Memorial Award and the IEEE 2022 Richard Chu Award for Excellence in Thermo-Mechanical Management of Electronics.

P-10 Two-Phase Electronics Cooling

FRIDAY, MAY 31, 11:00 AM – 12:30 PM, RED ROCK 10-11

Moderator: John R. Thome (JJ Cooling Innovation SARL)

Panelists: Victor Chiriac (GCTG), Ali Heydari (NVIDIA), Todd Salamon (Nokia), Jackson Marcinichen (JJ Cooling Technologies), and Winston Zhang (Novark Technologies)

Two-phase cooling is coming forward as the new solution for datacenters to handle the AI HPC heat loads, mobile electronics, Edge AI, 5G, battery cooling, new semiconductor power electronics, EV-aircraft systems, etc. These primarily fall into the categories of pumped two-phase cooling and passive two-phase cooling (thermosyphons and pulsating heat pipes). The panelists will present their experiences on laying out new two-phase cooling technologies for their industrial sectors.

Cooling of Mobile Electronics with Advanced Pulsating Heat Pipes

Victor Chiriac
CEO and Managing Director
Global Cooling Technology Group (GCTG)

Abstract: The consumer electronics require higher performance, more data and faster processors, better graphics processing units (GPUs), high speed interconnects and other elements that push forward the computing industry. The emergence of 5G/6G leads to a significant rise in mobile communication, IoT technology, providing the infrastructure needed to carry large amounts of data. All these advancements require better cooling, especially in thin and compact mobile applications. The presentation will present a breakthrough cooling solution for the mobile industry of the future and beyond.

Bio: ASME Fellow, CEO and Managing Director of Global Cooling Technology Group, LLC. Held technology/engineering leadership roles, led corporate thermal technology teams and roadmaps, worked on leading-edge wireless technologies with Motorola (1999-2010), Qualcomm (2010 – 2018) and Futurewei (2018 – 2019). Elected Chair of the ASME K-16 Electronics Cooling Committee in 2015 and the Arizona and New Mexico IMAPS (International Microelectronics and Packaging Society) Chapter President in 2010. Co-editor of Electronics Cooling Magazine since 2016 and leading member of the organizing committees of ASME/InterPack,IMECE and IEEE/Itherm. 25 U.S. and International issued patents, 2 US Trade Secrets, 1 US Defensive Publication and 117 papers in scientific journals and at conferences. Recipient of the ASME K-16 Clock award in 2018 for "scientific contributions and leadership in promoting best thermal management of electronics engineering practices". Diamond Innovation and Technology Leadership Awards at Qualcomm in 2016-2017, and the Award for Technology Innovation at Motorola in 2002. PhD (1999) in Aerospace and Mechanical Engineering, University of Arizona, Tucson, USA.

SINGLE AND TWO-PHASE COOLING TECHNOLOGY FOR HIGH POWER DENSITY DATACENTERS

Ali Heydari
NVIDIA

Abstract: As NVIDIA continues to push the boundaries of high-performance computing, managing escalating power densities in data centers has become a crucial challenge. This Panel talk addresses the significant shift towards racks with power densities approaching 100 kW and the critical role of advanced liquid cooling systems in sustaining these high-density environments. The presentation will highlight the transformative impact these cooling solutions have on enhancing energy efficiency and operational sustainability in modern data centers. Attendees will gain insight into the challenges and innovations shaping the future of data center infrastructure, poised to support the intensive requirements of high-performance computing.

Bio: Ali Heydari is a Director of Data Center Cooling and Infrastructure and a Distinguished Engineer at Nvidia in charge of all data center cooling technology development. He has 20+ years of experience in design and deployment of high-performance servers and data centers, including some of the largest in existence, involving hardware, software, infrastructure, efficiency, reliability, manufacturing, and deployment. He has extensive experience with design and deployment of customized high-performance as well as energy efficient systems in low, medium, and high-volume operations. His current focus is on design and development of data centers capable of handling over 100kW/rack power using hybrid of air with single- or two-phase liquid cooling systems. He has a doctoral degree in Mechanical Engineering from UC Berkeley. Over a hundred published papers and patents related to data center cooling applications.

A THERMAL ENERGY ARCHITECTURE ENABLING SERVER DENSIFICATION AND ENERGY EFFICIENCY

Todd Salamon
NOKIA

Abstract: The success of Generative AI and Large Language Models is driving a tremendous demand for more powerful GPU hardware. Two-phase liquid cooling incorporating surface structuring for enhanced flow boiling represents an attractive solution to reliably meet the increasing heat density demands of current and future GPU architectures. A low chip-to-coolant thermal resistance also offers the potential for heat re-use due to a high heat capture temperature, with concomitant benefits in energy efficiency, minimizing facility water usage, and simplifying the facility cooling infrastructure.

Bio: Todd R. Salamon received the Ph.D. degree in chemical engineering from the Massachusetts Institute of Technology (MIT), Cambridge, MA, USA. He is currently a Distinguished Member of Technical Staff in the Opto-Electronic Integration Research Department, Nokia Bell Labs, Murray Hill, NJ, USA, where he has worked on thermal management, microfluidics, transport phenomena in optical fiber manufacturing, design of photonic crystal fibers, and Raman and erbium amplifier dynamics and control in transparent optical networks. He has authored over 60 publications and conference presentations and holds 36 issued or pending patents. He is the Principal Investigator on ARPA-E project titled “Delivering energy and exergy efficiency in the converged 5G RAN/EDGE compute network”, and was the Principal

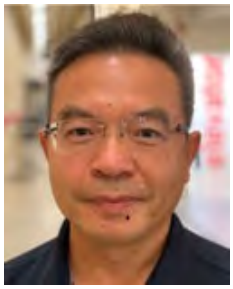
Investigator on a DOE project titled “Advanced Refrigerant-based Cooling Technologies for the Information and Communications infrastructure” to develop and commercialize refrigerant-based cooling technology targeting the Information and Communications Technology (ICT) sector.

THERMOSYPHON COOLING OF EDGE MICRO-DATACENTERS AND AI HIGH PERFORMANCE DATACENTER RACKS

Jackson Marcinichen
Founder and CEO
JJ Cooling Technologies

Abstract: Two-phase microchannel cooling has excellent high heat flux and scalable cooling characteristics, whose heat transfer coefficient increases with heat flux and whose fluid temperature is nearly isothermal from inlet to outlet. 1) For datacenters without underfloor water, a new air-cooled thermosyphon coldplate for 2U servers is described handling 450+W (four per server = 37.8kW for entire 2U air-cooled rack) with a PUE of 1.03 for 25°C. 2) An air-cooled thermosyphon for Edge Micro Datacenters is presented for 11 ComExpress cards packaged in a 3U height: PUE of 1.0 (part-load with fans off) to PUE of 1.03 at max power and architecture for up to 96 CPUs/GPUs per 3U. 3) A new passive two-phase thermal cooling system for 1U and 2U racks up to and beyond 100kW is presented.

Bio: J.B. Marcinichen is founder and CEO of JJ Cooling Innovation and has over 30 years of experience in HVAC & R systems. He received his PhD in Mechanical Engineering from the Federal University of Santa Catarina, Brazil in 2006. He has authored over 60 scientific and technical papers in indexed journals and international peer-reviewed conferences, book chapters and patents. He is mainly engaged in the development of novel hybrid cooling systems (passive and active) to cool high heat flux electronics using on-chip cooling, pulsating heat pipes and loop thermosyphons. He received the IEEE Best Paper Award at the ITHERM 2020 conference (USA, 2020).



PULSATING HEAT PIPES FOR POWER ELECTRONICS COOLING

Winston Zhang
Founder and CEO
Novark Technologies

Abstract: Pulsating heat pipes are gaining traction in numerous cooling applications, specifically where their unique characteristics make them the solution of choice. Two types of PHP units are ready for cooling of power electronics and 5G transmitters/base stations. The first is a flat plate PHP with fin pack for cooling of power electronics, either with a fan or no fan. The second is a very large thin plate with an internal PHP, set up in arrays for cooling 5G electronics boards, either passively or with a fan, with or without louvers for the air flow, that is very light weight compared to existing extruded units and has significantly higher cooling capacity. Some thermal performance test results will be shown.

Bio: L. Winston Zhang is the founder and CEO of Novark Technologies based in Shenzhen, China since 2004, and is an adjunct lecturer in the Department of Mechanical Science and Engineering at University of Illinois at Urbana-Champaign since 2022. He has over 35 years of experience in the area of heat transfer and electronics cooling. He received his Ph.D. in mechanical engineering from the University of Illinois at Urbana-Champaign in 1996. He is a licensed professional engineer (P.E.) in the State of Wisconsin, USA and a Fellow of the American Society of Mechanical Engineers (ASME), Asia Liaison

for the IEEE Annual Semiconductor Thermal Measurement and Management Symposium (SEMI-THERM), Track Co-Chair for the ASME International Technical Conference and Exhibition on Packaging and Integration of Electronic and Photonic Microsystems (InterPACK) and a board member of the Taiwan Thermal Management Association (TTMA).

P-11: Electronics Cooling for Large Scale Applications

FRIDAY, MAY 31, 2:00 – 3:30 PM, RED ROCK 10-11

Moderator: Kimberly Saviers (RTX)

Panelists: Vaidehi Oruganti (Microsoft), Ryan Enright (Seguente), Bahgat Sammakia (SUNY Binghamton), Kaz Yazawa (Purdue) and Damena Agonafer (UMD)

As electronic devices continue to evolve and scale up in complexity, efficient cooling solutions are crucial to ensure optimal performance and reliability. This panel will bring together experts to discuss cutting-edge approaches, challenges, and innovations in electronics cooling for large-scale applications. Topics will include advancements in thermal management techniques, novel cooling technologies, integration strategies, and the impact of emerging applications such as data centers, electric vehicles, and aerospace systems. With advancements in technology leading to smaller form factors and higher power densities, conventional air-cooling methods struggle to dissipate heat effectively. Alternative cooling techniques such as liquid cooling, phase change materials and advanced thermal management solutions are gaining popularity to address the growing thermal challenges in electronic devices. These innovative approaches offer improved heat dissipation capabilities, enabling electronic devices to operate more efficiently and reliably even in demanding applications.

Liquid Cooling in the Cloud – Advanced technologies to meet the challenges of newer gen AI gear

Vaidehi Oruganti
Senior Hardware Engineer
Microsoft

Abstract: Technical challenges of cooling GPUs – the HBM cooling problem and evolution of liquid cooling technologies – to bridge the gap. Standard direct liquid cooling – nearing its limit. Also will present potential solutions for Embedded In-Silicon cooling and Immersion (discussion of pros and cons).

Bio: Vaidehi Oruganti is currently a Senior Hardware Engineer at Systems Technology Team in Microsoft's Research and Development group/ CO+I CTO Office in Azure. Her research background is in high density liquid cooling technologies. As a thermal Engineer, she works on various advanced cooling technologies in datacenters such as Embedded In-Silicon Cooling (a.k.a. Microfluidics), Advanced Cold Plates for GPU cooling, Single and two-phase Immersion, and other novel technologies for efficiently cooling and powering new generation of HPC/AI Compute with the aim of developing reliable, futuristic, sustainable technologies. She works on scaling up technologies from lab-prototypes to small pilots in datacenters. In addition, she has been working on the use of chemical engineering technologies in data centers. Vaidehi also investigates various fluid chemistries and materials from the point of view of material compatibility, stability, reliability, degradation, Life Cycle Assessment, and EHS.

PASSIVE DIRECT-TO-CHIP TWO-PHASE TECHNOLOGY IN THE DATA CENTER

Ryan Enright
CTO
SEGUENTE

Abstract: Compute workloads increasingly require thermal performance exceeding air-cooling limits to manage rising heat dissipation across multiple length scales in data centers and telecom installations. Direct liquid cooling offers a solution to this thermal challenge with the main objective being the efficient extraction of heat from multiple heat sources within the servers, with the smallest thermal resistance possible, and then rejecting this heat outside the rack envelope. A promising liquid-cooling strategy is the extension of passive two-phase thermal management to rack scale that can provide high thermal performance, reliability, and advantageous total cost of ownership.

Bio: Dr. Ryan Enright is the Corporate Chief Technology Officer of SEGUENTE Inc., leading global R&D, product development, and deployment teams in the company. Prior to taking on this role, Dr. Enright was a Senior Member of Technical Staff at Nokia Bell Labs for nine years in the Efficient Energy Transfer Department. During his career, Dr. Enright's research spanned the areas of materials interface engineering, micro/nanoscale heat/mass transfer, passive heat transfer mechanisms and integrated RF, photonic and electronic thermal management. He received his B.Eng.(Hons) and PhD. degrees in Mechanical Engineering from the University of Limerick, Ireland in 2004 and 2008, respectively. He was a Research Assistant at Bell Labs (USA) from 2005-2007 during his doctoral work. After receiving his PhD., he was a SFI CTVR postdoctoral associate from 2008-2009 and a Marie-Curie postdoctoral fellow at the Massachusetts Institute of Technology from 2009-2012. Dr. Enright has (co-)authored over 100 journal and conference publications and more than 20 patent applications.

OVERVIEW OF RESEARCH RELATED TO THE THERMAL MANAGEMENT OF HETEROGENEOUSLY INTEGRATED SYSTEMS AT BINGHAMTON UNIVERSITY

Bahgat Sammakia
VP for Research
SUNY Binghamton

Abstract: Heterogeneously Integrating multiple devices into a single system result in challenging and sometimes complex thermal, electrical and reliability requirements. The team at Binghamton is developing approaches that rely on machine learning by data gathering and model verification. Such systems can then be integrated in software tools that are used to design and optimize performance. The use of this approach enables co-design of systems to include thermal, electrical and reliability considerations. Ultimately this will enable digital twinning of electronic systems.

Bio: Dr. Bahgat Sammakia is the Vice President for Research at Binghamton University. He is a Distinguished SUNY Professor and founding Director of the Small Scale Systems Integration and Packaging Center, a NY State Center of Excellence. Dr. Sammakia is also the founding Director of Energy Smart Electronic Systems, a National Science Foundation Center (IUCRC). Dr. Sammakia has spent much of his research career working to improve thermal management strategies in electronic systems at multiple scales ranging from devices to entire Data Centers. Dr. Sammakia joined the faculty of the Watson School for Engineering and Applied Science in 1998 following a fourteen-year career at IBM where he worked on research and development of organic electronic systems. He has contributed to several books on heat transfer and has over 300 peer reviewed publications related to electronic systems integration and packaging and thermal management of electronic systems. He is also the

principal investigator or co-principal investigator on several cross-disciplinary research projects and is the Co-Director of three research centers. Dr. Sammakia is a Fellow of the IEEE, the ASME and of the National Academy of Inventors. Dr. Sammakia served as Interim President for the SUNY Polytechnic Institute from January 2016 to June 2018.

IRREVERSIBLE PROCESS IN ELECTRONICS COOLING FOR EDGE, TRANSPORTATION, AND EXTREME ENVIRONMENTS

Kaz Yazawa
Purdue University

Abstract: In a few years to come, IoT and AI network tend to be edge-center hybrid. Transportation vehicles are electrified and integrating climate control simultaneously. Let us look at a toy model to design a consistent heat flow across the complexity and discuss the balance point to minimize energy use.

Bio: Mechanical and thermal energy engineer specializing in Thermo-energy technology, heat transfer, thermo-fluid dynamics, thermo-mechanical, mechanical structural and modal analysis, thermal imaging, thermal management for electronics and semiconductor packaging. He worked as a Distinguished Engineer and Thermal Architect at Sony Corp (-2009). He is now a Research Professor at Purdue University. The main research areas in academia include (1) analytical optimization of thermoelectric power generation and heat pumps with respect to cost and power density, (2) highly transient heat transfer, (3) high heat-flux heat removal, (4) conjugate thermo-fluid dynamics with heat engines, (5) electron gas heat engines, (6) wearable and conformal heat energy harvesting, (7) data analytics with AI for industrial processes. Industrial application areas of the research include consumer and professional electronics, semiconductor devices and packaging, thermal materials, thermal spreading devices, thermal characterization equipment, and electrified terrestrial and aerospace vehicles.

THERMAL MANAGEMENT CHALLENGES FOR HIGH-POWERED ELECTRONICS

Damena Agonafer
University of Maryland

Abstract: Key thermal management challenges in implementing heterogeneous integration are the heat load of different dies stacked together and thermal cross-talks. Addressing this challenge requires innovative integration and thermal management techniques to improve heat dissipation, where co-design is necessary. Furthermore, the trend towards smaller form factors and higher power densities exacerbates thermal challenges, necessitating the development of advanced cooling solutions. Emerging technologies such as in-chip two-phase, single-phase microchannel, and immersion cooling offer promising avenues for efficiently managing heat in heterogeneous integrated chips. I will discuss the need for heterogeneous integration and the challenges and barriers associated with the industry-wide implementation of these chips, including the implementation of direct-to-chip evaporative cooling, two-phase immersion cooling for servers, direct-to-chip evaporating cooling, encapsulated PCM slurry microchannel cooling, and near-junction diamond coatings and diamond substrate to reduce junction hotspots and ML approaches for Data Center Cooling.

Bio: Dr. Damena Agonafer (Ph.D., Mechanical Science and Engineering, University of Illinois Urbana-Champaign) is an Associate Professor of Mechanical Engineering and the Inaugural Clark Faculty Fellow

at the University of Maryland, College Park. He earned his PhD at the University of Illinois Urbana-Champaign, where he was supported by the Alfred P. Sloan fellowship, Graduate Engineering Minority Fellowship, and NSF Center of Advanced Materials for Purification of Water with Systems (WaterCAMPWS). After his PhD, Damena joined Professor Ken Goodson's Nanoheat lab as a Stanford University Postdoctoral Scholar in the Mechanical Engineering Department. Before joining the University of Maryland, Damena was an Assistant Professor in the Department of Mechanical Engineering at Washington University in Saint Louis. He is a Faculty member in the Center for Advanced Life Cycle Engineering (CALCE), the Maryland Energy Innovation Institute, and the Center of Risk and Reliability. He is a recipient of the Google Research Award, Sloan Research Fellowship Award, Cisco Research Award, NSF CAREER Award, ASME Early Career Award, and ASME K-16 Outstanding Early Faculty Career in Thermal Management Award. He was also one of 85 early-career engineers in the US selected to attend the 2021 National Academy of Engineering's 26th annual US Frontiers of Engineering symposium.

EPS PRESIDENT'S PANEL

CHALLENGES IN EDUCATION AND WORKFORCE DEVELOPMENT IN THE NEW CHIPS ECONOMY

FRIDAY, MAY 31, 8:00-9:00 AM, AURORA A (ECTC, LEVEL 2)

Chairs: **Patrick Thompson (Texas Instruments), Mark Poliks (Binghamton University), Jeff Suhling (Auburn University),** and **Kitty Pearsall (Boss Precision Inc.)**

The semiconductor and packaging industries are currently experiencing unparalleled growth, driven by demand in areas such as AI, transportation electrification, digital manufacturing, data centers, mobile devices, hybrid flexible electronics, virtual reality, and photonics and MEMS. This expansion has prompted substantial global investments in new fabs and packaging infrastructure, supported by government spending in North America, Europe, and Asia.

However, the parallel surge in demand for skilled labor poses a considerable challenge, with estimates indicating a threefold increase in headcount required over the next five years. The industry is seeking individuals with multidisciplinary education, ranging from technician degrees to Ph.D. degrees. The panel will explore workforce needs, industry perspectives on student preparation, global approaches to electronics packaging education, and innovative strategies to attract students to the semiconductor packaging field.

Panelists:

John Oakley
Semiconductor Research Corporation

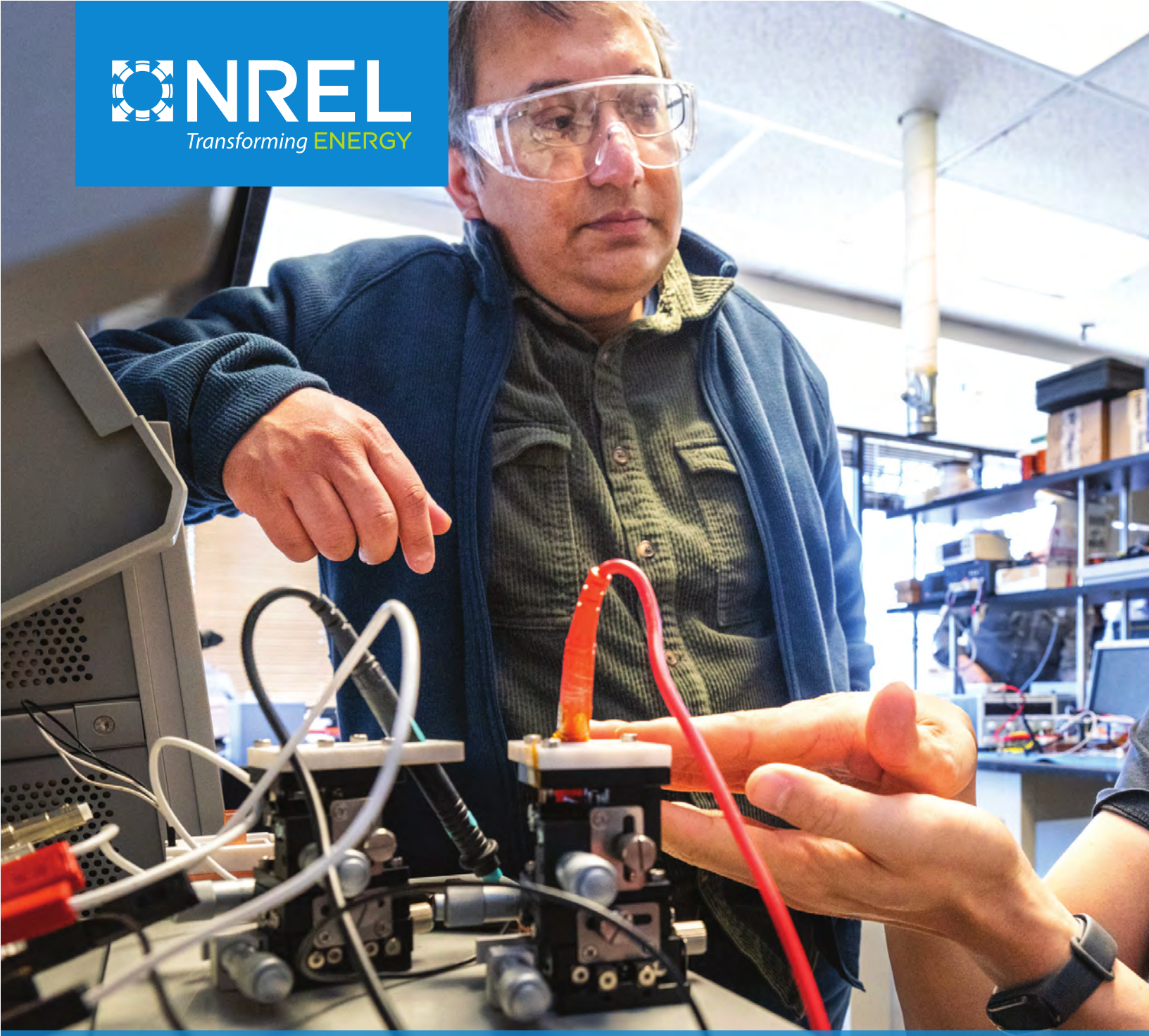
Robert Geer
SUNY Polytechnic University

Toni Mattila
Business Finland

Wenhui Zhu
Central South University

Jim Wieser
Texas Instruments

NREL
Transforming ENERGY

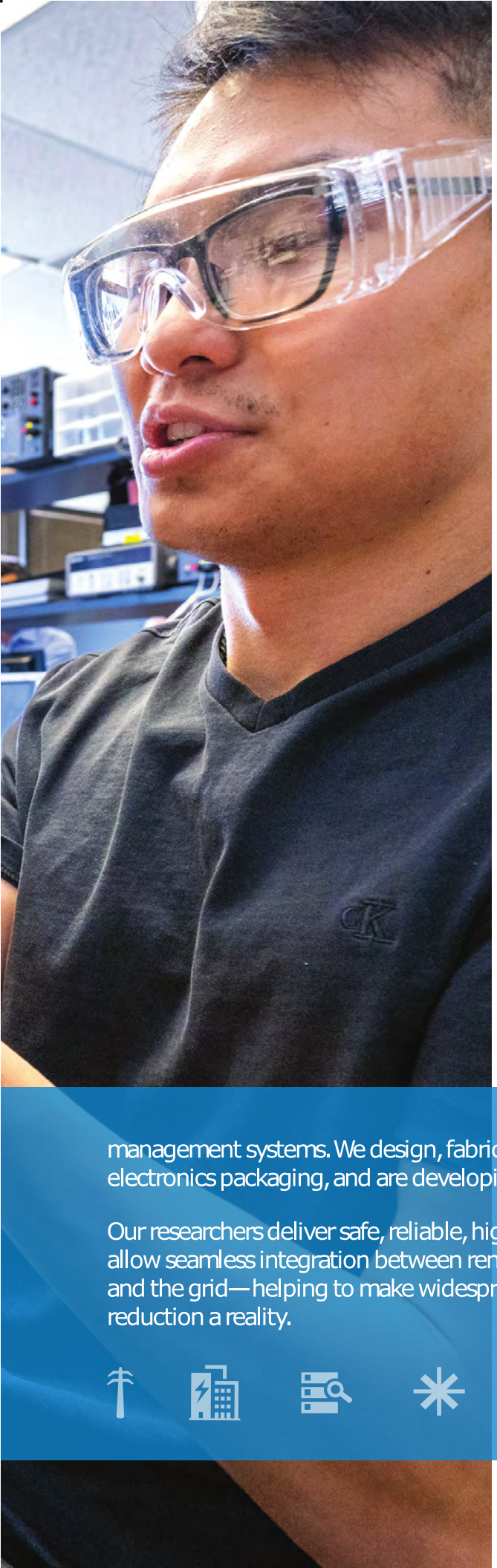


Advanced Power Electronics and Electric Machines

NREL's advanced power electronics and electric machines (APEEM) group is working to overcome the most challenging technical barriers to electric vehicle (EV) commercialization.

Our world-class experimental and modeling capabilities enable the design and demonstration of ef cient, reliable power electronics and electric machines thermal

NREL is a national laboratory of the U.S. Department of Energy, Of ce of Energy Ef ciency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.



Awards

Dozens of industry, government, society and academic awards, including an R&D 100 Award for wide-bandgap research

Publications

200+ peer-reviewed journal articles, conference papers, and book chapters

Collaboration

Nearly 100 collaborators within industry, government, labs, and academia

Expertise

15 researchers

Innovation

15 patents

management systems. We design, fabricate, and characterize advanced power electronics packaging, and are developing novel state-of-health monitoring techniques.

Our researchers deliver safe, reliable, high-performing, power-dense components that allow seamless integration between renewable energy sources, electric transportation, and the grid—helping to make widespread EV adoption and greenhouse gas emissions reduction a reality.

Learn more at

www.nrel.gov/transportation/peem.html

CONFERENCE TECHNICAL PROGRAM

TRACKS & SESSIONS

COMPONENT-LEVEL THERMAL MANAGEMENT

- TI-01 Jet Impingement and Hot Spot Management
- TI-02 Heatsinks and Coldplates I
- TI-03A Embedded Cooling
- TI-03B TIMs and Spreaders
- TI-04 Heat Pipes and Vapor Chambers I
- TI-05 Single and Two-Phase Liquid Cooling
- TI-06 Two-Phase Cooling I
- TI-07A Two-Phase Cooling II
- TI-07B Thermal Modeling and Analysis
- TI-08 Heat Pipes and Vapor Chambers II
- TI-09 Heatsinks and Codplates II
- TI-10 Packaging and Thermal Management
- TI-11 Packaging and Thermal Management II

EMERGING TECHNOLOGIES & FUNDAMENTALS

- E-01 Immersion Cooling
- E-02 Reliability of Additively Printed Electronics
- E-03 Heatpipes, Vapor Chambers and Wicks
- E-04 Novel Materials and Fabrication Techniques
- E-05 Phase Change on Enhanced Surfaces
- E-06 Sustainability and Additive Manufacturing
- E-07 Machine Learning and Predictive Analytics
- E-08 Two-Phase Cooling
- E-10 Packaging and MEMS
- E-11 Additively Printed Electronics and Two-Phase Fundamentals

SYSTEM-LEVEL THERMAL MANAGEMENT

- TII-01 Automotive, Batteries and Thermal Storage
- TII-02 Advances in Design and Modeling
- TII-03 Data Center Thermal Management I
- TII-04 Immersion Cooling and Refrigeration I
- TII-05 Thermal Management in Space and Aerospace
- TII-06 Data Center Thermal Management II
- TII-07 Immersion Cooling and Refrigeration II
- TII-08 Phase Change Materials and Novel Cooling Techniques
- TII-09A Mobile and Internet of Things
- TII-09B Thermal Management
- TII-10 Liquid Cooling Solutions

MECHANICS & RELIABILITY

- M-01 EMC Reliability
- M-02 Solder Joint Reliability and Methodologies
- M-04 Board Level Reliability
- M-05 Thermal Interface Reliability
- M-06 Board Level Reliability - BGAs
- M-08 Solder Metallurgy
- M-10 Accelerated Testing and Novel Reliability Methods

DAY 1: WEDNESDAY, MAY 29

7:00 AM	**Breakfast**				***Colorado Ballroom C-D***
8:15 AM	**TT-01 Data Centers in 2035** (see page 27) ***Red Rock 10-11***	**TI-01 Jet Impingement and Hot Spot Management** ***Willow Lake 1-2***	**TII-01 Automotive, Batteries & Thermal Storage I** ***Homestead 1***	**M-01 EMC Reliability** ***Homestead 2***	**E-01 Immersion Cooling** ***Homestead 3***
9:15 AM	**Break**				
9:30 AM	 **Keynote K1: CHIPS NAPMP and CHIPS Metrology Programs** **David A. LaVan, Program Manager, NAPMP** (see page 8 for details)				***Colorado Ballroom B***
10:30 AM	**Coffee Break**				***Colorado Prefunction***
11:00 AM	**P-02 Opportunities at the Intersection of AI and Thermal Management** (see page 38) ***Red Rock 10-11***	**TI-02 Heat Sinks and Cold Plates I** ***Willow Lake 1-2***	**TII-02 Advances in Design and Modeling** ***Homestead 1***	**M-02 Solder Joint Reliability and Methodologies** ***Homestead 2***	**E-02 Reliability of Additively Printed Electronics** ***Homestead 3***
12:30 PM	**Luncheon: Richard Chu ITherm Award Presentation (see page 11)**				***Colorado Ballroom C-D***
2:00 PM	**TT-03 Quantum Computing - Packaging and Thermal Considerations** (see page 28) ***Red Rock 10-11***	**TI-03A Embedded Cooling** ***Willow Lake 1-2***	**TII-03 Data Center Thermal Management I** ***Homestead 1***	**TI-03B TIMs and Heat Spreaders** ***Homestead 2***	**E-03 Heatpipes, Vapor Chambers and Wicks** ***Homestead 3***
3:30 PM	**Coffee Break**				***Colorado Prefunction***
4:00 PM	**P-04 Mechanics and Co-Design Opportunities** (see page 41) ***Red Rock 10-11***	**TI-04 Heat Pipes and Vapor Chambers I** ***Willow Lake 1-2***	**TII-04 Immersion Cooling and Refrigeration I** ***Homestead 1***	**M-04 Board Level Reliability** ***Homestead 2***	**E-04 Novel Materials and Fabrication Techniques** ***Homestead 3***
5:30 PM	**Student Heat Sink Design Challenge** (see page 15)				***Homestead 2***
6:30 PM	**ECTC/ITherm Diversity and Career Growth Panel and Reception** (see page 13)				***Aurora A (Level 2)***
7:30 PM	**Break**				
7:45 PM	**ASME K-16 & Journal of Electronic Packaging Meeting**				***Red Rock 10-11***

Day 1: Wednesday, May 29th 08:15 AM–09:15 AM

TI-01 Jet Impingement and Hot Spot Management

Willow Lake 1-2 Chairs: *Tiwei Wei (Purdue University), Xiangyu Li (University of Tennessee)*

08:15 AM (p29) **Experimental and Numerical Investigation of Thermal Performance of Piezoelectric Fan**; ***Ahmet Koyuncu***[1], Abdullah Berkan Erdogmus[1]; [1]*Aselsan*

08:30 AM (p51) **Heat Transfer Enhancement for Direct-on-Chip Impingement Jet Cooling Using Variable Micro Pin Fins and Tapered Impingement Cavity**; ***Akshat Hetal Patel***[1], Gopinath Sahu[1], Tiwei Wei[1]; [1]*Purdue University*

08:45 AM (p102) **Enhancement of Direct Liquid Jet Impingement Cooling Through Laser-Fabricated Micro Pin-Fins on the Chip-Backside**; ***Georg Elsinger***[1], Herman Oprins[2], Vladimir Cherman[2], Geert Van der Plas[2], Eric Beyne[2], Ingrid De Wolf[1]; [1]*KU Leuven, imec,* [2]*imec*

09:00 AM (p117) **Automated Gimbaling of Conical Nozzles for Jet Vectoring Impingement Cooling to Mitigate Workload Dependent Hotspots in High Power Density Silicon**; ***Prabhakar Subrahmanyam***[1], Sankarananda Basak[1], Vishnu Prasadh Sugumar[1], Ying-Feng Pang[1], Arunkumar Krishnamoorthy[1], Mark Bianco[1]; [1]*Intel Corporation*

TII-01 Automotive, Batteries and Thermal Storage I

Homestead 1 Chairs: *M Cynthia Hipwell (Texas A&M University), Tiwei Wei (Purdue University)*

08:15 AM (p91) **An Innovative Examination of Composite PCM Capacitor**; Michal Fadida[1], ***Motti Raizner***[1]; [1]*Rafael – advanced defense systems*

08:30 AM (p132) **Closed-Loop Analysis of Thermal Energy Storage Device Arrangement in a Thermal Management System**; ***Parikesit Pandu Dewanatha***[1], Demetrius Gulewicz[1], Neera Jain[1]; [1]*Purdue University*

08:45 AM (p296) **Predicting Cell-to-Cell Thermal Runaway Propagation in Modular Battery Energy Storage Systems**; ***Christopher Doerrer***[1], Youhan Fu[2], Carlos M. DaSilva[1], Cristina Amon[1]; [1]*University of Toronto,* [2]*eCAMION Inc.,*

09:00 AM (p333) **A Novel Framework to Design Phase Change Material Composite for Cooling of Electronic Devices**; ***Ayushman Singh***[1], Srikanth Rangarajan[1], Bahgat Sammakia[1]; [1]*SUNY Binghamton*

M-01 EMC Reliability

Homestead 2 Chairs: *John Harris (University of Arkansas)*

08:15 AM (p190) **Novel Nano-Indentation Dynamic Mechanical Thermal Analysis (NiDMTA) Technique for Characterizing Viscoelastic Properties of Polymeric Materials in Semiconductor Packages**; ***Hung-Yun Lin***[1], Siva Gurrum[1], Alexander Gamez[1], Wassie Yusuf[1]; [1]*Texas Instruments*

08:30 AM (p320) **Cohesive Zone Modeling of Chip-Uf and EMC-Substrate Interfaces in FCBGAS Subject to Thermo-Mechanical Loading**; Pradeep Lall[1], ***Aathi Raja Ram Pandurangan***[1], Padmanava Choudhury[1], Madhu Kasturi[1]; [1]*Auburn University*

08:45 AM (p328) **Effect of Temperature and Humidity Conditioning on EMC-to-Substrate Interfacial Delamination Subjected to Monotonic and Fatigue Loading**; ***Pradeep Lall***[1], Madhu Kasturi[1], Jaimal Williamson[2], Varughese Mathew[3]; [1]*Auburn University,* [2]*Texas Instruments,* [3]*NXP Semiconductor*

09:00 AM (p366) **Investigation of Fatigue Performance for Bulk Epoxy Molding Compound (EMC) in Sustained High-Temperature Environment Up to 1 Year Aging.**; ***Pradeep Lall***[1], Yunli Zhang[1], Jeff Suhling[1]; [1]*Auburn University*

E-01 IMMERSION COOLING

HOMESTEAD 3 Chairs: *Arad Azizi (Honeywell International Inc.), Srikanth Rangarajan (Binghamton University)*

08:15 AM (p120) **Unveiling the Dual Limits of Critical Heat Flux and Implications for Immersion Cooling**; ***Suhas Tamvada***[1], Daniel Attinger[2], Saeed Moghaddam[1]; [1]*University of Florida,* [2]*Struo LLC*

08:30 AM (p231) **A Research on High Speed Signal Integrity Design Optimal for Immersion Cooled Server**; ***Ying-Shan Lo***[1], Jiahong Wu[1], Liwen Guo[2], Yaling Huang[3], Tong Xu[3], Carrie Chen[1], JUN ZHANG[1], Jeff Ho[4], ALLEN LIANG[1], Xiang Mao[2]; [1]*Intel Corporation,* [2]*Shenzhen institute for Advanced Study,* [3]*Foxconn Corporation,* [4]*Intel*

08:45 AM (p247) **Thermal Performance, Stability and Material Compatibility of a New Two-Phase Immersion Fluid**; Gustavo Pottker[1], ***Abigail Van Wassen***[1], Drew Brandt[1], Xue Sha[1]; [1]*The Chemours Company*

09:00 AM (p248) **Development of a Novel Analytical Model for Liquid Synthetic Jets and Introduction of Their Application in Immersion Cooling Systems**; ***Mohammad Azarifar***[1], Faisal Ahmed[1], Muhammad Ikhlaq[2], Mehmet Arik[1]; [1]*Auburn University,* [2]*Newcastle University*

Day 1: Wednesday, May 29th 11:00 AM–12:30 PM

TI-02 Heat Sinks and Cold Plates I

Willow Lake 1-2

Chairs: *Ryan Enright (Seguente, Inc.), Anil Yuksel (Hewlett Packard Enterprise), Omidreza Ghaffari (University of Sherbrooke)*

11:00 AM (p10) **Additively Manufactured Cold Plate With Internal Phase Separator for Hybrid Two-Phase Cooling**; ***Mohammad Reza Shaeri***[1], Maksym Demydovych[1]; [1]*Advanced Cooling Technologies, Inc.*

11:15 AM (p84) **Thermal Performance of Transient Liquid Diffusion Bonded Multi-Layer Cold Plate**; ***Masahiro Matsuda***[1], Yoji Kawahara[1], Yasuhiro Hriuchi[1], Yuichiro Tahara[1], Yuji Saito[1], Toshimizu Tomitsuka[1]; [1]*Fujikura Ltd.*

11:30 AM (p151) **High Heat Flux Thermal Management Using CuW Microchannel Heat Sinks and FC3283**; ***Isabella Amyx***[1], Caleb Anderson[1], Nicole Cassada[1], Devin Funaro[2], Clint Frye[2], Salmaan Baxamusa[2], Jack Kotovsky[2], Kathy Jackson[2], Todd Bandhauer[1]; [1]*Colorado State University,* [2]*Lawrence Livermore National Laboratory*

11:45 AM (p245) **Compliant Direct Attach Liquid Cooling**; ***Mark Schultz***[1], Pritish Parida[1]; [1]*IBM T.J. Watson Research Center*

12:00 PM (p259) **Reduced Physics Modeling of Two-Phase Flow Through High-Density Cooling Structures**; ***Pritish Parida***[1], Shurong Tian[1], Mark Schultz[1], Timothy Chainer[1]; [1]*IBM T.J. Watson Research Center*

12:15 PM (p330) **Development of a Hybrid Single/Two-Phase Capillary-Based Micro-Cooler Using Copper Inverse Opals Wick With Silicon 3D Manifold for High-Heat-Flux Cooling Application**; ***Heungdong Kwon***[1], Qianying Wu[1], Daeyoung Kong[2], Sougata Hazra[1], Kaiying Jiang[1], Chulmin Ahn[3], Sreekant V.J. Narumanchi[4], Hyoungsoon Lee[2], James Palko[5], Ercan Dede[6], Mehdi Asheghi[1], Kenneth Goodson[1]; [1]*Stanford University,* [2]*Chung-Ang University,* [3]*Hyundai Motor Company,* [4]*National Renewable Energy Laboratory,* [5]*University of California, Merced,* [6]*Toyota Research Institute of North America*

TII-02 Advances in Design and Modeling

Homestead 1

Chairs: *Harish Ganapathy (Intel), Pratik Bansode (The University of Texas at Arlington)*

11:00 AM (p12) **Thermal Design & Performance of 300 Mm Wafer Scale System**; ***Evan Colgan***[1], Phillip Mann[2], Kai Schleupen[1]; [1]*IBM T.J. Watson Research Center,* [2]*IBM Systems Infrastructure*

11:15 AM (p13) **Co-Design of 300 Mm Wafer Scale Package**; ***Kai Schleupen***[1], Evan Colgan[1], Phillip Mann[2], Diego Anzola[1], Brian PEAR[1], Robert Kuder[1], James Speidell[1]; [1]*IBM T.J. Watson Research Center,* [2]*IBM Systems Infrastructure*

11:30 AM (p53) **Thermal Analysis of High Current Vertical Power Delivery Network With Embedded Microchannel Cooling**; ***Mingeun Choi***[1], Sriharini Krishnakumar[2], Ramin Khorasani[3], Inna Partin-Vaisband[2], Rohit Sharma[4], Madhavan Swaminathan[3], Satish Kumar[1]; [1]*Georgia Institute of Technology,* [2]*University of Illinois Chicago,* [3]*The Pennsylvania State University,* [4]*Indian Institute of Technology Ropar and The Pennsylvania State University*

11:45 AM (p94) **Micro-Piv Measurements Near Supercritical CO2 Conditions Inside the Channel**; Ritesh Ghorpade[1], Gihun Kim[2], ***Soroush Niazi***[1], Yoav Peles[3], Subith Vasu[4]; [1]*Student,* [2]*Postdoctoral Researcher,* [3]*Professor, Chair,* [4]*Associate Professor*

12:00 PM (p272) **Multi-Objective Design Optimization of Pin-Fin Cold Plates for Electric Vehicle Battery Packs Using Convolutional Neural Networks and Genetic Algorithms**; ***Takiah Ebbs-Picken***[1], Carlos M. DaSilva[1], Cristina Amon[1]; [1]*University of Toronto*

12:15 PM (p—) **FLIR Thermal Cameras for PCB/ASIC Thermal Analysis Including IR Microscopy**; ***Ross Overstreet***[1]; [1]*FLIR*

M-02 Solder Joint Reliability and Methodologies

Homestead 2 Chairs: *Gargi Kailkhura (Lunar Energy)*

11:00 AM (p21) **Interpretable Machine Learning Models Can Outperform Statistical Models in Solder Joint Reliability**; ***Qais Qasaimeh***[1], Haoran Li[1], Sa'd Hamasha[1], John Evans[1], Jia Liu[1]; *[1]Auburn University*

11:15 AM (p100) **Thermal Cyclic Fatigue Life Evaluation of BGA Solder Joints Using Approximate Formula for Strain Range Behavior**; ***Rintaro Okuzono***[1], Qiang Yu[1], Masahiro Kon[1], Hisataka Fukasu[2], Akihiro Takikawa[2]; *[1]Yokohama National University, [2]Komatsu Manufacturing Co.*

11:30 AM (p219) **Evaluating the Efficiency of Machine Learning Approaches for Predicting Solder Joint Characteristic Life Under Isothermal Aging and Thermal Cycling Test Conditions**; ***Soroosh Alavi***[1], Daniel Silva[1], Palash Pranav Vyas[1], Sa'd Hamasha[1]; *[1]Auburn University*

11:45 AM (p332) **Reliability of FPBGA Assemblies Under Martian Cold Thermal Cycles**; Reza Ghaffarian[1], ***Seth Gordon***[1], Thomas Sanders[1]; *[1]JPL*

12:00 PM (p373) **Prediction of the Mechanical Responses of Single Grain Lead-Free Solder Joints Using Machine Learning**; ***Debabrata Mondal***[1], Jeffrey Suhling[1], Elham Mirkoohi[1], Pradeep Lall[1]; *[1]Auburn University*

12:15 PM (p388) **Modeling of the Temperature Cycling Performance of BGA Packages With Hybrid SAC/LTS Joints and Various Bi Concentration Gradients**; ***Souvik Chakraborty***[1], Debabrata Mondal[1], Jeffrey Suhling[1], Pradeep Lall[1]; *[1]Auburn University*

E-02 Reliability of Additively Printed Electronics

Homestead 3 Chairs: *Unique Rahangdale (Rivian Automotive), Georges Pavlidis (University of Connecticut)*

11:00 AM (p321) **Reliability Assessment of Encapsulated Flexible Hybrid Electronic Assemblies Under Board-Level Drop Test**; ***Pradeep Lall***[1], Aathi Raja Ram Pandurangan[1], Md Golam Sarwar[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

11:15 AM (p323) **Repairability of Additively Printed Circuits Using Sustainable Aqueous-Based Silver Nanoparticle Ink on Polymide Substrates**; ***Pradeep Lall***[1], Daniel Karakitie[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

11:30 AM (p327) **Fabrication and Reliability Evaluation of Additively Printed Temperature and Humidity Sensor on Additively Manufactured ABS Substrate.**; ***Pradeep Lall***[1], Hyesoo Jang[1], Curtis Hill[2]; *[1]Auburn University, [2]QuaniTech Inc, Jacobs Space Exploration Group, ESSCA Contract, NASA MSFC*

11:45 AM (p345) **Screen-Printed Thermoformed Circuits Performance and Reliability Under Sustained High Temperatures for in-Mold Electronics**; ***Pradeep Lall***[1], Shriram Kulkarni[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

12:00 PM (p356) **Reliability of Additively Printed in-Mold Electronics Using ECA in Sustained High-Temperature Operation**; ***Pradeep Lall***[1], Md Golam Sarwar[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

12:15 PM (p357) **Performance Stability and Reliability of Gravure Offset Printed Thermoformed IME Circuits Subjected to Sustained High Temperature Storage**; ***Pradeep Lall***[1], Ved Soni[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

Day 1: Wednesday, May 29th 02:00 PM–03:30 PM

TI-03A Embedded Cooling

Willow Lake 1-2

Chairs: *Herman Oprins (imec), Gopinath Sahu (Purdue University), Remco Van Erp (Corintis)*

02:00 PM (p66) **Thermal Analysis of Dual-Sided Cooling for Backside Power Delivery Networks (BSPDN) on 2.5D Glass/Silicon Interposer Package**; Feifan Xie[1], ***Shuhang Lyu***[1], Tiwei Wei[1]; [1]*Purdue University*

02:15 PM (p68) **Transient Thermal Buffer for Microchannel Flow Boiling Using Gallium Phase Change Material**; ***Caleb Anderson***[1], C Lewinsohn[1], Todd Bandhauer[1]; [1]*Colorado State University*

02:30 PM (p99) **Presentation Moved to TI-11**; Friday, 02:00 PM; *Homestead 2*

02:45 PM (p127) **Thermal and Mechanical Analysis of Embedded Liquid Cooling With Microchannel and Pin-Fin Structures**; ***Risa Miyazawa***[1], Hiroyuki Mori[1], Akihiro Horibe[1]; [1]*IBM Research*

03:00 PM (p129) **Porous Liquid Metal-Based Phase Change Materials for Sustainable Thermal Buffer**; ***Seokkan Ki***[1], Seongjong Shin[2], Sumin Cho[3], Soosik Bang[2], Haejin Lee[1], Dongwhi Choi[3], Youngsuk Nam[2]; [1]*Samsung electronics Co., Ltd.,* [2]*Korea Advanced Institute of Science and Technology (KAIST),* [3]*Kyung Hee University*

03:15 PM (p257) **Presentation Moved to TI-11**; Friday, 02:30 PM; *Homestead 2*

TII-03 Data Center Thermal Management I

Homestead 1

Chairs: *Jessica Gullbrand (Intel Corporation), Anali Soto (Microsoft)*

02:00 PM (p49) **A Server-Level Test System for Direct-to-Chip Two-Phase Cooling of Data Centers Using a Low Global Warming Potential Fluid**; ***Qingyang Wang***[1], Serdar Ozguc[1], Akshith Narayanan[1], Richard Bonner[1]; [1]*Accelsius*

02:15 PM (p56) **Research of Operation Reliability on Cold Plate Liquid Solution Based on Data Center Deployment**; ***Wenbin Tian***[1], Chenglong Gui[2], Yulong Wang[2], Chen Shen[2], Bin Lin[2], Jialiang Xu[1], Zhiming Li[1], Kai Wang[1], Sandeep Ahuja[1], Nishi Ahuja[1]; [1]*Intel Corporation,* [2]*Bytedance Technology*

02:30 PM (p78) **Power Supply Unit Cooling in a High Heat Capture Ratio Liquid Cooled Datacenter Server**; David Zhou[1], ***Prabhakar Subrahmanyam***[1], Guocheng Zhang[1], Na Chen[1], Tejas Shah[1], dongrui xue[1], Yanbing Sun[1]; [1]*Intel Corporation*

02:45 PM (p183) **Compact Modeling of Distributed Flow Resistances for Data Center CFD**; ***Wei Tian***[1], Jim Van Gilder[1], Michael Condor[1]; [1]*Schneider Electric*

03:00 PM (p261) **A Heat Transfer Study of in-Direct Two-Phase Cold Plate Liquid Cooling Design for Data Center**; ***Yuehlin Tsai***[1], Jun Zhang[2], Hongxing Zhou[2], Ming Yi[2], Guilin Wang[1], Nishi Ahuja[2]; [1]*jd.com,* [2]*Intel Corporation*

03:15 PM (p303) **Effects of Datacenter Cooling Subsystems Performance on TUE: Air vs. Liquid vs. Hybrid Cooling**; ***Mark North***[1], Amit Kulkarni[1], David Haley[1]; [1]*NVIDIA*

TI-03B TIMs and Heat Spreaders

HOMESTEAD 2 Chairs: *Travis Mayberry (Raytheon), Keiji Matsumoto (IBM Research-Tokyo)*

02:00 PM (p14) **Thermal Characterization of Contemporary Electrical Insulation Materials**; ***Shanmukhi Sripada***[1], Chelsea Davis[1], Amy Marconnet[1]; [1]*Purdue University*

02:15 PM (p26) **Temperature and Pressure Dependent Thermal Interface Material Characterization Using Packaged Thermal Test Vehicle Assemblies**; ***Onur Yenigun***[1], Vladimir Cherman[2], Herman Oprins[2], Geert Van der Plas[2], Eric Beyne[2], Ingrid De Wolf[1]; [1]*KU Leuven, imec,* [2]*imec*

02:30 PM (p32) **Thermal Interface Material Analyzer Test Method Development for Gap Fillers: Simultaneous Thermal and Mechanical Stress Cycling**; ***Stephanie Valenzuela***[1], Joe Sootsman[1]; [1]*Dow Chemical Company*

02:45 PM (p44) **Fabrication and Thermal Characterization of Copper Nano-Wire (CuNWs) Thermal Interface Materials Tapes**; ***Kaiying Jiang***[1], Heungdong Kwon[1], Hansen Qiao[1], Yini He[1], Mehdi Asheghi[1], Kenneth Goodson[1]; [1]*Stanford university*

03:00 PM (p265) **Increasing Cooling Performance of Phase Change Materials With Metal Foam Structures**; ***Orkun Dogu***[1], Ahmet Koyuncu[1], Abdullah Berkan Erdogmus[1]; [1]*Aselan*

03:15 PM (p276) **Presentation Cancelled**; -; -

E-03 Heatpipes, Vapor Chambers and Wicks

HOMESTEAD 3 Chairs: *Tianli Feng (University of Utah)*

02:00 PM (p128) **An Unsteady Homogeneous Two-Phase Flow Model for Microchannel Oscillating Heat Pipes**; ***Qian Qian***[1], Md Emadur Rahman[1], Justin A. Weibel[1], Liang Pan[1]; [1]*Purdue University*

02:15 PM (p182) **Graphene-Enhanced Metal Condensers in Wick-Free Vapor Chambers for Thermal Management in Electronics**; ***Arani Mukhopadhyay***[1], Sungjoon Kim[1], Anish Pal[1], Roshan Nemade[1], Sreya Sarkar[1], Vikas Berry[1], Constantine Megaridis[1]; [1]*University of Illinois Chicago*

02:30 PM (p206) **Investigation of Flow and Thermal Performance in a Non-Uniform Channel Pulsating Heat Pipe Additively Manufactured From High-Temperature Resin**; ***Md. Jubayer Hossain***[1], Max Pawlick[1], Vu Tan Le[1], Amitav Tikadar[1], Xiangjin Zhang[1], Satish Kumar[1]; [1]*Georgia Institute of Technology*

02:45 PM (p274) **Experimental Investigation of the Heat Spreading Performance of Oscillating Heat Pipes for Electronics Cooling Applications**; ***Syed Faisal***[1], Rishav Roy[1], Sarwesh Parbat[1], David Apigo[1], Nagesh Basavanhally[1], Yang Liu[1], Mark Earnshaw[1], Todd Salamon[1]; [1]*Nokia Bell Labs*

03:00 PM (p370) **Experimental Study of a 3d-Printed Wick Condenser for Enhanced Condensation Heat Transfer**; Jay Saple[1], ***Behzad Ahmadi***[1], Mohammad Reza Shaeri[2], Sajjad Bigham[1]; [1]*North Carolina State University,* [2]*Advanced Cooling Technologies, Inc.*

03:15 PM (p372) **3d-Printed Ceramic Oscillating Heat Pipes for Improved Electronic Thermal Management**; Priom Agrawal[1], ***Behzad Ahmadi***[1], Joseph Cesarano[2], Sajjad Bigham[1]; [1]*North Carolina State University,* [2]*Robocasting Enterprises*

Day 1: Wednesday, May 29th 04:00 PM–05:30 PM

TI-04 Heat Pipes and Vapor Chambers I

Willow Lake 1-2 Chairs: *David Coenen (imec), Michael Fish (CCDC US Army Research Laboratory)*

04:00 PM (p20) **Physical Based Model of Air-Cooled Thermosyphon**; ***Po-Jui Huang***[1], Hao-Yu Lin[1], Amawasee Rukruang[1], Chi-Chuan Wang[1]; *[1]National Yang Ming Chiao Tung University*

04:15 PM (p34) **Evaluation of Vapor Chambers Incorporating Square-Shaped and Topology Optimized Pedestals**; Danny Lohan[1], Shailesh Joshi[1], ***Ercan Dede***[1]; *[1]Toyota Research Institute of North America*

04:30 PM (p46) **Optimizing the Vapor Chamber With Liquid Supply Layers for High Heat Flux Applications Using an ANN-based Multi-Objective Genetic Algorithm**; ***Soosik Bang***[1], Seungwoo Kim[1], Seokkan Ki[1], Junyong Seo[1], Jaechoon Kim[2], Bong Jae Lee[1], Youngsuk Nam[1]; *[1]Korea Advanced Institute of Science and Technology (KAIST), [2]Samsung electronics Co., Ltd.*

04:45 PM (p180) **Revolutionizing Electronic Cooling: Ultra-Short-Pulsed Laser Processed Surfaces in Wick-Free Vapor Chambers**; ***Anish Pal***[1], Arani Mukhopadhyay[1], Graham Kaufman[2], George Gogos[2], Craig Zuhlke[2], Constantine Megaridis[1]; *[1]University of Illinois Chicago, [2]University of Nebraska-Lincoln*

05:00 PM (p209) **Mitigation of Distortion in Fiber Laser Welded Ultra-Thin Vapor Chamber**; ***Joseph Ahn***[1], Haejin Lee[1]; *[1]Samsung electronics Co., Ltd.*

05:15 PM (p146) **Forced Air Cooling Thermal Design With Embedded Heat Pipes in a Heatsink for GaN-based High Power RF Amplifier Applications**; ***Abdul Baba***[1], Oliver Silva[1], Bharathidasan Sugumaran[1], Wajid Khattak[1], Mae Almansoori[1], Ahmed Alebri[1], Felix Vega[1], Chaouki Kasmi[1]; *[1]Technology Innovation Institute*

TII-04 Immersion Cooling and Refrigeration I

Homestead 1 Chairs: *Sachin Deshmukh (Intel), Ved Soni (Auburn University)*

04:00 PM (p16) **Experimental Investigation on Single-Phase Immersion Cooling Solution for Data Center Application**; ***Wenbin Tian***[1], Jianwu Zheng[2], Xiangwu Chen[2], Bing Cheng[2], Yongzhan He[2], Yipeng Zhong[1], Jiang Yu[1], Ying He[1], Lihui Wu[1], Nishi Ahuja[1]; *[1]Intel Corporation, [2]Baidu Inc.*

04:15 PM (p55) **Thermal Performance Characteristic of Single-Phase Immersion Cooling on Servers With Optimized Heatsink Design**; ***Wenbin Tian***[1], Jin Wang[2], Shoubiao Xu[2], Linghao Fan[2], Maoju Gao[2], Yan Zhao[2], Lizhi Zhou[3], Chao Zhou[1], Xiaoguo Liang[1], Nishi Ahuja[1]; *[1]Intel Corporation, [2]Tencent Cloud, [3]Inspur Electronic Information Industry*

04:30 PM (p57) **Analysis on Long Term Reliability of Single-Phase Immersion Solution Based on Data Center Deployment**; ***Wenbin Tian***[1], Yulong Wang[2], Chenglong Gui[2], Chen Shen[2], Bin Lin[2], Jialiang Xu[1], Zhiming Li[1], Kai Wang[1], Sandeep Ahuja[1], Nishi Ahuja[1]; *[1]Intel Corporation, [2]Bytedance Technology*

04:45 PM (p167) **Cooling Capability Enhancement in Single-Phase Immersion Using Targeted Flow**; ***Satyam Saini***[1], Eric McAfee[1], Casey Carte[1], Drew Damm[1], Suchismita Sarangi[1], Jessica Gullbrand[1], Mark Macdonald[1]; *[1]Intel Corporation*

05:00 PM (p176) **Server Level Impacts on CPU Cooling Capability in Single-Phase Immersion**; ***Suchismita Sarangi***[1], Satyam Saini[1], Eric McAfee[1], Jessica Gullbrand[1], Drew Damm[1], Casey Carte[1]; *[1]Intel Corporation*

05:15 PM (p185) **A Novel Design for Improving Heat Dissipation Capacity of Single-Phase Immersion Cooling System With the Perturbation Mechanism**; Po-Chien Hsu[1], Jiahong Wu[2], Chia-Lung Kuo[1], ***Carrie Chen***[2], JUN ZHANG[2], Ying-Shan Lo[2], Po-Tsang Huang[1]; *[1]National Yunlin University of Science and Technology, [2]Intel Corporation*

M-04 Board Level Reliability

Homestead 2 Chairs: *David Huitink (University of Arkansas)*

04:00 PM (p47) **The Effect of Conformal Coating on QFN Assembly Reliability: Thermal Cycling and HALT**; ***Reza Ghaffarian***[1]; [1]*JPL*

04:15 PM (p58) **Effects of Temperature on Prepreg & Glass Style in Printed Circuit Board (PCB) - Impact on Solid State Drive**; Vigneshwarram Kumaresan[1], ***Mutharasu Devarajan***[1]; [1]*Western digital corporation*

04:30 PM (p111) **Dynamic Testing and Simulation of Chassis Attached Remote Modular Heat Sink**; ***Phil Geng***[1], Ligang Wang[1], Francisco Colorado[1], Min Pei[1], Wang Chuanlou[1], John He[1], Jimmy Chuang[1], Roger Liu[1], Ralph Miele[1], Sanjoy Saha[1], Jeffory Smalley[1], Ashish Gupta[1]; [1]*Intel Corporation*

04:45 PM (p322) **Explicit FE Failure Prediction of at Potted Assemblies Under Inclined High-G Shock Loads**; ***Pradeep Lall***[1], Aathi Raja Ram Pandurangan[1], Ken Blecker[2]; [1]*Auburn University,* [2]*US Army CCDC-AC*

05:00 PM (p367) **Reliability Performance Analysis of Magnetically-Oriented ACA for Flexible and Stretchable Electronics**; ***Pradeep Lall***[1], Yunli Zhang[1], Scott Miller[2]; [1]*Auburn University,* [2]*NextFlex*

E-04 Novel Materials and Fabrication Techniques

Homestead 3 Chairs: *Tiwei Wei (Purdue University), Georges Pavlidis (University of Connecticut)*

04:00 PM (p165) **Enhancing Thermal Conductivity in Bulk Polymer-Matrix Composites**; ***Angie Rojas Cardenas***[1], Amy Marconnet[1], Chelsea Davis[2]; [1]*Purdue University,* [2]*University of Delaware*

04:15 PM (p166) **Resilient Polymer Nanocomposites for Type II Thermal Interface Materials**; ***Geeta Pokhrel***[1], John Howarter[1], Michael Wilson[1], Chelsea Davis[2]; [1]*Purdue University,* [2]*University of Delaware*

04:30 PM (p205) **Optimization of Structurally Enhanced Solder Transient Liquid Phase Bonding**; ***John Harris***[1], David Huitink[1]; [1]*University of Arkansas*

04:45 PM (p302) **Maximizing the Thermal Performance of Microheaters for Non-Volatile Phase Change Photonics: A Comparative Study of Pulse Width Parameter Effects**; ***Francis Vasquez***[1], Hongyi Sun[2], Chuanyu Lian[2], Yi-Siou Huang[2], Steven Vitale[3], Ichiro Takeuchi[2], Juejun Hu[3], Nathan Youngblood[5], Carlos A. Rios Ocampo[2], Georges Pavlidis[1]; [1]*University of Connecticut,* [2]*University of Maryland,* [3]*Massachusetts Institute of Technology,* [5]*The University of Pittsburgh*

05:00 PM (p312) **High Power Thermal Energy Storage From Ordered-Pore Additively Manufactured Phase-Transforming Nickel-Titanium Porous Cubes.**; ***Adam Wilson***[1], Mustafa Ozsipahi[1], Michael Fish[1], Darin Sharar[2], Andrew Bayba[1], Ibrahim Karaman[3], Raymundo Arroyave[3]; [1]*CCDC US Army Research Laboratory,* [2]*TauMat LLC,* [3]*Texas A&M University*

05:15 PM (p369) **PCM Heat Sinks for Chip Transient Thermal Management of GaN Electronic Chips**; ***Behzad Ahmadi***[1], Sajjad Bigham[1]; [1]*North Carolina State University*

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DAY 2: THURSDAY, MAY 30

7:00 AM	**Breakfast**				***Colorado Ballroom C-D***
8:15 AM	**TT-05 Innovations in Industrial Systems** (see page 30) ***Red Rock 10-11***	**TI-05 Power Electronics Cooling** ***Willow Lake 1-2***	**TII-05 Thermal Management in Space and Aerospace** ***Homestead 1***	**M-05 Thermal Interface Reliability** ***Homestead 2***	**E-05 Phase Change on Enhanced Surfaces** ***Homestead 3***
9:15 AM	**Break**				
9:30 AM	 **Keynote K-2: Multiscale Thermal Modeling of Electric Vehicle Batteries from Nanoscale Electrodes to Battery Pack Cooling Systems: Illustration of DeepEDH Neural Network-based Optimization of Battery Cold Plates** **Christina Amon, University of Toronto** (see page 9 for details)				***Colorado Ballroom B***
10:30 AM	**Coffee Break**				***Colorado Prefunction***
11:00 AM	**P-06 Thermal Challenges and Opportunities for Consumer Electronics/Mobile/IoT/ Auto/High Power Compute** (see page 43) ***Red Rock 10-11***	**TI-06 Two-Phase Cooling I** ***Willow Lake 1-2***	**TII-06 Data Center Thermal Management II** ***Homestead 1***	**M-06 Board Level Reliability - BGAs** ***Homestead 2***	**E-06 Sustainability and Additive Manufacturing** ***Homestead 3***
12:30 PM	**Luncheon: ITherm Sponsors and Partners**				***Colorado Ballroom C-D***
2:00 PM	**TT-07 Novel Structures and Surfaces for Enhanced Heat Transfer** (see page 32) ***Red Rock 10-11***	**TI-07A Two-Phase Cooling II** ***Willow Lake 1-2***	**TII-07 Immersion Cooling and Refrigeration II** ***Homestead 1***	**TI-07B Thermal Modeling and Analysis** ***Homestead 2***	**E-07 Machine Learning and Predictive Analytics** ***Homestead 3***
3:30 PM	**Coffee Break**				***Colorado Prefunction***
4:00 PM	**FFL Federal Funding Landscape** (see page 17) ***Red Rock 10-11***	**TI-08 Heat Pipes and Vapor Chambers II** ***Willow Lake 1-2***	**TII-08 Phase Change Materials and Novel Cooling Techniques** ***Homestead 1***	**M-08 Solder Metallurgy** ***Homestead 2***	**E-08 Two-Phase Cooling** ***Homestead 3***
5:30 PM	**Student Poster and Networking Session** (see page 20)				***Colorado Ballroom B***
7:45 PM	**ITherm 2025 Program Planning Meeting**				***Red Rock 10-11***

Day 2: Thursday, May 30th 08:15 AM–09:15 AM

TI-05 Power Electronics Cooling

Willow Lake 1-2 Chairs: *Scott Schiffres (Binghamton University), Xuhui Feng (NREL)*

08:15 AM (p189) **Droplet-Train Cooling of Electronic Substrates: Effects of Droplet Parameters, Substrate Wettability Distribution and Power Input**; Shashwata Moitra[1], ***Anish Pal***[1], Md Safwan Mondal[1], Arani Mukhopadhyay[1], Constantine Megaridis[1]; *[1]University of Illinois Chicago*

08:30 AM (p240) **An Evaluation of Microtube Array Density for Liquid Delivery in Pump-Assisted Capillary Loop Coolers**; ***Danny Lohan***[1], Bhaskarjyoti Sarma[2], Shailesh Joshi[1], Ercan Dede[1], Justin A. Weibel[2]; *[1]Toyota Research Institute of North America, [2]Purdue University*

08:45 AM (p317) **Thermal Characterization of Two-Phase Cooling Using Embedded Microchannels in a High Current Density Electric Motor**; ***Ryan Regan***[1], Kimberly Saviers[2], Wenping Zhao[2], Andrzej Kuczek[2], Jagadeesh Tangudu[2], Justin A. Weibel[1]; *[1]Purdue University, [2]RTRC*

09:00 AM (p340) **Experimental Analysis of Heat Transfer and Pressure Drop in Aluminum Metal Foams Immersed in Dielectric Synthetic Fluid**; ***Pratik Bansode***[1], Gautam Gupta[1], Vivek Nair[1], Sai Abhideep Pundla[1], Satyam Saini[1], Pardeep Shahi[1], Dereje Agonafer[1], Yilma Birhane[2], Metodi Zlatinov[3], Denver Schaffarzick[3]; *[1]The University of Texas at Arlington, [2]Addis Ababa University, [3]ERG Aerospace*

TII-05 Thermal Management in Space and Aerospace

Homestead 1 Chairs: *Matthew Harrison (Aero Corporation), Andres Sarmiento (University of Maryland)*

08:15 AM (p110) **Thermal Management of Omnimagnet for Space Debris Mitigation**; ***Mason Pratt***[1], Tim Ameel[1], Sameer Rao[1]; *[1]University of Utah*

08:30 AM (p159) **Enclosure for Data Processing Unit Electronics (DPU) With Integrated Phase-Change Thermal Capacitor for Space Applications - A Design Overview**; ***Artur Jurkowski***[1], Kamil Lysek[1], Marcin Wójcik[1], Adam Klimanek[2]; *[1]KP Labs sp. z o.o., [2]Silesian University of Technology*

08:45 AM (p214) **Design and Testing of an Efficient and Rapid Electro-Thermal Pulsed Interfacial Deicing Framework for Electrified Aircraft**; ***Alexandra Solecki***[1], Siavash Khodakarami[1], Pouya Kabirzadeh[1], Muhammad Jahidul Hoque[1], Wentao Yang[1], Nicole Stokowski[1], Joshua Jacobs[2], Edward Lovelace[2], Andrew Stillwell[1], Nenad Miljkovic[1]; *[1]University of Illinois at Urbana-Champaign, [2]Ampaire Inc.*

09:00 AM (p281) **Characterizing Critical Interfaces in a Spacebourne Rotorcraft Avionics Unit: Comprehensive Thermal Testing and Model Correlation**; ***Allison Orr***[1], Christopher Kim[1], Amelia Cherian[1]; *[1]Johns Hopkins Applied Physics Lab*

M-05 Thermal Interface Reliability

Homestead 2 Chairs: *Muhammad Ghufran (University of Arkansas), Uday Manda (University of Central Florida)*

08:15 AM (p48) **Accelerated Testing of Thermal Grease Degradation: Combined Thermal Gradients and Forced Mechanical Cycling**; ***Pranay Nagrani***[1], Amy Marconnet[1]; *[1]Purdue University*

08:30 AM (p107) **IR and Optical Imaging Technique for Stability Analysis of Thermal Interface Materials Under Accelerated Power Cycling**; ***Peter McClure***[1], Ali Davoodabadi[1]; *[1]Universal Instruments Corporation*

08:45 AM (p191) **Accelerated Test for Thermal Grease Pump-Out.**; ***Emma Gonzalez***[1], Peter Li[1], Dorab Bhagwagar[1], Trevor Ewers[1]; *[1]Dow Chemical Company*

09:00 AM (p329) **Thermal Conductivity and Interface Strength Evolution of TIM-Copper With Temperature and Humidity Conditioning**; ***Pradeep Lall***[1], Madhu Kasturi[1], Jaimal Williamson[2], Varughese Mathew[3]; *[1]Auburn University, [2]Texas Instruments, [3]NXP Semiconductor*

E-05 PHASE CHANGE ON ENHANCED SURFACES

HOMESTEAD 3 Chairs: *Luke Gregory (Omniva), Sreya Sarkar (University of Illinois Chicago)*

08:15 AM (p40) **Characterization of Enhanced Two-Phase Jet Impingement on Femtosecond Laser Surface Processed (FLSP) Aluminum Surfaces**; ***Alexander Ceperley***[1], Gopinath Sahu[1], Andrew Reicks[2], Craig Zuhlke[2], George Gogos[2], Justin A. Weibel[1]; *[1]Purdue University, [2]University of Nebraska-Lincoln*

08:30 AM (p114) **Enhancing Minichannel Flow Boiling With Femtosecond Laser Surface Processed Stainless Steel Surfaces in Water**; ***Logan Pettit***[1], Josh Gerdes[1], Andrew Reicks[1], Craig Zuhlke[1], George Gogos[1]; *[1]University of Nebraska-Lincoln*

08:45 AM (p181) **Atmospheric Water Vapor Condensation on Ultra-Short Pulsed Laser Surface-Processed Copper**; ***Arani Mukhopadhyay***[1], Anish Pal[1], Graham Kaufman[2], Craig Zuhlke[2], George Gogos[2], Ranjan Ganguly[3], Constantine Megaridis[1]; *[1]University of Illinois Chicago, [2]University of Nebraska-Lincoln, [3]Jadavpur University*

09:00 AM (p277) **Microchannel Flow Boiling Enhancement of PF-5060 With Femtosecond Laser Surface Processed 6061 Aluminum**; ***Josh Gerdes***[1], Logan Pettit[1], Andrew Reicks[1], Craig Zuhlke[1], George Gogos[1]; *[1]University of Nebraska-Lincoln*

Day 2: Thursday, May 30th 11:00 AM–12:30 PM

TI-06 Two-Phase Cooling I

Willow Lake 1-2 Chairs: *Nitin Karwa (Honeywell International Inc.), John Kim (Seguente, Inc.)*

11:00 AM (p24) **Experimental and Numerical Study of Two-Phase Immersion Cooling for High-Power Chips**; ***Cheng-Han Chiang***[1], Wei-Cheng Tan[2], Hua Chen[1], Yang-Yao Niu[2], Sheng-Yen Lin[1], Tsen-Hsuan Yen[1], Howard Chuang[1]; [1]*Wistron Corporation,* [2]*Tamkang University*

11:15 AM (p25) **Experimental Study on HFE-7000 Flow Boiling Heat Transfer in a Heat Sink With 8 Hot Spots for High-Power Defense Applications**; ***Murat Parlak***[1], Abdolali K Sadaghiani[2], Behnam Parizad Benam[2], Ali KOŞAR[2], Vedat Yağci[1], Muhammed Çağlar Malyemez[1], Mandana Mohammadilooey[2]; [1]*Aselsan Inc.,* [2]*Sabnaci University*

11:30 AM (p28) **Experimental Study on HFE-7100 Pool Boiling Heat Transfer in a Honeycomb Structures Produced by Additive Manufacturing**; ***Muhammed Çağlar Malyemez***[1], Murat Parlak[1], Vedat Yağci[1]; [1]*Aselsan Inc.*

11:45 AM (p41) **Two-Phase Immersion Cooler for Medium-Voltage Silicon Carbide MOSFETs**; Hari Pandey[1], Xinyuan Du[1], Ethan Weems[1], Stephen Pierson[1], Ahmad Al-Hmoud[1], Yue Zhao[1], ***Han Hu***[1]; [1]*University of Arkansas*

12:00 PM (p74) **Performance Assessment of Hybrid Microchannel-Pin Fin Heat Sink for Hotspot Thermal Management Under Flow Boiling Conditions**; ***Amitav Tikadar***[1], Satish Kumar[1]; [1]*Georgia Institute of Technology*

12:15 PM (p140) **Surface-Enhanced Two-Phase Cold Plate Designs for High Power Dissipation in Data Centers**; ***Haoyun Qiu***[1], Pouya Kabirzadeh[1], David Apigo[2], Sarwesh Parbat[2], Syed Faisal[2], Rishav Roy[2], Bakhshish Preet Singh[1], Todd Salamon[2], Nenad Miljkovic[1]; [1]*University of Illinois Urbana-Champaign,* [2]*Nokia Bell Labs*

TII-06 Data Center Thermal Management II

Homestead 1 Chairs: *Christina Seeholzer (HRL Laboratories), Gautam Gupta (The University of Texas at Arlington)*

11:00 AM (p15) **Air Cooling and Water Cooling for Data Center High-Speed I/O Interconnects**; ***Taolue Zhang***[1], Nabhanshul Satra[1], Jalan Salter[1], Peerouz Amleshi[1]; [1]*Molex LLC*

11:15 AM (p250) **Touch Temperature Safety Standards and Their Impact on Server Design**; ***Milnes David***[1], Felipe Valenzuela-Gaete[1], Kenneth Arenella[1], John Werner[1], Dustin Demetriou[1], Cory VanDeventer[1], John Torok[1]; [1]*IBM Corp.*

11:30 AM (p316) **Long Term Reliability Test on an Air Assisted Liquid Cooling System**; ***Yin Hang***[1], Wenying Zhang[1], Grace Piette[1], Pradip Pichumani[1], Mahendra Lokhande[1], Joseph Tseng[2], Feroz Ahamed[3], Keegan Yaroch[4], Ellie Chen[1], John Fernandes[1], Yueming Li[1], Jiu Xu[1]; [1]*Meta,* [2]*Coolermaster,* [3]*Delta Electronics,* [4]*Dow Chemical Company*

11:45 AM (p371) **Acoustics Analysis of Air and Hybrid Cooled Data Center**; Uschas Chowdhury[1], Jeremy Rodriguez[1], ***Mohammad Tradat***[1], Qusai Soud[1], Scott Wallace[1], Dennis O"Brien[1], Steven Hambruch[1], Ali Heydari[1], Vahideh Radmard[1], Pardeep Shahi[1]; [1]*NVIDIA*

12:00 PM (p414) **Novel Subcooled Boiling Chamber With Submerged Condensation for High Heat Flux Removal for Data Center Application**; ***Maharshi Y. Shukla***[1], Satish Kandlikar[1]; [1]*Rochester Institute of Technology*

12:15 PM (p416) **Maximizing Cooling Potential: A Step-by-Step Guide to Commissioning Liquid-Cooled Data Centers**; ***Pardeep Shahi***[1], Ali Heydari[1], himanshu Modi[2], Lochan Sai Reddy Chinthaparthy[2], Anto Barigala[2], Bahareh Eslami[1], Mohammad Tradat[1], Dereje Agonafer[2], Jeremy Rodriguez[1]; [1]*NVIDIA,* [2]*The University of Texas at Arlington*

M-06 BOARD LEVEL RELIABILITY - BGAS

HOMESTEAD 2 Chairs: *Yuanchen Hu (IBM Corp.)*

11:00 AM (p148) **Evaluating Shear Properties of Individual Solder Joints in Ball Grid Arrays: The Impact of Ag and Bi Content**; ***Waad Tarman***[1], Ali Alahmer[1], Sergio Bolanos[1], Shaheen Pouya[1], Abdallah Alakayleh[1], Mohamed El Amine Belhadi[1], Sa'd Hamasha[1]; *[1]Auburn University*

11:15 AM (p168) **Drop Shock Testing of BGA Test Vehicles at Elevated Temperature**; ***Palash Pranav Vyas***[1], Sergio Bolanos[1], Shaheen Pouya[1], Saddam Daradkeh[1], Mohamed El Amine Belhadi[1], Ali Alahmer[1], Sa'd Hamasha[1]; *[1]Auburn University*

11:30 AM (p178) **Effect of Isothermal Aging on Anisotropic Creep Properties of SAC305 Single Crystals**; ***Aniket Bharamgonda***[1], Abhijit Dasgupta[1], Torsten Hauck[2], Yaxiong Chen[2], Johnathan Martin[1], Yongrae Jang[1]; *[1]University of Maryland, [2]NXP Semiconductor*

11:45 AM (p196) **Aging Effect on Drop-Shock Reliability of SnAgCu305 Solder Alloy**; ***Saddam Daradkeh***[1], Palash Pranav Vyas[1], Abdallah Alakayleh[1], Mohamed El Amine Belhadi[1], Sufyan Tahat[1], Ali Alahmer[1], Sa'd Hamasha[1]; *[1]Auburn University*

12:00 PM (p361) **Study of High-G Level Shock Damage-Accrual in Doped/Undoped SAC Solders During Prolonged Sustained Operation at 100oC**; ***Pradeep Lall***[1], Vishal Mehta[1], Jeff Suhling[1], David Locker[2]; *[1]Auburn University, [2]US Army CCDC-AvMC*

12:15 PM (p365) **Investigation of the Effects of Sustained High-Temperature on the Reliability of Lead-Free Solder Joint Assemblies in Vibration**; ***Pradeep Lall***[1], Vishal Mehta[1], Jeff Suhling[1], David Locker[2]; *[1]Auburn University, [2]US Army CCDC-AvMC*

E-06 SUSTAINABILITY AND ADDITIVE MANUFACTURING

HOMESTEAD 3 Chairs: *Tiwei Wei (Purdue University), Vibin Simon (NVIDIA)*

11:00 AM (p325) **Biodegradable Substrates for Sustainable Aerosol-Jet Additively Printed Electronics**; ***Pradeep Lall***[1], Daniel Karakitie[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

11:15 AM (p346) **Performance Analysis of Screen-Printed Functional Circuits on Biodegradable PET Substrates Using Low-Temperature ECA for SMD Component Attachment**; ***Pradeep Lall***[1], Shriram Kulkarni[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

11:30 AM (p347) **Impact of Thermal Cycling on in-Mold Flexible Substrates Fabricated via Direct-Write Printing**; ***Pradeep Lall***[1], Fatahi Musa[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

11:45 AM (p351) **Advancing Sustainability in Printed Electronics: Low-Temperature Interconnects and Water-Based Ink Performance**; ***Pradeep Lall***[1], Sabina Bimali[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

12:00 PM (p353) **Performance Comparison of Sustainable and Non-Sustainable Silver Inks Through a Printed Differentiator Circuit**; ***Pradeep Lall***[1], Sabina Bimali[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

12:15 PM (p359) **Sustainability and Life Cycling Investigation of Buck Charging Circuits Printed Using Gravure Offset Printing**; ***Pradeep Lall***[1], Ved Soni[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

Day 2: Thursday, May 30th 02:00 PM–03:30 PM

TI-07A Two-Phase Cooling II

Willow Lake 1-2 Chairs: *Solomon Adera (University of Michigan), Filippo Cataldo (Wieland)*

02:00 PM (p184) **Single-Phase and Two-Phase Liquid Immersion Cooling of Data Center Power Supply Units for Heat Capture**; ***Haoyun Qiu***[1], Pouya Kabirzadeh[1], Vivek S. Garimella[1], Arjit Bali[1], Keerthivasan Gurusami[1], Kang Joon Lee[1], Andrew Stillwell[1], Todd Salamon[2], Nenad Miljkovic[1]; [1]*University of Illinois Urbana-Champaign,* [2]*Nokia Bell Labs*

02:15 PM (p202) **Experiments and Modeling of Two-Phase Cooled IGBT Module for Rail Transit Applications**; Weiwei Gan[1], ***Zhaozan Feng***[2], Hui Wu[1], Liangjie Liu[2], Bin Liu[2], Chengxi Li[2]; [1]*Zhuzhou CRRC Times Electric Co.,Ltd,* [2]*Zhuzhou CRRC Times Electric UK Innovation Center*

02:30 PM (p226) **Effect of Micro-Channel Cross-Section and Coolant Pressure on Two-Phase Cooling**; ***Pritish Parida***[1]; [1]*IBM T.J. Watson Research Center*

02:45 PM (p235) **Thermal Management of Multiple High-Heat-Flux Heat Sources Using Additively Manufactured Two-Phase Cold Plate**; ***Mohammad Reza Shaeri***[1], Maksym Demydovych[1]; [1]*Advanced Cooling Technologies, Inc.*

03:00 PM (p315) **An Integrated Simulation Framework for Thermal-Mechanical Performance Analysis of Two-Phase Microchannel Evaporators**; ***Sarwesh Parbat***[1], David Apigo[1], Haoyun Qiu[2], Pouya Kabirzadeh[2], Rishav Roy[1], Syed Faisal[1], Nenad Miljkovic[2], Todd Salamon[1]; [1]*Nokia Bell Labs,* [2]*University of Illinois at Urbana-Champaign*

03:15 PM (p393) **Thermal Characterization of a Two-Phase Integrated Heat Sink With Different Heat Source Locations**; ***Roberta Perna***[1], Mohamed Hasan[1], Ahmed Elkholy[1], Jason Durfee[2], Roger Kempers[1]; [1]*York University,* [3]*Magna Internaitonal Inc*

TII-07 Immersion Cooling and Refrigeration II

Homestead 1 Chairs: *Kanan Pujara (NVIDIA), Arad Azizi (Honeywell International Inc.)*

02:00 PM (p221) **High Heat Flux Investigation of Copper-Nickel Alloys in R-1233zd(E) Pool Boiling**; ***Shau Wai Cheng***[1], Sumit Sharma[1], Cho-Hsin Yang[1], Chin-Shiang Shih[2], Yu-Lin Chung[2], Chi-Chuan Wang[1]; [1]*National Yang Ming Chiao Tung University,* [2]*Metal Industries Research & Development Centre*

02:15 PM (p236) **Immersion Oil Thermal Performance Characteristics and Comparisons**; ***Yuanchen Hu***[1], Milnes David[1]; [1]*IBM Corp.*

02:30 PM (p237) **An Advanced 48U Single Phase Immersion Cooling System Design for Commercial Data Center Deployments**; ***Allen Liang***[1], Brant Chang[2], Jimmy Chang[2], Jun Zhang[1], Jiahong Wu[1], Carrie Chen[1], Tang Hu[3], QingYi Kong[3]; [1]*Intel,* [2]*Inventec Corporation,* [3]*OPPO*

02:45 PM (p251) **Simulation Study of Single-Phase Immersion Cooling of a Single Server and a Cluster of Servers in a Tank**; ***Milnes David***[1], Pranay Nagrani[2], Anil Yuksel[1], Yuanchen Hu[1]; [1]*IBM Corp.,* [2]*Purdue University*

03:00 PM (p287) **Low Electrical Conductivity Glycol Coolants as Alternative to Perfluorinated Fluids for Electronics Cooling Applications**; Carter Prokesch[1], ***Sreya Dutta***[1], Satish Mohapatra[1]; [1]*Dynalene Inc.*

03:15 PM (p291) **CFD Evaluation of Electrochemical Additively Manufactured Heatsinks for Single-Phase Immersion Cooling**; ***Joseph Herring***[1], Jacob Lamotte-Dawaghreh[1], Gautam Gupta[1], Dereje Agonafer[1], Joseph Madril[2], Tim Ouradnik[2], Michael Matthews[2], Ian Winfield[2]; [1]*The University of Texas at Arlington,* [2]*Fabric8Labs*

TI-07B THERMAL MODELING AND ANALYSIS

HOMESTEAD 2 Chairs: *Rachel McAfee (US Army Research Laboratory), Risa Miyazawa (IBM Corp.), Shrivani Pandiya (Université de Sherbrooke)*

02:00 PM (p31) **Accelerating Thermal Analysis of Chiplet Designs by Embedding FANTASTIC BCI-ROMs in CFD Models**; Byron Blackmore[1], ***John Wilson***[1]; [1]*Siemens DISW*

02:15 PM (p62) **Micro Scale Phosphor Particles in an LED Package: Heat Transfer, Fluid Dynamics, Optical Characteristics**; Erphan Safdari[1], ***Mehmet Arik***[2], Altug Melik Basol[1], Mete Budakli[1]; [1]*Ozyegin University,* [2]*Auburn University*

02:30 PM (p149) **Modeling of Backside Power Delivery and Thermal Management in Semiconductor Die Packages**; ***Zekun Wu***[1], Xin Zhang[2], Shurong Tian[2], Ashwin Kidambi[1], Justin A. Weibel[1], Liang Pan[1]; [1]*Purdue University,* [2]*IBM T. J. Watson Research Center*

02:45 PM (p150) **Numerical Investigation of Flow Boiling in Fin-Enhanced Microgaps Using an Improved Lee Model**; Ammar Osman[1], ***Yogendra Joshi***[1]; [1]*Georgia Institute of Technology*

03:00 PM (p—) **Lights Speed FEA Simulations for Thermal Distributions of Large Scale 3DIC Packages Using XSim**; ***Jianping Xun***[1]; [1]*DG Claim*

03:15 PM (p232) **The Study on Improving CFD Simulation Accuracy for Heat Sink Design Optimization in Single-Phase Immersion Cooling System**; Jiahong Wu[1], ***Carrie Chen***[2], Pang Wei[3], Jun Zhang[1], Ying-Shan Lo[1], Checa Hung[1], Liwen Guo[4], Monica Zhang[5], Grace Yang[5], Jacky Wang[6], Wenming Zheng[3]; [1]*Intel,* [3]*China Telecom Cloud Technology Co.,Ltd.,* [4]*Shenzhen institute for Advanced Study, UESTC,* [5]*Foxconn Corporation,* [6]*Jotactic Automotive Consulting Corporation*

E-07 MACHINE LEARNING AND PREDICTIVE ANALYTICS

HOMESTEAD 3 Chairs: *Gautam Gupta (The University of Texas at Arlington), Vibin Simon (NVIDIA)*

02:00 PM (p195) **Image Driven Deep Learning Based Compact Model to Predict Critical Heat Flux in Direct Immersion Cooling via Pool Boiling**; ***Pranay Nirapure***[1], Ayushman Singh[1], Srikanth Rangarajan[1], Bahgat Sammakia[1]; [1]*Binghamton University*

02:15 PM (p243) **Physics-Informed Neural Network on Thin Film Evaporation**; ***Amirmohammad Jahanbakhsh***[1], Rojan Firuznia[1], Sina Nazifi[1], Hadi Ghasemi[1]; [1]*University of Houston*

02:30 PM (p249) **Applied Machine Learning for Enterprise SSDs Operating Curve Predictions**; ***Chaolun Zheng***[1], Hedan Zhang[1], Li Chen[1], Ning Ye[1]; [1]*Western digital corporation*

02:45 PM (p264) **Modeling Flow Boiling Utilizing Machine Learning Vision Data**; ***Cho-Ning Huang***[1], Sang Hyeon Chang[2], Youngjoon Su[2], Yoonjin Won[2], Chirag Kharangate[1]; [1]*Case Western Reserve University,* [2]*University of California, Irvine*

03:00 PM (p398) **CFD Surrogates for Data Center Sustainability Using 3D U-Net Convolutional Neural Network**; ***Soumyendu Sarkar***[1], Antonio Guillen-Perez[1], Zachariah Carmichael[1], Avisek Naug[1], Vineet Gundecha[1], Ricardo Luna[1], Ashwin Ramesh Babu[1], Cullen Bash[1]; [1]*Hewlett Packard Enterprise*

03:15 PM (p406) **Detection of Cooling Operational Statuses in Data Center Energy Management Using Clustering Algorithms**; ***Vlatko Milic***[1], Maria Andersson[2], Linus Kåge[2], Patrik Thollander[1], Jim Enkel[3], Bahram Moshfegh[1]; [1]*Linköping University and University of Gävle,* [2]*Linköping University,* [3]*Ericsson AB*

Day 2: Thursday, May 30th 04:00 PM–05:30 PM

TI-08 Heat Pipes and Vapor Chambers II

Willow Lake 1-2 Chairs: *Kevin McCarthy (PCKA), Aalok Gaitonde (Purdue University)*

04:00 PM (p278) **Dependence of Oscillation Frequencies on Operating Conditions in an Oscillating Heat Pipe**; ***Rishav Roy***[1], Sarwesh Parbat[1], Todd Salamon[1]; [1]*Nokia Bell Labs*

04:15 PM (p284) **Enhancing Predictive Capabilities of Pulsating Heat Pipes (PHPs) Through Validation With Diverse Configurations**; Michael Bialocur[1], André Seuret[1], Jackson Marcinichen[1], ***John R. Thome***[1]; [1]*JJ Cooling Innovation SARL*

04:30 PM (p297) **Comparison of Cooling Methods for Underground Electric Vehicle Chargers**; ***Siddhesh Shinde***[1], Gautham Ram Chandra Mouli[1], Chiara Falsetti[1], Pavol Bauer[1]; [1]*Delft University of Technology*

04:45 PM (p342) **Thermal Behavior and Visualization of Electrochemical Additive Manufactured Copper Lattice Wicks in a Flat Heat Pipe**; ***Mohamed Hasan***[1], Roberta Perna[1], Ian Winfield[2], Michael Matthews[2], Joseph Workman[2], Jason Durfee[3], Roger Kempers[1]; [1]*York University,* [2]*Fabric8Labs,* [3]*Magna Internaitonal Inc*

05:00 PM (p—) **Infrared Innovations: Newest Developments in High Performance Thermal Imaging at Telops**; ***Vince Morton***[1]; [1]*Telops*

TII-08 Phase Change Materials and Novel Cooling Techniques

Homestead 1 Chairs: *Solomon Adera (University of Michigan), Xiang Zhang (Oregon State University)*

04:00 PM (p23) **Thermal Performance of 0.7mm-Thick Ultra-Thin Vapor Chambers With Composite Mesh-Groove Wick**; Kuan-Wei Tseng[1], Shwin-Chung Wong[1], ***Chih-Yuan Fu***[2], Lian-Qi Huang[2], Chih-Chao Hsu[3], Chung-Yen Lu[3]; [1]*National Tsing Hua University,* [3]*National Chung-Shan Institute of Science & Technology*

04:15 PM (p98) **Comparison of Single and Dual Orifice Synthetic Jets for Flow Structure and Heat Transfer**; ***Faisal Ahmed***[1], Mohammad Azarifar[1], Muhammad Ikhlaq[2], Mehmet Arik[1]; [1]*Auburn University,* [2]*Dyson Institute of Engineering and Technology*

04:30 PM (p204) **Experimental Measurements of the Effective Thermal Conductivity and Contact Resistance of Compressed and Uncompressed Metal Foam for Applications to Cold Plates**; ***Bolape Alade***[1], Alfonso Ortega[1], Metodi Zlatinov[2], Denver Schaffarzick[2]; [1]*Villanova University,* [2]*ERG Aerospace*

04:45 PM (p225) **Methodology to Evaluate the Thermal Performance of the Encapsulated Phase Change Materials Based Nanofluid Coolant**; ***Muhammad Ghufran***[1], David Huitink[1]; [1]*University of Arkansas*

05:00 PM (p234) **Analysis of Additively Manufactured Phase Change Heatsinks for Transient Thermal Management**; ***Michael Manno***[1], Cole Lahmann[1]; [1]*Johns Hopkins Applied Physics Lab*

05:15 PM (p412) **Design and Characterization of a Thermal Test Vehicle With Embedded Phase Change Material**; ***Meghavin Bhatasana***[1], Amy Marconnet[1]; [1]*Purdue University*

M-08 SOLDER METALLURGY

HOMESTEAD 2 Chairs: *Paul Paret (National Renewable Energy Laboratory)*

04:00 PM (p130) **The Effect of Bi Content and Strain Rate on Tensile Properties of SnAgCu-Bi Alloys**; ***Sergio Bolanos***[1], Ali Alahmer[1], Abdallah Alakayleh[1], Shaheen Pouya[1], Palash Pranav Vyas[1], Mohamed El Amine Belhadi[1], Sa'd Hamasha[1]; *[1]Auburn University*

04:15 PM (p177) **Shear Strength Analysis of Aging SAC-Bi Solder Joints With Different Solder Paste Volumes**; ***Shaheen Pouya***[1], Sergio Bolanos[1], Sufyan Tahat[1], Waad Tarman[1], Mohamed El Amine Belhadi[1], Ali Alahmer[1], Sa'd Hamasha[1]; *[1]Auburn University*

04:30 PM (p192) **Microhardness Analysis of Reflowed Solder Joints: Effect of Paste Alloy and Paste Volume**; ***Abdallah Alakayleh***[1], Sufyan Tahat[1], Mohamed El Amine Belhadi[1], Sergio Bolanos[1], Saddam Daradkeh[1], Waad Tarman[1], Qais Qasaimeh[1], Ali Alahmer[1], Sa'd Hamasha[1]; *[1]Auburn University*

04:45 PM (p354) **Effects of Combined Isothermal Aging and Mechanical Cycling Exposures on the Mechanical Behavior of Lead Free Solder Alloys**; ***Mahbub Alam Maruf***[1], Golam Rakib Mazumder[1], Souvik Chakraborty[1], Jeffrey Suhling[1], Pradeep Lall[1]; *[1]Auburn University*

05:00 PM (p379) **Characterization of the Mechanical Response and Microstructure of iSAC Lead-Free Solder**; ***Golam Rakib Mazumder***[1], Mahbub Alam Maruf[1], Souvik Chakraborty[1], Jeffrey Suhling[1], Pradeep Lall[1]; *[1]Auburn University*

05:15 PM (p402) **Constitutive Behaviors for Sn58Bi, Sn57Bi-1Ag and Other Low Temperature Alloys**; ***Sean Y. Lai***[1], Lijia Xie[1], Sukshitha Achar P. L.[1], Morgana Ribas[2], John Blendell[1], Carol Handwerker[1], Ganesh Subbarayan[1]; *[1]Purdue University, [3]MacDermid Alpha Electronics Solutions*

E-08 TWO-PHASE COOLING

HOMESTEAD 3 Chairs: *Sreya Sarkar (University of Illinois Chicago), Luke Gregory (Omniva)*

04:00 PM (p61) **Embedded Microchannel Cryogenic Cooling for Silicon Crystal Monochromators Using Liquid Nitrogen and Liquid Argon**; ***Tiwei Wei***[1], Lin Zhang[2], Mehdi Asheghi[3], Kenneth Goodson[3]; *[1]Purdue University, [2]SLAC National Accelerator Laboratory, [3]Stanford university*

04:15 PM (p64) **Direct-on-Chip Hotspot Targeted Microjet Cooling for Ultra-Fast Inference at Scale Running on Groq Language Processing Unit (LPU™)**; Feifan Xie[1], ***Shuhang Lyu***[1], Zhi Yang[2], Tiwei Wei[1]; *[1]Purdue University, [2]Groq Inc*

04:30 PM (p82) **The Impact of Liquid Supply Delivery Methods on the Thermal Performance of a Capillary-Based Two-Phase Micro-Cooler for the Power Electronics**; ***Yujui Lin***[1], Heungdong Kwon[1], Hao Chen[2], Man Prakash Gupta[3], Michael Degner[3], Mehdi Asheghi[1], Alan Mantooth[2], Kenneth Goodson[1]; *[1]Stanford University, [2]University of Arkansas, [3]Ford Motor Company*

04:45 PM (p158) **Pulsed Flash Boiling for High Heat Flux Electronics Cooling**; ***Rishi Pugazhendhi***[1], Timothy S. Fisher[1], Subramanian S. Iyer[1]; *[1]University of California Los Angeles*

05:00 PM (p174) **Pseudo-Boiling of CO2 Inside a Parallel-Flow Microchannel and an Array of Micro Jets Impingement Device**; ***Pranzal Ahmed***[1], Stephen Adeoye[1], Anatoly Parahovnik[1], Uday Manda[1], Yoav Peles[1]; *[1]University of Central Florida*

05:15 PM (p405) **Capillary Suction for Evaporative Cooling**; Sylvie Lorente[1], ***Xuewei Zhang***[1]; *[1]Villanova University*

DAY 3: FRIDAY, MAY 31

7:00 AM	**Breakfast** *Colorado Ballroom C-D*				
8:00 AM	**IEEE EPS President's Panel: Challenges in Education and Workforce Development in the New Chips Economy** (see page 53, ends at 9:00 AM) *Aurora A (Level 2)*				
8:15 AM	**TT-09 Coolants for High Performance Computing and Industrial Systems – Challenges and Advances** (see page 35) *Red Rock 10-11*	**TI-09 Heat Sinks and Cold Plates II** *Willow Lake 1-2*	**TII-09A Mobile and Internet of Things** *Homestead 1*	**TII-09B Thermal Management** *Homestead 2*	
9:15 AM	**Break**				
9:30 AM	 **Keynote K-3: How Generative AI and Accelerated Compute is Creating the Next generation Liquid Cooled Data Centers with focus on Challenges, Opportunities and the Road Ahead** **Ali Heydari, Distiguished Engineer, NVIDIA** (see page 10 for details) *Colorado Ballroom B*				
10:30 AM	**Coffee Break** *Colorado Prefunction*				
11:00 AM	**P-10 Two-Phase Electronics Cooling** (see page 47) *Red Rock 10-11*	**TI-10 Packaging and Thermal Management** *Willow Lake 1-2*	**TII-10 Liquid Cooling Solutions** *Homestead 1*	**M-10 Accelerated Testing and Novel Reliability Methods** *Homestead 2*	**E-10 Packaging and MEMS** *Homestead 3*
12:30 PM	**Luncheon: ITherm Awards and Organizer Recognition** *Colorado Ballroom C-D*				
2:00 PM	**P-11 Electronics Cooling for Large Scale Applications** (see page 50) *Red Rock 10-11*			**TI-11 Packaging and Thermal Management** *Homestead 2*	**E-11 Additively Printed Electronics and Two-Phase Fundamentals** *Homestead 3*

Day 3: Friday, May 31st 08:15 AM–09:15 AM

TI-09 Heat Sinks and Cold Plates II

Willow Lake 1-2 Chairs: *Rinaldo Miorini (GE Research), Manohar Bongarala (Nokia Bell Labs)*

08:15 AM (p50) **Thin Form Factor Tunable Cold-Plates and Locking Tensioner Cooling Assemblies for Next Generation Memory Modules**; ***Prabhakar Subrahmanyam***[1], Ying-Feng Pang[1], Vishnu Prasadh Sugumar[1], Tong Wa Chao[1], Ridvan Sahan[1]; [1]*Intel Corporation*

08:30 AM (p69) **Hydraulic Performance Analysis of an Additively Manufactured Multipass Microchannel Heat Exchanger**; ***Zhengda Yao***[1], Andres Sarmiento[1], Amir Shooshtari[1], Hugh Bruck[1], Michael Ohadi[1]; [1]*University of Maryland*

08:45 AM (p169) **Study of Aluminum Foam Material for Heat Dissipation of Heat Source at Varying Heat Generation**; ***Ethan Trulson***[1], Gerardo Carbajal[1], Edwar Romero-Ramirez[1], Younggil Park[1], Emily Geiger[1]; [1]*Florida Polytechnic University*

09:00 AM (p384) **Investigation of Rib Characteristics in Structured Cooling Channels**; Arturo Garcia[1], ***Shadi Mahjoob***[1]; [1]*California State University Northridge*

TII-09 Mobile and Internet of Things

Homestead 1 Chairs: *Phil Geng (Intel Corporation), himanshu Modi (The University of Texas at Arlington)*

08:15 AM (p108) **Experimental Analysis and Measurement of Hotspot Location With Thermal Test Vehicle in Mobile SOC**; ***Youngsang Cho***[1], Heonwoo Kim[1], Wonsik Shin[1], Jun So Pak[1], Seungwook Yoon[1]; [1]*Samsung electronics Co., Ltd.*

08:30 AM (p164) **Digital Twin in Manufacturing: Transient Thermo-Mechanical Simulations**; ***Alireza Ameli***[1], Markus Mäkeläinen[1], Jari Huttunen[1], Davide Frigerio[2], Andreas Rydin[2], Kelvin Qin[2]; [1]*Nokia,* [2]*ANSYS*

08:45 AM (p228) **Robust Pothole Detection in Adverse Weather Conditions Using Thermal Imaging and Image Processing**; ***Pathmanaban P***[1], Gnanavel B K[2]; [1]*SRM Easwari Engineering College,* [2]*SRM Institute of Science and Technology,*

09:00 AM (p399) **Thermal Testing and Analysis of on-the-Market Smartwatches**; ***Guy Wagner***[1], Kevin Ibarra[1], Amith Mathew[1]; [1]*Electronic Cooling Solutions, Inc.*

TII-09B Thermal Management

Homestead 2 Chairs: *Vivek Nair (The University of Texas at Arlington), Karthik Kumar (Amazon)*

08:15 AM (p121) **Ultrathin Blowers: A Study on Parameters Influencing Flow and Thermal Performance in Notebook Applications**; ***Ravishankar Srikanth***[1], Amit Kumar[1], Arnab Sen[1]; [1]*Intel Corporation*

08:30 AM (p271) **Experimental and Numerical Study of Thin Vapor Chambers for Dual Heat Sources in Gaming Notebooks.**; ***Ritu Bawa***[1], Chethan Holla[1], Ravishankar Srikanth[1], Doddi Raghavendra[1], Manash Lekharu[2]; [1]*Intel Corporation,* [2]*IIT Bhilai*

08:45 AM (p282) **Modularized Thermal and Mechanical Cold Plate Based High Power Memory Liquid Cooling Solution**; ***Yuehong Fan***[1], Xiang Que[1], Wang Chuanlou[1], Ming Zhang[1], Yanbing Sun[1], Qing Jiang[1], Jinbo Li[2], Guangzhi Liu[3], Shaonan Jiang[2], Xiaowei Zhang[2]; [1]*Intel Corporation,* [2]*IEI System*

09:00 AM (p295) **Cold Plate Liquid Cooling Solution for Hot-Swapped Components in Server System**; ***Yuehong Fan***[1], Guocheng Zhang[1], Yanbing Sun[1], Na Chen[1], Jinbo Li[2], Guangzhi Liu[2], Shaonan Jiang[2], Xiaowei Zhang[2]; [1]*Intel Corporation,* [2]*IEI System*

Day 3: Friday, May 31st 11:00 AM–12:30 PM

TI-10 Packaging and Thermal Management

Willow Lake 1-2 Chairs: *Aakrati Jain (IBM Research), Muhammad Ikhlaq (Newcastle University), Prabudhya Chowdhury (IBM Research)*

11:00 AM (p116) **3D Modeling and Mitigation Strategies in the Thermal Runaway of Single-Cell and Modular Lithium-Ion Batteries Architectures**; ***Jiajun Xu***[1], Faridreza Attarzadeh[2], Tanjee Afreen[2]; [1]*University of the District of Columbia,* [2]*UDC CAMSTAR*

11:15 AM (p139) **Immediate Thermal Evaluation of Power Modules Independent of the Number and Placement of Chips**; ***Sudo Tomoya***[1], Gakuto Hiraoka[1], Qiang Yu[1], Wei Liu[2], Mitsutoshi Muraoka[2], Yuji Komatsu[2]; [1]*Yokohama National University,* [2]*ZF Japan Co., Ltd*

11:30 AM (p199) **Thermal Management and Integrated Heat Spreader Assembly Challenges of Products With Variable Die Heights**; ***Arifur Chowdhury,***[1], Krishna Vasanth Valavala[1], Amitesh Saha[1], Sergio A Chan Arguedas[1], Shenavia S Howell[1], Peng Li[1]; [1]*Intel Corporation*

11:45 AM (p242) **Accurate Temperature Prediction of Complex Die Power Maps Using Quadtree Based Surrogate**; ***John Wilson***[1]; [1]*Siemens DISW*

12:00 PM (p275) **Multi-Resolution Method for Thermal Resistance Matrix Based on 2D Haar Wavelet**; ***Heeseok Lee***[1], Jun So Pak[1], Kisu Joo[1], Heonwoo Kim[1], Youngsang Cho[1]; [1]*Samsung Electronics*

12:15 PM (p306) **3d-Ic in-Design Thermal Analysis and Optimization**; ***Li Lu***[1], Jinbiao Zhu[1], Yixing Li[1], Anand Nagarajan[1], Jarod Liu[1], Shinyu Shiau[1], Xin Ai[1]; [1]*Cadence Design Systems*

TII-10 Liquid Cooling Solutions

Homestead 1 Chairs: *Adam Wilson (US Army Research Laboratory), Palash Acharya (Qualcomm)*

11:00 AM (p54) **Hydrothermal Characteristics of P2P Loop With Ribbed Spiral Channel in Evaporator**; Shyy-Woei Chang[1], Shu-Jung Tsai[1], ***Tzu-An Wang***[1]; [1]*National Cheng Kung University*

11:15 AM (p71) **The Study of Liquid Cooling Solution on 51.2T Switch**; ***Yaoyin Fan***[1], peng Xiao[1], Yan Liu[1]; [1]*Celestica*

11:30 AM (p72) **The Study on Cold Plate Liquid Cooling Solution for High Performance Server**; ***Yaoyin Fan***[1], Liang Ji[1], Colin Yu[1], Minquan Fang[1]; [1]*Celestica*

11:45 AM (p211) **System-Level Assessment of Green Refrigerant Replacements for Direct-to-Chip Two-Phase Cooling**; Ali Heydari[1], ***Omar Al-Zu'bi***[2], Yaman Manaserh[1], Mehdi Mehrabikermani[3], Farzaneh Hosseini[2], Jeremy Rodriguez[1], Bahgat Sammakia[2]; [1]*Nvidia,* [2]*Binghamton University,* [3]*Villanova University*

12:00 PM (p227) **CFD Study of Electrochemical Additive Manufacturing Based Cold Plate Designs for Enhanced Electronics Cooling**; ***Jacob Lamotte-Dawaghreh***[1], Joseph Herring[1], Gautam Gupta[1], Dereje Agonafer[1], Joseph Madril[2], Tim Ouradnik[2], Ian Winfield[2], Michael Matthews[2]; [1]*The University of Texas at Arlington,* [2]*Fabric8Labs*

12:15 PM (p410) **Liquid to Refrigerant Cooling System Challenges, Characterization, and Operational Limits: A Case Study**; Ali Heydari[1], ***Qusai Soud***[1], Mohammad Tradat[1], Ahmad Gharaibeh[1], Pardeep Shahi[1], Bahareh Eslami[1], Uschas Chowdhury[1], Bahgat Sammakia[1], Jeremy Rodriguez[1]; [1]*Nvidia*

M-10 ACCELERATED TESTING AND NOVEL RELIABILITY METHODS

HOMESTEAD 2 Chairs: *Phil Geng (Intel Corporation)*

11:00 AM (p186) **Pool Boiling Reliability Tests and Degradation Mechanisms of Microporous Copper Inverse (CuIOs) Structures**; ***Kaiying Jiang***[1], Daeyoung Kong[2], Kiwan Kim[2], Sreekant V.J. Narumanchi[3], James Palko[4], Ercan Dede[5], Chulmin Ahn[6], Hyoungsoon Lee[2], Mehdi Asheghi[1], Kenneth Goodson[1]; *[1]Stanford University, [2]Chung-Ang University, [3]National Renewable Energy Laboratory, [4]University of California, Merced, [5]Toyota Research Institute of North America, [6]Hyundai Motor Company*

11:15 AM (p309) **Altering Electromigration Response in Aluminum Wire Bonds Through Heat Treatment**; ***Whit Vinson***[1], Frida Torres[1], David Huitink[1]; *[1]University of Arkansas*

11:30 AM (p349) **Development and Performance Evolution of Thermoformed in-Mold Gravure Offset Printed Band-Pass Filters Due to Thermal Cycling**; ***Pradeep Lall***[1], Padmanava Choudhury[1], Ved Soni[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

11:45 AM (p350) **Assessment and Comparison of Interface Fracture Toughness in Potting/Substrate Material Systems Using ENF and CNF Bi-Material Specimen**; ***Pradeep Lall***[1], Padmanava Choudhury[1], Aathi Raja Ram Pandurangan[1], Ken Blecker[2]; *[1]Auburn University, [2]US Army CCDC-AC*

12:00 PM (p407) **Reliability Analysis of Sintered Silver (S-Ag) for Die Attachment Using a Four-Point Cyclic Isothermal Bend Test Approach at High Temperature and Strain Rates**; ***Saroj Majakoti***[1], Mohammad Bakhtiyar[1], David Huitink[1]; *[1]University of Arkansas*

12:15 PM (p170) **Quantile-Based LSTM Remaining Useful Life Prediction of MOSFETs**; ***Yonatan Saadon***[1], Noam Auslander[2], Patrick McCluskey[1]; *[1]University of Maryland, [2]Wistar*

E-10 PACKAGING AND MEMS

HOMESTEAD 3 Chairs: *Tianli Feng (University of Utah)*

11:00 AM (p17) **Performance Enhancement of Advanced Integrated Circuits via CVD Diamond Embedding in a Chip**; Danny Lipovitch[1], ***Shye shapira***[2]; *[1]Intel, [2]Phononics*

11:15 AM (p188) **Experimental Thermal Characterization of Thin Film Low-K Dielectric Materials**; ***Herman Oprins***[1], Vladimir Cherman[1], Bjorn Vermeersch[1], Xinyue Chang[2], Valeria Founta[2], Youqi Ding[2], Federica Luciano[2], Christoph Adelmann[1], Zsolt Tokei[1]; *[1]imec, [2]KU Leuven, imec*

11:30 AM (p258) **Predicting Accurate Hot Spots in a More Than Ten-Thousand-Core GPU With a Million-Time Speedup Over FEM Enabled by a Physics-Based Learning Algorithm**; Lin Jiang[1], Yu Liu[2], ***Ming-Cheng Cheng***[2]; *[1]Hong Kong University of Science and Technology, [2]Clarkson University*

11:45 AM (p298) **Static and Dynamic Thermal Modelling of Si Photonic Thermo-Optic Phase Shifter**; ***David Coenen***[1], Minkyu Kim[1], Herman Oprins[1], Kristof Croes[1], Peter De Heyn[1], Joris Van Campenhout[1], Ingrid De Wolf[2]; *[1]imec, [2]KU Leuven, imec*

12:00 PM (p299) **Important Factors in the Design of Systems Containing a MEMS Sensor and ASIC in Relation to a Variable Temperature Environment**; ***Jacek Nazdrowicz***[1], Mariusz Jankowski[1]; *[1]Lodz University of Technology*

12:15 PM (p308) **Changes in the Response of an Inertial MEMS Sensor Due to Changes in the Temperature of the Working Environment.**; ***Jacek Nazdrowicz***[1], Mariusz Jankowski[1]; *[1]Lodz University of Technology*

Day 3: Friday, May 31st 02:00 PM–03:30 PM

TI-11 Packaging and Thermal Management II

Homestead 2 Chairs: *Rinaldo Miorini (GE Research), Darin Sharar (TauMat LLC)*

02:00 PM (p99) **Embedded Cooling to Meet the 2kW Thermal Design Power of HPC Chips in the Future**; ***Jianyu Feng***[1], Chuan Chen[1], Rong Fu[1], Liqiang Cao[1], Qidong Wang[1], Fengze Hou[1]; *[1]Institute of Microelectronics of the Chinese Academy of Sciences*

02:15 PM (p160) **The Model and Influence Factors of Thermal Interaction in Chiplet 2.5D Integration**; ***Jianyu Feng***[1], Chuan Chen[1], Rong Fu[1], Liqiang Cao[1], Qidong Wang[1]; *[1]Institute of Microelectronics of the Chinese Academy of Sciences*

02:30 PM (p257) **Embedded Manifold Microchannel Cooling for Chiplet Thermal Management**; ***Guoran Lu***[1], Yuxin Ye[1], Jie Wang[1], Binbin Jiao[1], Yanmei Kong[1], Ruiwen Liu[1]; *[1]Institute of Microelectronics of the Chinese Academy of Sciences*

02:45 PM (p408) **Novel Programmable Package-Level 3D Thermal Evaluation System**; ***Suresh Parameswaran***[1], Gamal Refai-Ahmed[1], Suresh Ramalingam[1], Jonathan Chang[1], Saravanan Balakrishnan[1]; *[1]AMD*

E-11 Additively Printed Electronics and Two-Phase Fundamentals

Homestead 3 Chairs: *Sreya Sarkar (Stealth Startup), Gautam Gupta (The University of Texas at Arlington)*

02:00 PM (p326) **Development of in-Mold Integration of EDA Sensors via Additive Printing**; ***Pradeep Lall***[1], Hyesoo Jang[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

02:15 PM (p348) **Process-Performance Interaction of in-Mold Electronics for Signal Processing Applications**; ***Pradeep Lall***[1], Fatahi Musa[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

02:30 PM (p358) **Development and Performance Evaluation of Additively Printed in-Mold-Electronic Sensors**; ***Pradeep Lall***[1], Ved Soni[1], Scott Miller[2]; *[1]Auburn University, [2]NextFlex*

02:45 PM (p79) **Modification of Flow Boiling Regimes and Mechanisms in Near-Critical Flows**; ***Trevor Whitaker***[1], Sameer Rao[1]; *[1]University of Utah*

03:00 PM (p103) **Transport Mechanisms Governing the Evaporation of a Sessile Droplet in Its Pure Vapor Environment**; ***Erdem Omer Demirci***[1], Osman Akdag[1], Yigit Akkus[1]; *[1]Aselsan Inc.*

03:15 PM (p294) **Assessment of Bubble Pump Model for Fluid Directional Motion From Asymmetric Heated Ratchets**; ***Fnu Gutta Prudhvi Reddy***[1], Ramuel Safarkoolan[1], Sushil Bhavnani[2], Vinod Narayanan[1]; *[1]University of California Davis, [2]Auburn University*

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Abstracts Due: September 16, 2024

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Important Dates

Abstract Deadline:	**Sept. 16, 2024**
Notification of Acceptance:	Oct. 14, 2024
Draft Paper Submission:	Dec. 16, 2024
Reviews Returned:	Feb. 3, 2025
Final Paper Submission:	Mar. 3, 2025

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The IEEE ITherm Conference is the leading international conference for scientific and engineering exploration of thermal, thermomechanical, and emerging technology issues associated with electronic devices, packages, and systems. ITherm 2025 will be a physical conference held along with the 75th ECTC. Joint ITherm/ECTC registrations will be available at a significant discount. All abstracts are followed by full papers to be peer reviewed and published in the IEEE Xplore ITherm proceedings. Student first authors will have the opportunity to apply for ITherm travel grants, covering registration and 1 to 3 nights stay at the conference hotel, in order to participate in the Student Poster and Networking Session. ITherm 2025 will also feature keynotes by prominent speakers, vendor exhibits, panel discussions, invited technology talks, ECTC/ITherm joint networking events and short courses, an art-in-science exhibition, and a student design competition. Original papers are solicited in the following areas of interest:

Component-Level Thermal Management

- 3D Packaging & Heterogeneous Integration
- Package-Integrated Thermal Management
- Embedded Cooling
- Hotspot and Impingement Cooling
- Thermal Interface Materials and Heat Spreaders
- Thermoelectric and Peltier Devices
- Heat Pipes, Vapor Chambers and Thermosyphons
- Single / Two-Phase Cold Plates and Heat Sinks
- RF and Power Electronics
- LEDs, Photovoltaics, and Optoelectronics
- Thermal Management of Electric Machines
- Pulsed Power Dissipation

System-Level Thermal Management

- Air Cooling Techniques and Heat Exchangers
- Liquid Cooling Solutions
- Immersion Cooling and Refrigeration
- Pumps, Compressors, Fans, and Blowers
- Phase Change Materials
- Automotive, Batteries, and Thermal Storage
- Mobile and Internet of Things
- Telecommunication Systems
- Space and Aerospace
- Data Center Thermal Management
- Thermal Management in Electric Aircraft
- Modeling of Complex Thermal Systems
- Next-Gen Electronics Systems Co-Design

Mechanics and Reliability

- Thermo-Mechanical Modeling and Simulation
- Mechanics and Reliability of Solder Joints and Interconnects
- Materials Characterization, Processing, and Models
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- Accelerated Stress Testing and Modeling
- Lifetime Prognostics and Condition Monitoring

Emerging Technologies and Fundamentals

- Boiling, Evaporation, and Condensation
- Convection in Microchannels, Microgaps, and Jets
- Pulsating / Oscillating and Non-Conventional Heat Pipes
- Nanoscale and Transistor-Level Thermal Transport
- Novel Materials and Fabrication Techniques
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- Grand Lodge Level
- Guest Room Wings
- Convention Center
- Restaurants
- Lower Level

- Front Desk
- Valet
- Bell Service
- Restrooms
- Elevator
- Stairs
- Escalator
- ATM, Reverse ATM & Parking Pay Station

FOOD + DRINK

1. Mountain Pass Sports Bar *(Grand Lodge)*
2. Old Hickory Steakhouse *(Grand Lodge)*
3. Embers Lodge Bar *(Grand Lodge)*
4. The Fortunate Prospector *(Grand Lodge)*
5. Cantina Montaña *(Lobby Level)*
6. Rockies Marketplace *(Lobby Level)*
7. Cocoa Bean *(Lobby Level)*
8. Arapahoe Springs Bar & Grill
9. Dive Delights *(Arapahoe Springs)*
10. Lazy Horse Trailer Bar & Grill *(Grand Lodge Lawn)*

RECREATION

- Relâche Spa *(Lower Level)*
- Fitness Center *(Lower Level)*
- Sunrise Yoga *(Sunrise Lawn)*
- Arapahoe Spring Water Park
- Arcade *(Lower Level)*
- Recreation Area *(Tennis Court, Putting Green, Pickle Ball Court, Basketball Court)*
- Topgolf Swing Suites *(Located in Mountain Pass)*

AMENITIES

- Ride Share Pick Up
- Firepit/Fireplace
- Games Lawn *(Bocce Ball, Corn Hole, Lawn Chess Access via Arapahoe Springs)*
- Grand Lodge Lawn

GIFT SHOPS

- Rockies Trading Post
- Relâche Boutique

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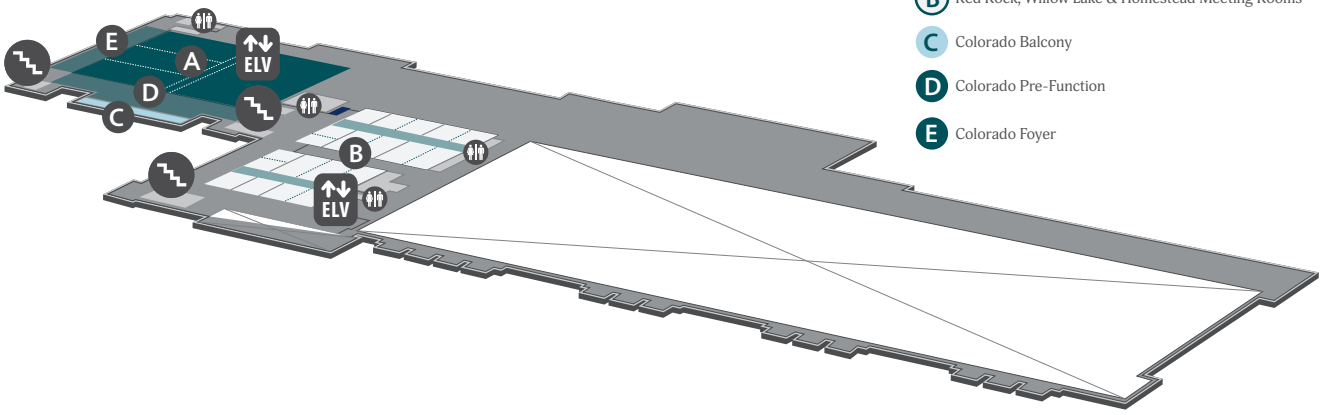
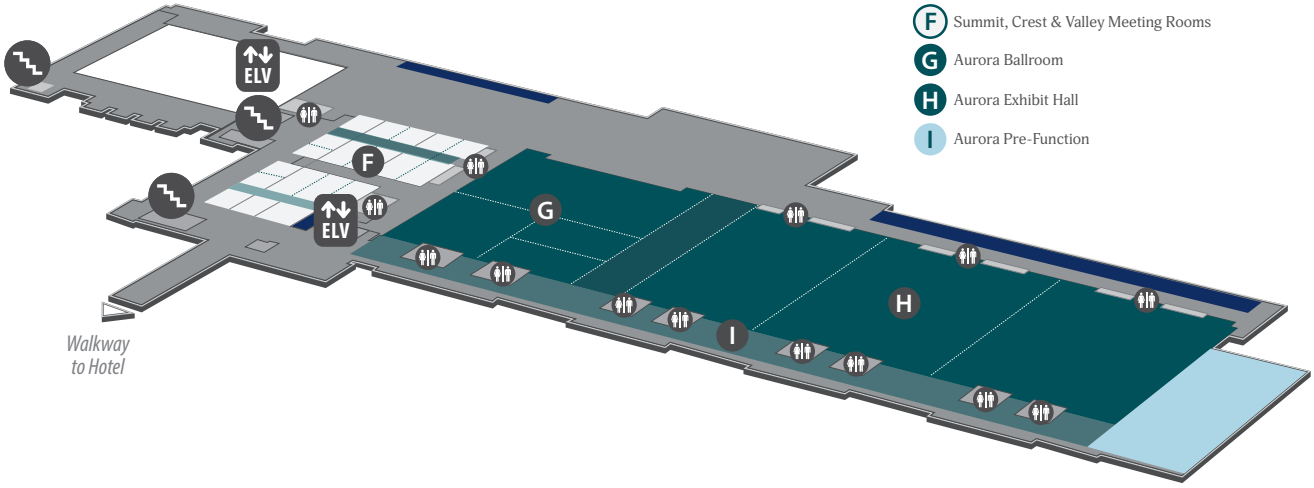


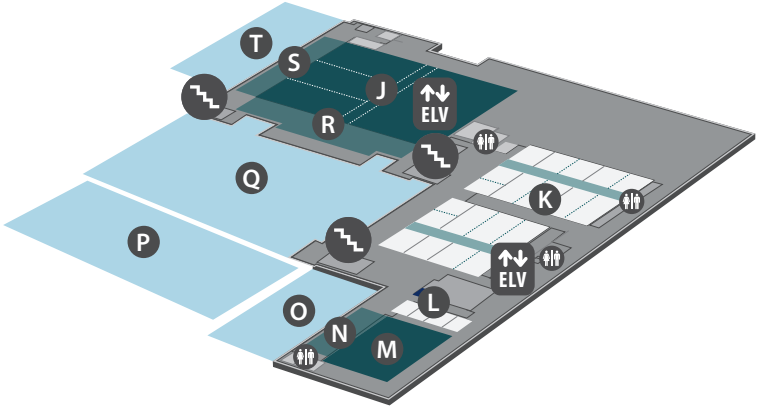
- A Colorado Ballroom
- B Red Rock, Willow Lake & Homestead Meeting Rooms
- C Colorado Balcony
- D Colorado Pre-Function
- E Colorado Foyer

Aurora Ballroom & Exhibit Hall - Level 2



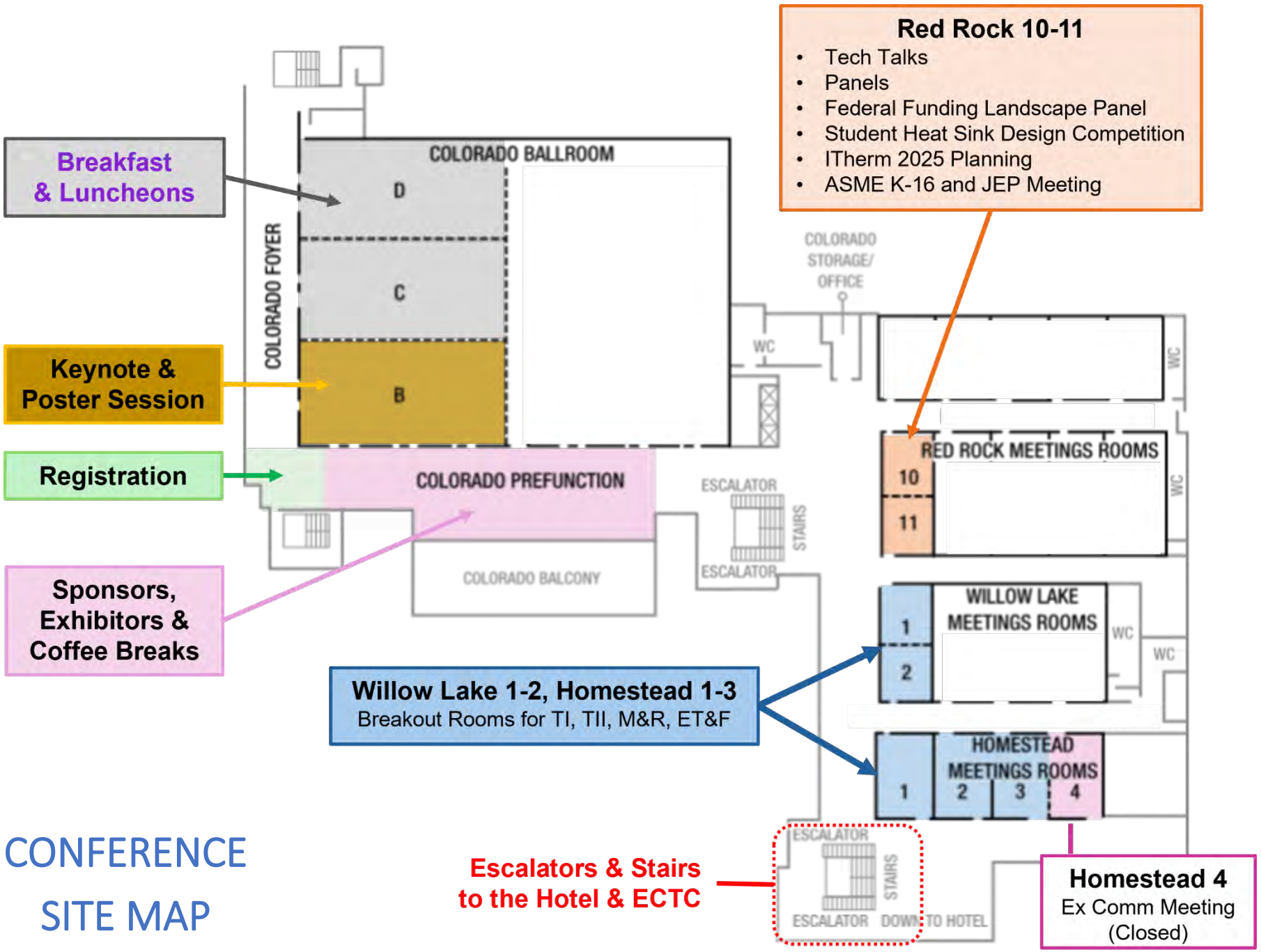
- F Summit, Crest & Valley Meeting Rooms
- G Aurora Ballroom
- H Aurora Exhibit Hall
- I Aurora Pre-Function

Adams & Juniper Ballrooms - Level 1



- J Adams Ballroom
- K Cottonwood, Maple & Spruce Meeting Rooms
- L Aspen Boardroom, Breckenridge, Vail & Telluride Meeting Rooms
- M Juniper Ballroom
- N Juniper Pre-Function
- O Juniper Lawn
- P Mountain View Pavilion & Lawn
- Q Front Range Lawn
- R Adams Pre-Function
- S Adams Foyer
- T Adams Terrace

CONFERENCE SITE MAP



CONFERENCE PROGRAM OVERVIEW

Day-0: Tuesday, May 28, 2024

8:00 - 12:00	12:00 - 1:30	1:30 - 5:30
ECTC/ITherm Joint Professional Development Courses (PDC)	Luncheon for PDC Course Attendees	ECTC/ITherm Joint Professional Development Courses (PDC)
HIR Workshop		
Registration (11:00 am - 5:00 pm)		

Day-1: Wednesday, May 29, 2024

7:00 - 8:15	8:15 -9:15		9:30-10:30		11:00 - 12:30	12:30 - 2:00	2:00 - 3:30		4:00 - 5:30	5:30 - 6:20	6:30 - 7:30		7:45 - 9:00
Breakfast	TI-01	BREAK	K-1 Keynote	COFFEE BREAK	TI-02	**Luncheon** Richard Chu ITherm Award Presentation	TI-03A	COFFEE BREAK	TI-04	Student Heat Sink Design Challenge	ECTC / ITherm Diversity & Career Growth Panel and Reception	BREAK	ASME K-16 and Journal of Electronic Packaging Meetings (open)
	TII-01				TII-02		TII-03		TII-04				
	M-01				M-02		TI-03B		M-04				
	E-01				E-02		E-03		E-04				
	TT-01				P-02		TT-03		P-04				
							ITherm Sponsors & Exhibits						
Registration (6:30 am - 5:30 pm)													

Day-2: Thursday, May 30, 2024

7:00 - 8:15	8:15 -9:15		9:30-10:30		11:00 - 12:30	12:30 - 2:00	2:00 - 3:30		4:00 - 5:30	5:30 - 7:00	7:00 - 8:00	
Breakfast	TI-05	BREAK	K-2 Keynote	COFFEE BREAK	TI-06	**Luncheon** ITherm Sponsors and Partners	TI-07A	COFFEE BREAK	TI-08	Student Poster Networking Session and Reception	ITherm 2025 Program Planning (open)	ITherm Organizers' Dinner (by Invitation)
	TII-05				TII-06		TII-07		TII-08			
	M-05				M-06		TI-07B		M-08			
	E-05				E-06		E-07		E-08			
	TT-05				P-06		TT-07		Fed. Funding Landscape			
			ITherm Sponsors & Exhibits				ITherm Sponsors & Exhibits					
Registration (7:00 am - 5:30 pm)												

Day-3: Friday, May 31, 2024

7:00 - 8:15	8:15 -9:15		9:30-10:30		11:00 - 12:30	12:30 - 2:00	2:00 - 3:30
Breakfast	TI-09	BREAK	K-3 Keynote	COFFEE BREAK	TI-10	**Luncheon** ITherm Awards & Organizer Recognitions	
	TII-09A				TII-10		
	TII-09B				M-10		TI-11
					E-10		E-11
	TT-09				P-10		P-11
			ITherm Sponsors & Exhibits				
Registration (7:00 am - 12:00 pm)							

Legend:	
TI: Component Thermal	Keynote
TII: System Thermal	Special Events
M: Mech & Reliabiltiy	Meetings
E: Emerging Tech.	PDCs
TT: Tech Talks	P: Panels

ITherm DENVER, CO 2024