The 22nd Intersociety Conference on Thermal and Thermomechanical Phenomena in Electronic Systems

ITherm

ORLANDO, FL

2023

JW Marriott Grande Lakes
Orlando, FL
May 30 – June 2, 2023

WELCOME LETTER

On behalf of the organizing committee, it is a great pleasure to welcome you to ITherm 2023, 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 2023 is once again being held along with the 73rd Electronic Components and Technology Conference (ECTC), a premier electronic packaging conference.

ITherm 2023 is packed with many activities, including over 140 Technical Papers across 4 Technical Tracks, 3 Keynote Talks addressing the topics of transformation of data centers from air to liquid cooling, innovative chiplet integration technologies, and thermal control and protection challenges for space mission; 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; 4 Technology Talk Sessions providing deep dive talks on high profile topics; a Research 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 2023 ASME/K-16 and IEEE/EPS Student Heat Sink Design Competition; 16 Professional Development Course; and Vendor Exhibits. ITherm 2023 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 on, including a Young Professionals Networking Panel on Tuesday evening and the EPS President's Panel on Friday morning. On Wednesday evening, ITherm and ECTC will jointly host the 2023 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 and diversify 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 tremendous 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 thank them for their sponsorship.

Many thanks go to everyone who has contributed to the success of ITherm 2023. We know all this organization is above your regular everyday responsibilities and it is highly appreciated. We would like to thank our track chairs and co-chairs, session chairs/co-chairs, panel/technology talk organizers, and many others. Last but not least, the support of our Executive Committee is highly appreciated. A complete list of key contributors is listed later in this program.

Thank you for participating in the ITherm 2023 conference. 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 2023 will be held in Orlando, Florida, USA on May 30 – June 2, 2023, and we hope that you mark your calendars to be there as well. Please join us for the ITherm 2023 Program Planning meeting (open to all) to volunteer. Like never before we appreciate the dedication of this community and are eager to see you all again.

Satish Kumar
General Chair

Ashish Gupta
Program Chair

Amy Marconnet
Vice Program Chair

Milnes David
Communications Chair

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CONFERENCE DESCRIPTION

Sponsored by the IEEE's Electronics Packaging Society (EPS), ITherm 2023 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 2023 will be held along with the 73rd Electronic Components and Technology Conference (ECTC 2023 - http://www.ectc.net), a premier electronics packaging conference at the JW Marriott Grande Lakes (Orlando, FL). Joint registration for ITherm and ECTC is offered at a substantial discount.

CONFERENCE SUMMARY

- **Access to over 140 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 Transformation of Data Centers from Air to Liquid Cooling, Innovative Chiplet Integration Technologies for HPC and AI Hardware Systems, and Space Mission Thermal Control and Protection Challenges – Past, Present, and Future.
- **Richard Chu ITherm Award and Seminar**
- **4 Technology-Talks** providing deep dive talks on high profile topics
- **Research Workshop** with representatives from government funding agencies.
- **5 Panels** discussing the latest industry challenges and trends
- **52 Student Posters** showcasing the latest research in an interactive networking environment
- **Student Heat Sink Design Challenge**
- **ECTC/ITherm Joint Diversity Panel**
- **16 Professional Development Courses** offered as a collaboration with ECTC
- **Heterogeneous Integration Roadmap (HIR) All-Day Sessions**

GENERAL INFORMATION

REGISTRATION

Location: JW Marriott Grande Lakes, Orlando, FL, Outside of Del Lago (Lower Level)

Opening Hours:

Tuesday, May 30 — 3:30 PM – 5:30 PM
Wednesday, May 31 — 6:30 AM – 5:30 PM
Thursday, June 1 — 7:00 AM – 5:30 PM
Friday, June 2 — 7:00 AM – 12:00 PM

Conference Registration Includes:

- Admission to All Conference Sessions
- Luncheons (Wednesday/Thursday/Friday)
- Digital Conference Proceedings

Fees (Onsite Registration)	IEEE Member	Non-Member	Student Member	Student Non-Member
Joint ITherm/ECTC Registration	1,250 USD	1,500 USD		
ITherm Registration	800 USD	950 USD	450 USD	540 USD
One-Day Registration	600 USD	720 USD		

Speakers: On the day of your talk/session, please attend the Speakers' Breakfast in Palazzo Salon F and G from 7:00-7:45 AM to meet your session chairs and go over session procedures.

MISCELLANEOUS INFORMATION

HOTEL AMENITIES

JW Marriott Orlando, Grande Lakes features:

- Luxury resort, located on a lush, 500-acre property.
- New Grande Lakes Water Park featuring a lazy river; Headwaters Slide Tower with three waterslides.
- Hotel Airport Shuttle: Not Provided, around 20 min drive.
- Transportation included to SeaWorld, Universal Studios, and Disney theme parks.
- Several Restaurants and Starbucks.
- Enhanced in-room wireless internet included for up to six (6) devices.
- Baggage will be stored at no charge for early arrivals and late departures.

GENERAL EMERGENCY INFORMATION

Security Personnel respond to all emergencies 24 hours. Security On-Duty extension is 4357 with Direct Line: +1 (407)-393-4357. Safety & Security Emergency extension line is 88. Mike Kikas served as director of security has (321) 354-5995 as Manager on Duty number.

COMMITTEE MEETINGS

ITherm EXECUTIVE COMMITTEE

Thursday June 1st 4:30 to 5:30 PM.
Amarante 1 (Lower Level)
By invitation only.

ASME K-16 COMMITTEE AND JOURNAL OF ELECTRONIC PACKAGING

Wednesday May 31st 7:30 to 9:00 PM.
Amarante (Lower Level)
Open to Committee Members and to all interested in becoming involved.

ITherm 2024 PROGRAM PLANNING

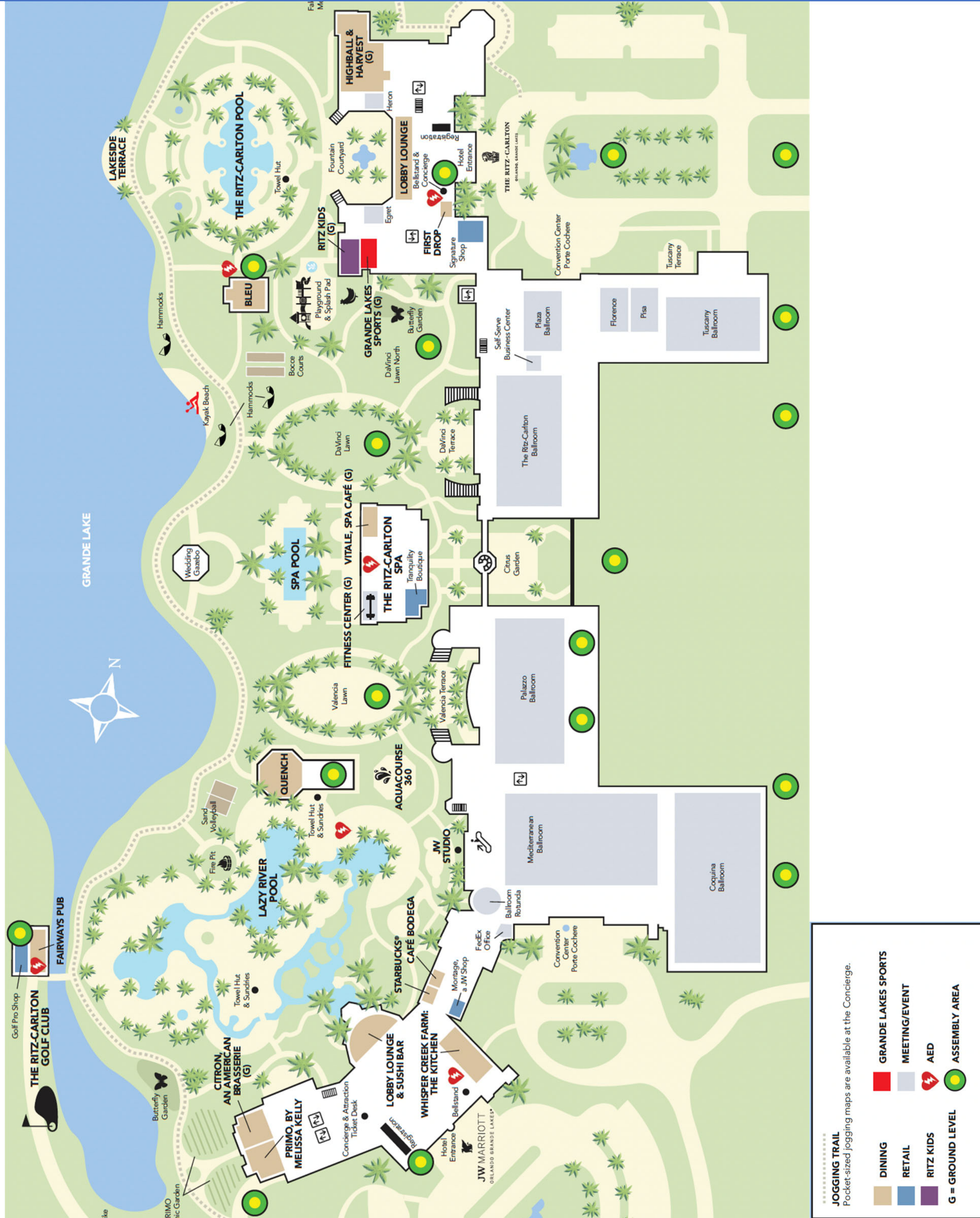
Thursday June 1st 7:00 to 8:00 PM.
Amarante (Lower Level)
Open to all current and future contributors.

ITHERM 2023 ORGANIZERS' DINNER

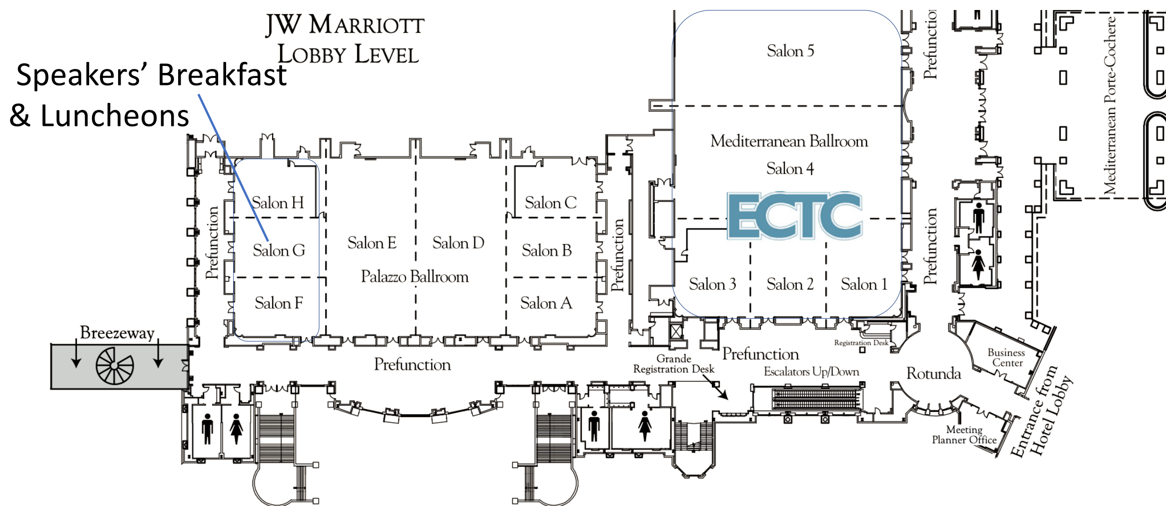
Thursday June 1st 8:00 to 10:00 PM.
By invitation only.

CONFERENCE SITEMAP

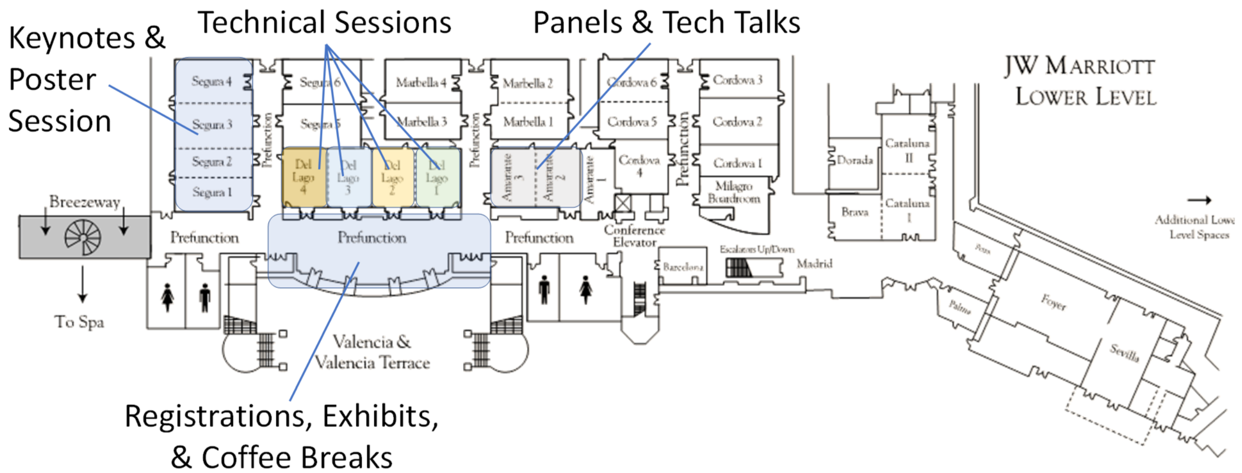
JW MARRIOTT ORLANDO GRANDE LAKES MAP



ITherm 2023 MEETING LOCATIONS FLOOR MAP – LOBBY LEVEL



ITherm 2023 MEETING LOCATIONS FLOOR MAP – LOWER LEVEL



SPONSORS & EXHIBITORS

PANEL SPONSORS

CONFERENCE SPONSORS

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

Advanced Heat Exchangers and Process Intensification Group
Smart and Small Thermal Systems Lab
S2TS

CENTER FOR ENVIRONMENTAL ENERGY ENGINEERING

https://s2ts.umd.edu/

EXHIBITORS

UNIVERSITY OF
TEXAS
ARLINGTON

PARTNERS

CONFERENCE ORGANIZATION COMMITTEE

ORGANIZATION COMMITTEE		
General Chair	Satish Kumar	Georgia Institute of Technology
Program Chair	Ashish Gupta	Intel Corporation
Vice Program Chair	Amy Marconnet	Purdue University
Communications Chair	Milnes David	IBM Corporation
COMPONENT-LEVEL THERMAL MANAGEMENT TRACK		
Chair	Luca Amalfi	Seguente
Co-Chair	Stephanie Allard	IBM Corporation
Co-Chair	Darin Sharar	Army Research Labs
SYSTEM-LEVEL THERMAL MANAGEMENT TRACK		
Chair	Amir H. Shooshtari	University of Maryland
Co-Chair	Patrick Shamberger	Texas A&M University
Co-Chair	Weihua Tang	Intel Corporation
EMERGING TECHNOLOGIES & FUNDAMENTALS TRACK		
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Co-Chair	Mahsa Ebrahim	Loyola Marymount University
MECHANICS & RELIABILITY TRACK		
Chair	David Huitink	University of Arkansas
Co-Chair	Przemek Gromala	Bosch
Co-Chair	Paul Paret	NREL
SPECIAL TECHNICAL CONTRIBUTIONS		
Keynote Chair	John Thome	EPFL
Keynote Co-Chair	Justin Weibel	Purdue University
Technology-Talk Chair	Naveenan Thiagarajan	GE
Technology-Talk Co-Chair	John (Jack) Maddox	University of Kentucky
Technology-Talk Co-Chair	Chandra Mohan (CM) Jha	Intel
Panels Chair	Victor Chiriac	Global Cooling Technology Group, LLC
Panels Co-Chair	Kimberly Saviers	Raytheon Technologies
Panels Co-Chair	Vaibhav Bahadur (VB)	UT Austin
Poster Session Chair	Arjang Shahriari	Google
Poster Session Co-Chair	Joseph Hanson	Intel Corporation
Poster Session Co-Chair	Georges Pavilidis	University of Connecticut
PDC Short Course Chair	Jeffrey Suhling	Auburn University
Diversity Panel Representative	Cristina Amon	University of Toronto
EPS/K16 Student Design Competition	Joe Alexandersen	Southern Denmark University
EPS/K16 Student Design Competition	Naveenan Thiagarajan	GE Research
EPS/K16 Student Design Competition	Amy Marconnet	Purdue University

ADMINISTRATIVE		
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Technical Program and Design	Ashish Gupta	Intel Corporation
Technical Program and Design	Amy Marconnet	Purdue University
Outreach & Engagement	Vaibhav Bahadur (VB)	University of Texas at Austin
Publicity	John (Jack) Maddox	University of Kentucky
Social Media	Chirag Kharangate	Case Western Reserve University
AWARD COMMITTEE		
Richard Chu ITherm Award Chair	Sushil Bhavnani	Auburn University
Richard Chu ITherm Award Co-Chair	Koneru Ramakrishna	Thermal Consultant
Richard Chu ITherm Award Co-Chair	Yogendra K. Joshi	Georgia Institute of Technology
Best Paper Award Chair	Yogendra K. Joshi	Georgia Institute of Technology
Best Paper Award Co-Chair	Koneru Ramakrishna	Thermal Consultant
Best Paper Award Co-Chair	Jeffrey Suhling	Auburn University
INTERNATIONAL ITHERM AMBASSADORS		
Ambassador	Roger Kempers	York University, Canada
Ambassador	Poh Seng Lee	NUS, Singapore
Ambassador	Mehmet Arik	Ozyegin University, Turkey
Ambassador	Rishi Raj	IIT Patna, India
Ambassador	Liang Chen	Xi’an Jiaotong University
Ambassador	Fushinobu Kazuyoshi	Tokyo Institute of Technology
Ambassador	Tim Persoons	Trinity College Dublin
Ambassador	Ryan Enright	Seguente

FAST MOVING TECHNOLOGY

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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.

Dereje Agonafer	University of Texas at Arlington
Cristina H. Amon	University of Toronto
Mehdi Asheghi	Stanford University
Sushil H. Bhavnani	Auburn University
Thomas Brunschwiler	IBM Research – Zurich
Vadim Gektin	NUVIA
Madhusudan Iyengar	Google
Yogendra K. Joshi	Georgia Institute of Technology
Gary B. Kromann	Thermal Consultant
Tom Lee	Xilinx
Michael Ohadi	University of Maryland
Alfonso Ortega	Villanova University
Koneru Ramakrishna	Thermal Consultant
Bahgat Sammakia	State University of New York at Binghamton
Jeffrey Suhling	Auburn University
Sandeep Tonapi	Anveshak
Justin Weibel	Purdue University
Dustin Demetriou	IBM Corporation

ITherm 2023 BEST PAPER AWARD

Award Committee Members:

Prof. Yogendra K. Joshi, Georgia Institute of Technology, USA, Committee Chair
Dr. Koneru Ramakrishna, Thermal Consultant, USA, Committee Co-Chair
Prof. Jeffrey Suhling, Auburn University, USA, Committee Co-Chair
Prof. Damena Agonafer, Washington University, USA
Dr. Stephanie Allard, International Business Machines Corporation, Canada
Prof. Mehmet Arik, Auburn University, USA
Prof. Sushil H. Bhavnani, Auburn University, USA
Prof. Kuo-Ning Chiang, National Tsing Hua University, Taiwan
Dr. Victor A. Chiriac, Global Cooling Technology Group, USA
Prof. Sukwon Choi, Pennsylvania State University, USA
Dr. M. Baris Dogruoz, Maxar Technologies Company, USA
Dr. Krishna Darbha, Microsoft Corporation, USA
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Dr. Przemyslaw J. Gromala, Robert Bosch GmbH, Germany
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Prof. Shi-Wei Ricky Lee, Hong Kong University of Science & Technology, Hong Kong, China
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Prof. John Maddox, University of Kentucky, USA
Dr. Ravi Mahajan, Intel Corporation, USA
Prof. Tim Persoons, Trinity College, University of Dublin, Ireland
Prof. Roger Schmidt, Syracuse University, USA
Prof. Amir H. Shooshtari, University of Maryland, USA
Prof. Andrew Tay, formerly of National University of Singapore, Singapore

LAST YEAR'S BEST PAPERS (ITherm 2022)

COMPONENT-LEVEL THERMAL MANAGEMENT TRACK

PROF. AVRAM BAR-COHEN BEST PAPER

Comparison between Direct Winding Heat Exchanger and Slot-liner Confined Evaporative Cooling of Electric

Amitav Tikadar, Yogendra Joshi, Satish Kumar (Georgia Institute of Technology)

BEST PAPER - RUNNER UP

Layered Unsupervised Learning-based Identification and Quantification of Voids in Package Thermal Interface Materials

Rahul Lall, Kamal Sikka, Isabel De Sousa (IBM)

SYSTEM-LEVEL THERMAL MANAGEMENT TRACK

PROF. AVRAM BAR-COHEN BEST PAPER

Two-phase thermofluidic modeling and validation of a multi-zone microchannel evaporator

Qianying Wu (Nokia Bell Labs and Stanford University), Todd Salamon (Nokia Bell Labs)

BEST PAPER - RUNNER UP

Numerical evaluation of bimetallic self-adaptive fins acting as flow disturbing elements inside a microchannel

Montse Vilarrubi (Universitat de Lleida, Universal Smart Cooling S.L.), Desideri Regany, Francesc X Majos, Manel Ibanez, Joan Ignasi Rosell, Josep Illa, Ferran Badia (Universitat de Lleida), Amrid Amnache, Etienne Leveille, Rajesh Pandiyan (Universite de Sherbrooke), Luc G Frechette (Universite de Sherbrooke, Universal Smart Cooling S.L.), Jerome Barrau (Universitat de Lleida, Universal Smart Cooling S.L.)

EMERGING TECHNOLOGIES AND FUNDAMENTALS TRACK

PROF. AVRAM BAR-COHEN BEST PAPER

Chip-level Thermal Simulation for a Multicore Processor Using a Multi-Block Model Enabled by Proper Orthogonal Decomposition

Lin Jiang, Anthony Dowling, Yu Liu, Ming- Cheng Cheng (Department of Electrical and Computer Engineering Clarkson University)

BEST PAPER - RUNNER UP

Pulsating Heat Pipe Fin Plates for Enhancing Natural and Forced Convection Cooling of Electronics: Experimental Campaign

Gautier Rouaze, Jackson Marcinichen, John Thome (JJ Cooling Innovation SARL), Kangnin Xiong, Winston Zhang (Novark Technologies)

MECHANICS AND RELIABILITY TRACK

PROF. AVRAM BAR-COHEN BEST PAPER

Novel Test Device for Non-destructive Experimental Characterization of Void Evolution in Microscale Solder Joints subjected to Thermal Aging

Sudarshan Prasanna Prasad, Chetan Jois, Ganesh Subbarayan (Purdue University)

BEST PAPER - RUNNER UP

Impact of FEOL cross-heating on the thermal performance of advanced BEOL

Melina Lofrano, Bjorn Vermeersch, Herman Oprins, Seongho Park, Zsolt Tokei (IMEC)

KEYNOTES

Sandeep Ahuja
(Intel Corporation)

Griselda Bonilla
(IBM Research)

Steve Rickman
(NASA)

K-1: TRANSFORMATION OF DATA CENTERS FROM AIR TO LIQUID COOLING

Presenter: Sandeep Ahuja (Intel Corporation) Wednesday, May 31, 9:00 – 10:00 AM

Abstract: A typical air-cooled datacenter spends 30-40% of its power consumption in cooling. Electricity usage by datacenters crossed 200 TWh in 2021 and crypto mining further adds significant demand to energy needs. It is becoming clear that one needs to look for cooling technologies that can enable the datacenter industry to deliver more performance while spending less on cooling. Liquid cooling technologies such as cold plate and immersion can help achieve sustainability goals of the datacenter industry. The keynote shall cover various liquid cooling technologies being deployed in datacenters. Immersion cooling with single and two-phase options is discussed. Key engineering parameters such as thermal performance, signal integrity, material compatibility and reliability of IT equipment in immersion are discussed. The technology can deliver power savings of 15-38% compared to that for an equivalent air-cooled datacenter. The talk will end with call to action for the industry to accelerate deployment of this technology.

Sandeep Ahuja is a Sr. Principal Engineer in the Datacenter and AI Group of Intel. His area of expertise is platform thermal architecture and cooling technologies for Intel server products. Sandeep is currently focused on leading transformation of the data center industry from air cooled datacenters to energy efficient, higher performance liquid cooled datacenters. Sandeep has been with Intel for 22 years. Prior to joining Intel, Sandeep worked in the automotive sector on cooling of engine and transmission controllers. Sandeep holds Master of Science degree in Mechanical Engineering from The University of Iowa, Iowa City. Sandeep holds several patents and has a number of conference paper publications.

K-2: INNOVATIVE CHIPLET INTEGRATION TECHNOLOGIES FOR HPC AND AI HARDWARE SYSTEMS

Presenter: Griselda Bonilla (IBM Research) Thursday, June 1, 9:00 – 10:00 AM

Abstract: System-level performance gains in the forms of single- thread performance, throughput, and power efficiency have historically been fueled by performance, density, and power improvements by scaling device and on-chip interconnects. However, silicon economics and the limits of reticle size are driving a disruption, requiring HPC and AI hardware designers to look at new ways of designing chips and considering new architectures. Chiplet integration technologies offer a modular approach to continued performance scaling by providing enhanced functionality and improved operating characteristics. Instead of fabricating a single large multicore CPU die, smaller dies can be arranged within a package with very short chip to chip connections at the same performance. The smaller dies have higher yields, and if integration cost is reasonable, the overall solution then scales economically. Custom chips can then be made, with the flexibility to combine chips of different technology nodes for a specific application or workload. This talk will focus on key chiplet integration technologies that are gaining traction in the industry and are driving this chiplet revolution.

Griselda Bonilla is currently a Senior Technical Staff Member (STSM) and Senior Manager of the Advanced Interconnect Technology group at IBM Research. Griselda leads a cross-functional team involved in the integration, scaling, and optimization of semiconductor materials, on-chip interconnects, and processes for use in the next generation of chips and electronic devices. In this role, she has a proven track record of successfully taking research concepts from the laboratory to early production. Her work has been rewarded internally with several technical accomplishments, including a Corporate Award in 2016, IBM's highest technical recognition. She has authored or coauthored over 80 papers and presentations and has been issued over 30 patents. Prior to this role, Griselda was responsible for extending IBM's microelectronics technology and manufacturing leadership through innovations in materials, processes, and reliability methodology. Since joining IBM, she has delivered technology solutions for multiple generations of CMOS technology used in respective IBM "P" and "Z" servers and miscellaneous ASIC products, including game processors

K-3: SPACE MISSION THERMAL CONTROL AND PROTECTION CHALLENGES – PAST, PRESENT, AND FUTURE

Presenter: Steve Rickman (NASA) Friday, June 2, 9:00 – 10:00 AM

Abstract: Space missions must operate in extreme thermal environments whether they are orbiting a planet, on an interplanetary trajectory, or undergoing atmospheric entry. However, electronic equipment, batteries, scientific instruments, and crewed spacecraft require thermal control over a relatively narrow temperature range. Thermal control and protection strategies for past, present, and future missions are presented to show how missions can be accomplished in extreme environments over a temperature range extending from near absolute zero up to 14000 K.

Steve Rickman joined the NASA Engineering and Safety Center in January 2009 as the NASA Technical Fellow for Thermal Control & Protection. In this capacity, he leads a cross-agency Technical Discipline Team, leveraging expertise from within and outside of the Agency to solve high risk technical problems and foster a community of practice for the thermal control and protection disciplines. Mr. Rickman was named Deputy Chief of the Thermal Branch in 1998 and Chief of the Thermal Design Branch in 2002. He served as the NASA lead for the Flight-Day-Two Object Radar Team and worked with the U.S. Air Force on this facet of the investigation. In 2006, he led the Tile Overlay Repair Development Team, focused on developing a repair for Space Shuttle tile damage. Mr. Rickman's primary interest has been in the area of passive thermal control and analysis of orbiting spacecraft. He served on numerous design teams including the TransHab inflatable module project as lead environments engineer and lead thermal analyst. As the NASA technical manager, he led the development of the Thermal Synthesizer System (TSS) analysis tool suite. He was the thermal design engineer for the Inter-Mars Tissue Equivalent Proportional Counter, the ISS Extravehicular Charged Particle Directional Spectrometer, and the Mars Odyssey 2001 Martian Radiation Environment Experiment. He co-developed a general purpose on-orbit thermal environments tool which was used extensively during the STS 35 ASTRO-1 mission. Mr. Rickman has authored or co-authored numerous technical papers and conference presentations including public testimony given with the U.S. Air Force to the Columbia Accident Investigation Board. He authored a textbook chapter on natural and induced thermal environments. He holds three U.S. patents. He was the lead inventor of a novel technique and system for micrometeoroid/orbital debris impact detection and location on spacecraft. He was a co-inventor of an innovative space station concept. He was the overall project lead and inventor of a calorimeter for measuring energy yield from small format lithium-ion cells undergoing thermal runaway. Mr. Rickman has received numerous mentoring, Group Achievement, Tech Brief, and Space Act Awards and has been honored with the Silver Snoopy Award and the NASA Exceptional Achievement Medal. From 2011 to 2016, he was an Adjunct Professor/Lecturer of Mechanical Engineering at Rice University. He earned a B.S. in Aerospace Engineering from the University of Cincinnati and a M.S. in Physical Science from the University of Houston-Clear Lake.

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 30, 2023, 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 located in the Mediterranean Foyer on the Lobby Level.

2023 PROFESSIONAL DEVELOPMENT COURSES

MORNING COURSES 8:00 AM – 12:00 PM

1. High Reliability of Lead-Free Solder Joints -- Materials Considerations
   Course Leader: Ning-Cheng Lee – ShinePure Hi-Tech
2. Wafer-Level Chip-Scale Packaging (WCSP) Fundamentals
   Course Leader: Patrick Thompson– Texas Instruments, Inc.
3. Fundamentals of RF Design and Fabrication Processes of Fan-Out Wafer/Level and Advanced RF Packages
   Course Leader: Ivan Ndip and Markus Wöhrmann – Fraunhofer IZM
4. Eliminating Failure Mechanisms in Advanced Packages
   Course Leader: Darvin Edwards – Edwards Enterprises
5. Reliability Engineering testing Methodology and Statistical Knowledge for Qualifications of Consumer and Automotive Electronic Components
   Course Leader: Fen Chen (GM Cruise)
6. Reliability Physics and Failure Mechanisms in Electronics Packaging
   Course Leaders: Xuejun Fan – Lamar University
7. Reliable Integrated Thermal Packaging for Power Electronics
   Course Leader: Patrick McCuskey – University of Maryland
8. Introduction to PWB Thermal Analyses
   Course Leaders: Patrick Loney - Northrop Grumman

AFTERNOON COURSES 1:30 PM – 5:30 PM

1. Additive Flexible Hybrid Electronics – Manufacturing and Reliability
   Course Leader: Pradeep Lall – Auburn University
2. Fan-Out Packaging and Chiplet Heterogeneous Integration
   Course Leaders: John Lau - Unimicron
3. Photonic Technologies for Communication, Sensing, and Displays
   Course Leader: Torsten Wipiejewski, Huawei Technologies
4. Flip Chip Technologies
   Course Leader: Shengmin Wen – HaiSemi and Eric Perfecto – IBM Research
5. Packaging and Heterogeneous Integration for Automotive Electronics and Advanced Characterization of EMCs
   Course Leader: Przemyslaw Gromala – Robert Bosch GmbH
6. Analysis of Fracture and Delamination in Microelectronic Packages
   Course Leader: Andrew Tay - National University of Singapore
7. Polymers in Wafer Level Packaging
   Course Leaders: Jeffrey Gotro –InnoCentrix, LLC
8. Thermal Management of Electronics
   Course Leaders: Jaime Sanchez – Intel Corporation

Georgia Tech College of Engineering

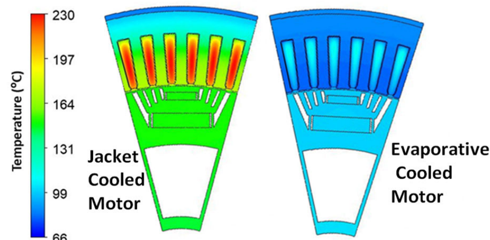
George W. Woodruff School of Mechanical Engineering

Micro Nano Devices and Systems Lab (MiNDS)

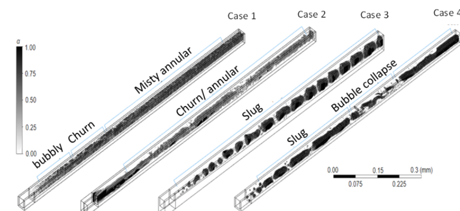
https://sites.gatech.edu/minds/

Microelectronics and Emerging Technologies Thermal Lab (METTL)

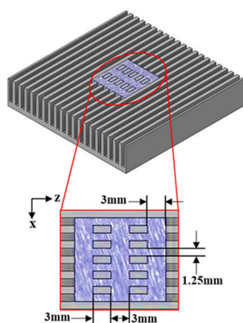
https://mettl.gatech.edu/

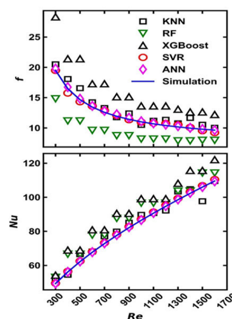


Electro-thermal co-design of electric motors

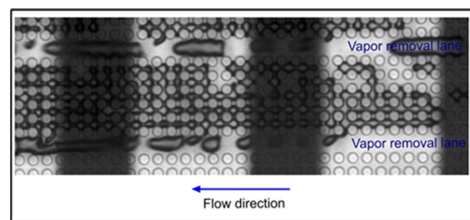


Void fractions and flow regimes renderings for geometrically enhanced microchannels: straight, constricted inlet, diverging microchannel, and microchannel with auxiliary jet (cases from left to right)





Machine learning approach to predict thermal-hydraulic performance



Flow boiling and vapor removal mechanism for a microfluidic device operating with a mass flow rate of 0.25 kg/h and 15 W/cm^2

HETEROGENEOUS INTEGRATION ROADMAP (HIR) SPECIAL SESSIONS

TUESDAY, MAY 30, 8:00 AM – 4:45 PM, PALAZZO E

Heterogeneous Integration uses packaging technology to integrate dissimilar chips, devices or components with different materials and functions, and from different fabless design houses, foundries, wafer materials, feature sizes and companies into a system or subsystem. The HIR special sessions is a full-day event with the following schedule.

Open to ITherm attendees. ECTC Registration not required to attend HIR Special Sessions only.
For more information, please visit: https://eps.ieee.org/technology/heterogeneous-integration-roadmap.html

08:00 am – 8:30 am	Welcome & Agenda Review
08:30 am – 10:00 am	AI/ML in Package Co-Design for Chiplets Perspective
10:15 am – 11:45 am	Heterogeneous Integration of MEMS & Sensors: Challenges and Opportunities
11:45 am - 12:15 pm	LUNCH
01:15 pm – 02:45 pm	The CHIPS and Science Act
03:00 pm – 04:30 pm	Additively Manufactured Electronics for Heterogenous Integration

AI/ML IN PACKAGE CO-DESIGN FOR CHIPLETS PERSPECTIVE

The session will address the co-design science & engineering in heterogeneous integration - Chiplets perspective addressing questions from both academic and industry research standpoint with the goal to forge a vision for basic research for next decade. Developments in AI/ML as well as systems requirements and advanced packaging technologies will be included.

HETEROGENEOUS INTEGRATION OF MEMS & SENSORS: CHALLENGES AND OPPORTUNITIES

In this session, panelists from HIR technical working groups will collaborate in describing the challenges and opportunities for the heterogeneous integration of MEMS from their perspective in application requirements such as mobile, automotive, Internet of Thing (IoT) as well as highlighting power, and thermal requirements, challenges and solutions decades into the future.

THE CHIPS AND SCIENCE ACT

The CHIPS and Science Act of 2022 provided the Department of Commerce resources for a suite of programs to strengthen and revitalize the U.S. position in semiconductor research, development, manufacturing, and investment in American workers. In this session the NIST CHIPS leadership will present to the ECTC community the four components of the CHIPS for America R&D program, including the National Semiconductor Technology Center, the National Advanced Packaging Manufacturing Program, Manufacturing USA, and the NIST Metrology & Standards program.

ADDITIVELY MANUFACTURED ELECTRONICS FOR HETEROGENOUS INTEGRATION

This HIR session will focus on Additively Manufactured Electronics (AME) for heterogeneous integration, highlighting the benefits of AME methods, recent AME science and technology advances, promising AME applications and growth areas and challenges requisite for electronics industry adoption.

YOUNG PROFESSIONALS NETWORKING PANEL

TUESDAY, MAY 30, 7:00 – 7:45 PM, PALAZZO D

Chairs: Yan Liu (Medtronic)

Join your peers for a session designed with you in mind. You will network with industry professionals, ECTC leaders, EPS members, and other students as you team up for activities to learn more about packaging-related topics all the while engaging with top professionals. Make this opportunity a priority! Come and take advantage of meeting face to face with industry leaders and top professionals, ask career questions, and get to know what industry has to offer!

ECTC/ITHERM DIVERSITY AND CAREER GROWTH PANEL AND RECEPTION

WEDNESDAY, MAY 31, 6:30-8:00 PM, MEDITERRANEAN 4 & 5

DIVERSIFYING OUR TECHNICAL WORKFORCE TO MEET NATIONAL NEEDS INCLUDING THE CHIPS ACT INITIATIVE

Chairs: Cristina Amon (University of Toronto); Kimberly Yess (Brewer Science, Inc); Nancy Stoffel (GE Research)

The electronic industry has an urgent need to increase the technical workforce and address challenges related to recruitment, inclusion and retention of diverse talents. The panelists will discuss the development of initiatives, policies and programs to increase and diversify the workforce, along with metrics to assess progress. Discussions will include the benefits of diversity in high-performing workplaces, strategies to build a larger and more diverse workforce, and tools for inclusion and engagement – sharing both successes and challenges associated with achieving these goals.

Panel is 6:30PM-7:30PM, followed by a reception (with appetizers and open bar) 7:30PM-8:00PM

Panelists:

Dereje Agonafer
University of Texas Arlington

Courtney Power
NextFlex

Jennifer Edwards
GE Foundation/NEXT Engineer

Christine McGinn
NIST CHIPS Representative

EPS PRESIDENT'S PANEL SESSION

FRIDAY, JUNE 2, 8:00-9:15 AM, MEDITERRANEAN 4 & 5

HOW CAN PHOTONICS ENABLE THE BANDWIDTH DENSITIES WITH LOWER ENERGY PER BIT IN EMERGING SIP

Chairs: Kitty Pearsall (EPS President; Boss Precision, Inc.) and David McCann (Lyte)

This panel will discuss the tools, technologies and approaches that will enable the industry to enhance the bandwidth density of interconnections in SiP enabled by photonics. To be adopted, such capabilities must be provided with energy per bit which meets the roadmaps and standards targets for the interconnection protocols within the package and on chip.

Panelists:

Amr S. Helmy
University of Toronto

Stefano Oggioni
AT&S

Ritesh Jain
Lightmatter

Ajey Jacob
University of Southern California

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A RELIABILITY LANDSCAPE FOR HETEROGENEOUSLY INTEGRATED PACKAGING

AWARD LUNCHEON TALK, WEDNESDAY, MAY 31, 12:00 PM – 1:30 PM, PALAZZO BALLROOM (LOWER LEVEL)

Talk Presented by 2023 Awardee Dr. Suresh K. Sitaraman (Georgia Tech)

Abstract: Heterogeneously integrated packaging continues to evolve horizontally as well as vertically with 3D, Hybrid Bonding, Embedded Bridge, and other advanced technologies with new materials, innovative processes, and testing protocols. Application-Specific Heterogeneously Integrated Packaging (ASHIP) is finding increasing resonance for high-performance computing, automotive, aerospace, communication, consumer, medical, defense, and other applications. When demands for higher functionality, better performance, and enhanced power requirements are augmented with needs for smaller size and reduced weight and cost, reliability and testing challenges abound.

Regardless of the underlying architecture and roadmapping efforts, certain fundamental reliability challenges continue to dominate with new materials, processes, functionality, and performance targets. These include both overstress and wearout failures, and could involve, for example, interlayer delamination, cohesive fracture, interconnect failure, and excessive warpage-induced failures. In this presentation, I will highlight some of the reliability challenges and opportunities for heterogeneously integrated packaging. In particular, I will focus on through-silicon vias, interfacial debonding, cohesive fracture, field-specific mapping, and fine-pitch interconnect failure. Towards the end of the talk, I will discuss flexible and wearable packaging opportunities which are amenable to stretching, bending, folding as well as twisting, and explore reliability assessment and accelerated test protocols for flexible and wearable electronics. I will conclude my talk by examining the reliability landscape for Heterogeneously Integrated Packaging.

Dr. Suresh K. Sitaraman is a Regents' Professor and a Morris M. Bryan, Jr. endowed Professor in the George W. Woodruff School of Mechanical Engineering at the Georgia Institute of Technology (Georgia Tech). Dr. Sitaraman is the Director for the Flexible and Wearable Electronics Advanced Research (FlexWEAR@Tech) Program and the Director for the Computer-Aided Simulation of Packaging Reliability (CASPaR) Lab at Georgia Tech. His expertise is in the areas of fabrication, characterization, physics-based modeling, and thermo-mechanical and reliable design of nano-scale and micro-scale structures for a wide range of applications. Dr. Sitaraman has co-authored more than 340 journal and conference publications in these areas. He has managed several research and development projects funded by US federal agencies, industry, and other sources totaling millions of dollars, and has mentored a vast array of post-doctoral fellows as well as doctoral, master's, bachelor's, and high-school students. Prior to joining Georgia Tech in 1995, Dr. Sitaraman was with IBM Corp.

Dr. Sitaraman's work has been recognized through several awards and honors. Among them, he has received a Best Associate Editor award from the IEEE Transactions on Components, Packaging, and Manufacturing Technology (T-CPMT) in 2023, the Zeigler Outstanding Educator Award from Georgia Tech/Mechanical Engineering in 2019, the Outstanding Achievement in Research Program Development Award (Team Leader) from Georgia Tech in 2017 and the ASME/EPPD (Electronic and Photonic Packaging Division) Applied Mechanics Award in 2012. Dr. Sitaraman has received the Sustained Research Award from Georgia Tech – Sigma Xi in 2008 and the Outstanding Faculty Leadership Award for the Development of Graduate Research Assistants, Georgia Tech in 2006. His co-authored papers have won the Commendable Paper Award from IEEE Transactions on Advanced Packaging in 2004 and the

Best Paper Award from IEEE Transactions on Components and Packaging Technologies in 2001 and 2000. Dr. Sitaraman has also received the Metro-Atlanta Engineer of the Year in Education Award in 1999 and the NSF-CAREER Award in 1997. Dr. Sitaraman is an ASME Fellow and a NextFlex Fellow.

Dr. Suresh Sitaraman received his Doctor of Philosophy (PhD) from The Ohio State University, his Master of Applied Science (M. A. Sc.) degree from the University of Ottawa, Canada and his B. Eng. degree in Mechanical Engineering from the Regional Engineering College, Tiruchirappalli (now known as National Institute of Technology) affiliated with the University of Madras, India. He received the Distinguished Alumnus Award for Excellence in Academic/Research from the National Institute of Technology, Tiruchirappalli in 2014 and the Thomas French Achievement Award for alumni who have distinguished themselves as scholars and educators from the Department of Mechanical and Aerospace Engineering, The Ohio State University in 2012.

STUDENT HEAT SINK DESIGN CHALLENGE

WEDNESDAY, MAY 31, 5:00-6:30 PM, SEGURA (LOWER LEVEL)

The Student Heat Sink Design Challenge is a team competition in which students design, analyze, and optimize an additively manufactured, aluminum 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.

2023 ASME/K-16 and IEEE/EPS Student Design Challenge Semi-Finalist Heat Sink Designs

Heat sink testing in the Vertical Natural Convection Test facility

Thanks the committee members: Prof. Joe Alexandersen, Prof. Jack Maddox, Prof. Sameer Rao, Prof. Amy Marconnet, Prof. Ron Warzoha, and Dr. Naveenan Thiagarajan!

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TECHNOLOGY-TALK SESSIONS

TT-1: ADVANCES IN CHIPLETS AND HETEROGENOUS INTEGRATION - PACKAGING, RELIABILITY AND THERMAL MANAGEMENT

WEDNESDAY, MAY 31ST, 8:00 – 9:00 AM, AMARANTE 2-3 (LOWER LEVEL)

Session Chair: Chandra Mohan Jha (Intel Corporation)

INCREASING ROLE OF INTEGRATED PHOTONICS AND CRITICALITY OF ADVANCED PACKAGING TECHNOLOGIES TO EXTEND MOORE'S LAW

Speaker: Sandeep Sane (Lightmatter)

Abstract: With explosive growth in the AI market coupled with slowing down of Moore's law and end of Dennard Scaling, is leading to a major shift in the semiconductor industry. The emergence of the chiplet ecosystem and rise in demands of advanced packaging technologies is a testament of these changes. Furthermore, there are growing concerns from service providers that increasing power consumption by the data centers will soon be unsustainable. Addressing the need to continue to meet ever increasing computing demand in a power efficient manner is of paramount importance. This talk will focus on the role of Integrated Photonics and advanced Packaging technologies in addressing some of the challenges faced by the semiconductor industry.

Sandeep Sane is a Lead Package Architect at Lightmatter where he is responsible for packaging technology definitions and execution for their Passage and Envise product lines. Prior to Lightmatter, he was a Principal Engineer in the Assembly and Test Technology Division at Intel. Sandeep has strong expertise in Si-Package-System Architecture definition to drive integrated solutions that optimize Silicon-Package design, Fab and Assembly processes, Reliability, and Cost. Sandeep holds more than 20 patents. He is the co-inventor of Intel's EMIB/Co-EMIB packaging technologies, which has been implemented across several Intel products. He has published several technical articles in various conferences and journal proceedings including a book chapter. He is a member of ASME, and actively participates in conference organization related to packaging. Prior to Intel, Sandeep worked at IBM, Endicott, NY at the Micro-Electronics Division as development staff engineer. He received his M.S./Ph.D. from Caltech in 2000 and B.S. from IIT Bombay (Mumbai), India in 1995.

NEW APPROACHES FOR SOLDER JOINT RELIABILITY MODELING IN ADVANCED PACKAGING USING DAMAGE MECHANICS

Speaker: Jeff Suhling (Auburn)

Abstract: Electronic products involving advance packaging and heterogenous integration are often subjected to harsh environments including extreme high and low temperatures, vibration, shock, and drop. The solder joints in such applications are subjected to thermal and mechanical cycling environments that lead to microstructure, mechanical response, and failure behavior that change with time. Traditional finite element based predictions for solder joint reliability during thermal and/or mechanical cycling accelerated life testing are based on solder constitutive equations (e.g., Anand viscoplastic model) and failure models (e.g. energy dissipation per cycle model) that do not evolve with changes in the material microstructure or damage accumulation. Thus, there can be significant errors in the calculations with lead free SAC alloys that illustrate changing behavior due to aging phenomena and damage accumulation. In this talk, we report on an improved reliability prediction framework that utilizes constitutive relations and failure criteria that incorporate aging effects (microstructural evolution) and/or damage accumulation (micro crack growth and propagation). As a part of this work, a revised set off Anand viscoplastic stress-strain relations for solder have been developed that included material parameters that evolve with the thermal history of the solder

material. In addition, a damage mechanics framework has been established to also evolve the material constants with damage accumulation occurring during cyclic loading. After development of such advanced tools, we have applied these approaches to predict reliability of PBGA components attached to FR-4 printed circuit boards that were subjected to thermal and mechanical cycling and correlated the results with accelerated life testing experimental data.

Jeffrey C. Suhling received his Ph.D. degree in Engineering Mechanics in 1985 from the University of Wisconsin. He then joined the Department of Mechanical Engineering at Auburn University, where he currently holds the rank of Quina Distinguished Professor and Department Chair. From 2002-2008, he served as Center Director for the NSF Center for Advance Vehicle Electronics. His research interests include solid mechanics, stress and strain analysis, material characterization, experimental mechanics, advanced and composite materials, finite element analysis and computational mechanics, additive manufacturing, electronic packaging, and silicon sensors. Dr. Suhling has authored or co-authored over 500 technical publications and has an H-Index of 58 on Google Scholar. He has advised over 100 graduate students at Auburn University. He is a Fellow of ASME, and is a member of IEEE, SMTA, IMAPS, SEM, and TAPPI. He served as Chair of the Electrical and Electronic Packaging Division of ASME during 2002-2003, and was on the EPPD Executive Committee from 1998-2003. Dr. Suhling was the Technical Program Chair of the ASME InterPACK '07 Conference, and General Chair of the ASME InterPACK '09 Conference. He currently serves as Vice President - Finance for the IEEE Electronics Packaging Society, and was the Program Chair of the 2018 IEEE ITherm Conference and General Chair of the 2019 IEEE ITherm Conference.

TT-3: IMPACT OF THERMAL MANAGEMENT ON CARBON NEUTRALITY AND SUSTAINABILITY

WEDNESDAY, MAY 31ST, 1:30 – 3:00 PM, AMARANTE 2-3 (LOWER LEVEL)

Session Chair: Naveenan Thiagarajan (GE)

ENVIRONMENTAL AND CLIMATE IMPACT OF THERMAL MANAGEMENT SYSTEMS: DESIGNING FOR SUSTAINABILITY

Speaker: Alfonso Ortega (Villanova)

Abstract: Engineering systems are complex because they are large, dynamic, and composed of many sub-systems, each with many sub-components and functions designed to operate seamlessly. Systems that are designed for critical functions, such as the systems on an airliner where passenger safety is paramount, or data centers, in which up-time is essential, cannot fail. Hence these systems are designed for functionality, reliability, life, and cost. The "total cost of ownership" or TCO has been used for some time by corporations in order to understand the total costs of systems including their capital costs (CAPEX) and annualized costs during operations (OPEX). Another cost that must be borne, but that has only recently started to receive similar attentiveness, is the environmental cost. In this talk I will focus on only one sub-system, the thermal management system, and will focus in particular on thermal management systems for data centers as a case study. We will show that the evolution of thermal management systems for data centers, from primarily refrigerated air-cooling, to evaporative cooling, to single phase water cooling, to two-phase refrigerant cooling, to immersion cooling, has not always taken system environmental impact and sustainability as a design consideration. That is changing and in this talk we will discuss examples of current efforts and future opportunities in reducing the impact of thermal management systems on the environment.

Dr. Alfonso Ortega is the James R. Birle Professor of Energy Technology at Villanova University and Professor of Mechanical and Sustainable Engineering. He is the Director of the Laboratory for Advanced Thermal and Fluid Systems which he has led for over 30 years. He is the Founding Director of the Villanova site of the NSF Center for Energy Smart Electronic Systems (ES2) founded in 2011. He currently is the co-Director of the Villanova Strategic Initiative for Climate, Justice, and Sustainability, a university wide academic initiative. Formerly he was the Associate Dean for Graduate Programs and Research in the College of Engineering and Villanova's inaugural

Associate Vice President for Research and Graduate Programs. Dr. Ortega received his B.S. from The University of Texas-El Paso, and his M.S. and Ph.D. from Stanford University, all in Mechanical Engineering. He was on the faculty of the Department of Aerospace and Mechanical Engineering at The University of Arizona in Tucson for 18 years. For two years, he served as the Program Director for Thermal Transport and Thermal Processing in the Chemical and Transport Systems Division of The National Science Foundation, where he managed the NSF's primary program funding heat transfer and thermal technology research in U.S. universities. Dr. Ortega is a teacher of thermodynamics, thermal and energy sciences, thermal-fluid design, and experimental methods. He is an internationally recognized expert in thermal and energy management in electronic systems. He has supervised over 40 M.S. and Ph.D. candidates to degree completion, 5 postdoctoral researchers, and more than 70 undergraduate research students. He is the author of over 300 journal and symposia papers, book chapters, and monographs and is a frequent short course lecturer and consultant on thermal and energy management and experimental measurements. He is a Fellow of the ASME and received the 2003 SEMITHERM Thermie Award and the 2017 ITHERM Achievement Award in recognition of his contributions to the field of electronics thermal management. He received the 2023 SEMITHERM Hall of Fame Award for his lifetime achievements in the field.

IMPACT OF THERMAL MANAGEMENT ON CARBON NEUTRALITY AND SUSTAINABILITY OF MODULAR DATACENTERS

Speaker: Vinod Narayan (UC Davis)

Abstract: High-efficiency cooling solutions play an important role in increasing the sustainable operation of datacenters. Modular datacenters, which permit low latency for edge computing applications, need to be agnostic to the climactic conditions and water availability. In this talk, two options for compressor-less directed cooling of CPUs and server boards will be discussed as a pathway to carbon-neutral cooling of such datacenters. The first option involves use of an evaporative chiller that cools water below its outdoor wet bulb temperature for use in liquid loops. The second is a dry cooling strategy that involves use of counter flow heat exchangers to efficiently reject heat to the ambient. The chip case temperature, chip-to-coolant resistance, and cooling system electrical power and water consumption will be compared between the two options, and with compressor-based cooling strategies. The potential for use of radiative cooling and thermal storage will also be discussed.

Vinod Narayanan is a Professor of Mechanical and Aerospace Engineering (MAE) at the University of California, Davis and the Director of the UC Davis Western Cooling Efficiency Center (wcec.ucdavis.edu). His areas of expertise include process intensification using microchannel technology and phase change heat transfer, energy efficiency of building HVAC and industrial processes, solar thermal energy utilization, and thermal management. His research has been sponsored by agencies such as the California Energy Commission, the National Science Foundation, the National Aeronautical and Space Administration, the U.S. Department of Energy, the Office of Naval Research, and the Australian Research Council. Prior to joining the faculty at UC Davis in 2015, he was a Professor and Welty Faculty Fellow in the School of Mechanical, Industrial, and Manufacturing Engineering at Oregon State University. He earned his PhD from Texas A&M University in Mechanical Engineering in 2001. Professor Narayanan is an ASME Fellow and is currently an Associate Editor for the ASME Journal of Thermal Science and Engineering Applications. He is a past chair of the ASME K-13 Committee on Multiphase flow and heat transfer, and served as Chair of the 2015 ASME International Conference on Nanochannels, Microchannels and Minichannels (ICNMM).

SUSTAINABLE COMPUTING – THERMAL CHALLENGES AND OPPORTUNITIES

Speaker: Pritish Parida (IBM)

Abstract: Sustainable Computing (also referred to as green computing) is the design, manufacture, use and disposal of information technology (IT) equipment and peripherals in a way that limits the harmful impact on the environment by manufacturers, data centers and end-users. In the information and communication technology (ICT) sector, which is responsible for over 300TWh of energy consumption, over 150 billion gallons water consumption and up to 3.9% of global greenhouse gas emissions annually, sustainable computing has the potential for considerable positive environmental impact. Every aspect of modern IT — from the smallest chip to the largest data center — carries a carbon price tag, and sustainable computing seeks to reduce that carbon price tag. This talk will highlight some of the thermal management challenges in computer systems ranging from millimeter scale chips to kilometer scale data centers and associated opportunities that provide a pathway to sustainable computing.

Dr. Pritish Parida is a Senior Research Scientist and technical lead for Sustainable Computing at IBM Research. He is currently the co-PI of IBM-ARPA-E program on Systems Two-phase cooling (DE-AR0001577) and the Chair of ITE-Energy Efficiency metric activity workgroup in The Green Grid. He has extensive experience in the development of cutting-edge thermal technologies including chip-embedded two-phase cooling, for high performance computing systems and embedded applications such as UAVs (unmanned aerial vehicles), RF (radio frequency), and 5G devices. He obtained his Ph.D. in Mechanical Engineering from Virginia Tech. Dr. Parida has received several technical and innovation awards at IBM as well as outside including Outstanding Technical Achievement Award (2016, 2021, 2022), Outstanding Research Award (2021), Research Division Award (2012, 2016, 2021), Outstanding Technical Paper Award (2012), Best Paper Award (SEMI-Therm 2017), Best Poster Award (GOMACTech 2017). Dr. Parida has co-authored over 60 peer-reviewed publications, three book chapters, and holds over 100 issued patents.

TT-5: ADVANCES IN ADDITIVE MANUFACTURING AND TOPOLOGY OPTIMIZATION FOR ELECTRONICS APPLICATIONS - PACKAGING AND THERMAL MANAGEMENT

THURSDAY, JUNE 1ST, 8:00 – 9:00 AM, AMARANTE 2-3 (LOWER LEVEL)

Session Chair: Naveenan Thiagarajan (GE)

FLEXIBLE AND ADDITIVE ELECTRONICS APPLICATIONS FOR NOVEL ADVANCE PACKAGING

Speaker: Janos Veres (NextFlex)

Abstract: Today's electronics can be manufactured in a more sustainable, low cost, and innovative way using flexible and additive processes that result in lighter weight products with thin form factors. NextFlex and its member community are focused on the manufacturability of products in healthcare, RF and communications, structural health monitoring, defense, aerospace, automotive, and more. More than 100 companies, academic institutions and government agencies are collaborating through NextFlex to advance the manufacturing readiness for full scale production. Dr. Wall will provide an overview of the technology and manufacturing approaches that are bringing these products to market and will discuss applications where additive technology is poised to disrupt traditional circuit board manufacturing and advanced packaging techniques.

Janos Veres is Director & VP of Engineering at NextFlex, the US Institute of Electronics Manufacturing Innovation for Flexible Hybrid Electronics. Janos is a technologist at heart, and he is passionate about the future of manufacturing and the new ecosystems enabled by digital technologies. Janos has held R&D, manufacturing and management positions in electronics, displays, specialty materials and printing companies including PARC, PolyPhotonix, Kodak, Merck, Avecia, Zeneca and Gestetner, where he developed printed circuits, functional

materials, OLEDs, displays, medical devices as well as novel process technologies. He brings experience of industrial partnerships and joint development projects in the U.S., Europe and Asia. Janos holds a Ph.D. in Solid State Electronics from Imperial College, London. He is author of over 50 patents.

TOPOLOGY OPTIMIZATION AND ADDITIVE MANUFACTURING OF HEAT EXCHANGERS

Speaker: Xiaoping Qian (University of Wisconsin)

Abstract: In this talk, I will discuss our recent work in applying multi-physics topology optimization to explore large design space enabled by additive manufacturing, more specifically on topology optimization of heat sinks and heat exchangers. We will present formulations for optimizing thermohydraulic performances under both physical constraints and additive manufacturability constraints. Navier-Stokes equations for fluid flow, heat transfer equations and elasticity equations are solved at each optimization step to account for thermohydraulic consideration and structural constraints. An adjoint approach is used to obtain sensitivity in a gradient based optimization approach. For additive manufacturability constraints, we consider undercut and self-supporting overhang angle in optimized components so they can be printed without support structures. We also consider simultaneous optimization of build orientation and part topology for reducing both support structures and improving part performances. I will present examples of topologically optimized heat sinks and two-fluid heat exchangers. I will also discuss our recent work on natural convection based phase-change material designs.

Xiaoping Qian is the Elmer and Janet Kaiser Professor in Mechanical Engineering at the University of Wisconsin-Madison. He also currently serves as the Associate Chair in Research for the department of Mechanical Engineering. His research focuses on computational design of multi-physics systems and design for additive manufacturing. He is an elected ASME fellow. He obtained his Ph.D. from the University of Michigan in USA.

TT-7: ENHANCED HEAT CONDUCTION AND SPREADING TECHNOLOGIES

THURSDAY, JUNE 1ST, 1:30 – 3:00 PM, AMARANTE 2-3 (LOWER LEVEL)

Session Chair: Jack Maddox (University of Kentucky)

DEVELOPMENT OF A CAPILLARY-BASED SILICON MICROCOOLER FOR HIGH HEAT FLUX (1 KW/CM2) MICROPROCESSOR COOLING APPLICATION

Speaker: Mehdi Asheghi (Stanford)

Abstract: Sustainable and efficient operation of US data centers, currently consuming ~100 billion kWh/year, requires transformative and innovative technologies. Nearly 20% of the total power is used to run the data center refrigeration cooling infrastructure, which is extremely sensitive to climate and environmental conditions. While increased public and private awareness in infrastructure operations of midsize and hyperscale data centers have resulted in improved cooling energy efficiency, the ever-increasing prevalence of higher-power processors and smaller edge data centers aggravate cooling/energy challenges. It is expected that reducing the thermal resistance of the device junction to coolant by 10×, will pave the way for elimination of refrigeration cooling system, resulting in considerable energy saving in the data centers. The conventional single/two-phase embedded microchannel cooling solutions are capable of cooling ~1 kW/cm2 heat flux from a microprocessor using pumped flow but require large flow rates and result in high pressure drop. In the case of two-phase flow, the flow instability and large superheat are major concerns that must be addressed. The ultimate two-phase cooling solution presents several fundamental challenges. The enhanced cooling IceCool Fundamentals initiative by the DARPA, and several ARPA-e recent initiatives, resulted in development of a series of remarkable thermal management solutions for very challenging performance metrics targets. Here, we have

developed capillary-based microcooler, capable of removing high heat flux ~ 1 kW/cm^2 with area specific thermal resistance of $R''_{two\text{-}phase}$ ~0.01 cm^2-^{o}C/W, by leveraging an innovative capillary-based 3D-manifold for liquid delivery and vapor extraction, achieving nearly complete vapor-liquid phase separation.

Mehdi Asheghi received the Ph.D. degree from Stanford University, Stanford, CA, USA, in 1999. He completed the post-doctoral training at Stanford University in 2000, conducting research in the area of nanoscale thermal engineering of microelectronic devices. He is currently an Adjunct Professor with the Department of Mechanical Engineering, Stanford University, where he has co-advised/supervised 25 Ph.D. students, and has been involved in more than ten major research project initiatives funded by NSF, DARPA, Semiconductor Research Corporation (SRC), Advanced Research Projects Agency-Energy (ARPA-E), and industry (Google, Intel, AMD, ADI, FORD, TOYOTA, and so on) supported projects. He is the author of more than 150 book chapters, journal publications, and conference papers. His research interests include but not limited to the following topics: design and optimization of advanced microcoolers for microprocessors and power electronics, development of technologies at the energy, food, water, and environment nexus, such as water harvesting from atmosphere and CO_2 capture from power plants, development of advanced metamaterials for revolutionary thermal management solutions, and thermal characterization of nanostructures relevant to semiconductor devices. Dr. Asheghi served as the General Chair and the Program Chair for the ASME 2017, the 2015 International Technical Conference and Exhibition on Packaging and Integration of Electronic and Photonic Microsystems, and the Intersociety Conference on Thermal & Thermomechanical Phenomena in Electronic Systems (ITHERM) 2014 and 2012.

PASSIVE RACK-SCALE THERMAL MANAGEMENT FOR HIGH-POWER-DENSITY SERVERS

Speaker: Ryan Enright (Seguente)

Abstract: Data processing and storage demands are increasing exponentially driven by applications in mobile broadband, gaming, 5G, Artificial Intelligence and Internet of Things (IoT). These demanding workloads increasingly require thermal performance exceeding air-cooling limits to manage rising heat dissipation at the processor, server, and rack level. Liquid cooling offers a solution to this thermal challenge with the main objective being the efficient extraction of heat from multiple heat sources within a highly constrained, compact volume with the smallest thermal resistance possible, and then rejecting this heat outside the server or rack envelope at an interface optimized primarily for heat transfer. A promising liquid-cooling strategy is the extension of passive two-phase thermal management to rack scale via thermosyphon-based systems that have the potential to provide similar operational advantages to that of widely deployed heat pipes and vapor chambers used at the processor/board scale. Thermosyphon loops incorporating with high-performance evaporators and condensers enable a scalable rack cooling system that can operate without the need for active pumping or control. This approach fits into a hybrid cooling paradigm complimenting the significant investment in current air-cooling technology and provides key differentiators with quantifiable advantages, including higher heat density handling, cooling energy reduction, lower carbon footprint, higher reliability, easy serviceability, near-zero-maintenance using low GWP dielectric fluids, and ease of implementation into new and existing installations. In this talk, I will outline how passive two-phase cooling at rack scale addresses the growing thermal challenges facing the ICT industry.

Dr. Ryan Enright is the Chief Technology Officer (CTO) and Co-Founder of Seguente Inc. and currently leads the technology commercialization of advanced energy and thermal management solutions for data centers and telecom. Prior to taking on this role, Dr. Enright was a Senior Member of Technical Staff in the Efficient Energy Transfer Department at Nokia Bell Labs from 2012-2022, where he carried out R&D in the areas of materials interface engineering, micro/nanoscale heat and mass transfer, passive heat transfer mechanisms and integrated RF, photonic and electronic thermal management. Dr. Enright 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, 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 authored over 100 journal and conference publications and more than 20 patents.

THERMALLY EXCITED OSCILLATION AND HEAT TRANSFER ENHANCEMENT IN AN OSCILLATING HEAT PIPE

Speaker: Hongbin "Bill" Ma (U. of Missouri)

Abstract: Heat transfer process in an oscillating heat pipe (OHP) involves liquid-vapor interfacial phenomenon, surface forces, thermally excited mechanical vibration, evaporation and condensation heat transfer, and oscillated forced convection. An OHP can effectively integrate thin film evaporation, oscillating flow, thermally-excited mechanical vibration, high heat transfer coefficient of entrance region, vortices induced by the oscillating flow of liquid plugs and vapor bubbles, and near-wall velocity overshoot (Richardson's annular effect), resulting in an extra high heat transport capability. In addition, the oscillating/pulsating motions in the OHP depends on the surface conditions, dimensions, working fluid, operating temperature, heat flux and total heat load, orientation, number of meandering turns, and, most importantly, the filling ratio. This presentation introduces recent results of OHPs in the field including theoretical models of oscillating motion and heat transfer of single phase and two-phase flows in capillary tubes or channels, heat transfer mechanisms enhancing oscillating motions and heat transfer of two-phase flows, neutron imaging study of oscillating motions, and liquid metal effect on the heat transfer performance in OHPs.

Dr. Bill Ma is Chair, Curators' Distinguished Professor, & Glen A. Barton Professor, in the Department of Mechanical & Aerospace Engineering, and the director of the Multiphysics Energy Research Center (MERC) in the College of Engineering at the University of Missouri (MU). He received his Ph.D. in 1995 from Texas A&M University. Since he joined MU in 1999, he has conducted active research in the fields of phase-change heat transfer, heat pipes, ejector refrigeration, and thermal management. His research has been supported by NSF, ONR, NIH, Intel, Dell, Foxconn, DARPA, Northrop Grumman, and many other federal agencies and private companies. His research work has resulted in more than 320 publications including 1 book, 8 book chapters, and over 180 refereed journal papers as well as 23 patentable technologies. The contributions he made are not only in scientific fundamental research but also in engineering applications. His research efforts led to the establishments of both companies of ThermAvant Technologies (TAT), where he is cofounder and president, and ThermAvant International (TAI), where he is cofounder and CEO, to further develop and commercialize his research results. He is a Fellow of American Society of Mechanical Engineering (ASME) and a Fellow of National Academy of Inventor (NAI).

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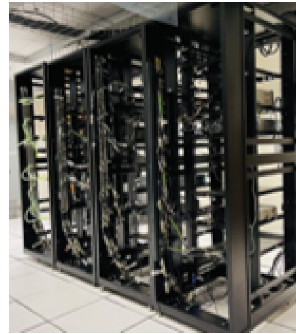
U.S. News and World Report

Electronics, MEMS, and Nanoelectronics Systems Packaging Center (EMNSPC) and NSF IUCRC for Energy-Smart Electronic Systems (ES2)

Primary objective is the advancement of cooling technology and reliability for electronics at the chip, server, rack, and room level with including air with direct and indirect evaporative heat exchangers, Liquid cooling, Immersion cooling & Reliability and testing for heterogeneous integration. New lab space (3000 sq. ft) completed & 2 Faculty lines have been allocated. Funding from various industry sources including currently - CoolIT, Fabric8Labs, Google, Honeywell, Intel, Lockheed Martin, Mestex, META, Microsoft, NVIDIA, silent-aire, Vertiv, and government agencies - NSF, NRC and ARPA-E. Currently 15 PhDs and several MS students.



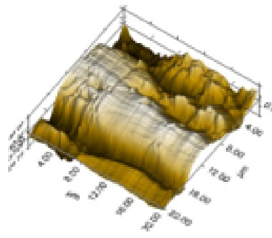
Liquid cooling rack system built from ground up.

Liquid cooling-
Extensive knowledge in setting up & testing liquid cooling systems utilizing both passive and active (ML/AI based) controls.

Air cooling-
Airflow bench for measuring system impedance for components and servers and characterizing performance of cooling media.

Hysitron TI 980 TI Nanoindenter.

Reliability & testing-
$650K Acquisition,
10,000+ indentation density,
1000 μm x 1000 μm test area.



Other equipment includes - TMA, DMA, Environmental chamber, & vaccum thermal chamber.

LaVision Tomographic PIV with PLIF capabilities.

Immersion cooling-
PIV - $400K Acquisition, Volumetric flow analysis, planar convective heat transfer analysis. Other equipment: 2U SPIC & TPIC tanks.

Future Acquisitions –
SONIX S.A.M, S.E.C 865 Flip chip bonder, thermal shock chamber, HALT chamber.

Director: Dr. Dereje Agonafer agonafer@uta.edu EMNSPC website: http://emnspc.uta.edu

RESEARCH WORKSHOP

THURSDAY, JUNE 1, 3:30-5:00PM, AMARANTE 2-3 (LOWER LEVEL)

Session Chair: Patrick Shamberger (Texas A&M University) and Satish Kumar (Georgia Tech)

The research workshop 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

Speaker: Peter de Bock (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. ARPA-E projects span a broad range of technologies but often include multi-disciplinary teams evaluation how to solve a challenge in a new and impactful way. Unique about ARPA-E is a focus on how such technologies could be positioned such that they are ready for post-project commercial investment. Thermal management plays an important role in projects such as ASCEND, REEACH, and COOLERCHIPS and an overview will be presented how significant advances are made in these areas

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 manages and supports over teams in zero-carbon hybrid aviation propulsion systems through the $63M ASCEND program and efficiency of cooling of Data Centers through the $42M COOLERCHIPS program. 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 with over 1000 citations. 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 UK.

THE OFFICE OF NAVAL RESEARCH – SCIENCE AND TECHNOLOGY IN SUPPORT OF THE US NAVY AND MARINE CORPS

Speaker: Mark Spector (Office of Naval Research)

Abstract: The Office of Naval Research is the catalyst of future naval power, ensuring technological dominance for our fleet and force. ONR finds the best minds from across the nation and around the globe, sponsoring new research and creating new capabilities for America's Sailors and Marines.

The Thermal Science and Engineering supports basic and applied research on multi-phase heat transfer, fluid dynamics and nanostructured materials. The program supports the development of technologies to efficiently acquire, transport, and reject heat and enable higher power density electronic systems. This work supports the Navy's interest in advanced naval power and energy systems science and technology.

Dr. Mark S. Spector is a Program Officer in the Advanced Naval Platforms Division at the Office of Naval Research where he manages research in thermal science, metamaterials, energy conversion, and climate resiliency. In addition, he sits on the Steering Committee of the Department of Defense Energy and Power Community of Interest, the US Navy Climate Working Group, and the NATO Applied Vehicle Technology Power and Propulsion Systems Technical Committee. Previously, he worked as a Research Physicist at the Naval Research Laboratory. He received his doctorate in Physics from the Massachusetts Institute of Technology and bachelor's degrees in physics and Applied Mathematics from the University of California at Berkeley. Dr. Spector has coauthored 54 journal publications, 3 invited book chapters, and holds 3 patents.

ARPA-E HITEMMP (HIGH INTENSITY THERMAL EXCHANGE THROUGH MATERIALS AND MANUFACTURING PROCESSES) PROGRAM

Speaker: Dr. Philseok Kim (ARPA-E)

Abstract: Thermal management plays a critical role in the overall size, weight, performance and cost (SWaP-C) of most energy conversion systems. It also plays a critical role in the overall system reliability and robustness over its desired operating conditions. ARPA-E's HITEMMP program supports the development of compact heat exchangers capable of operating for tens of thousands of hours in temperatures exceeding 800°C/1100°C (metals/ceramics) and pressures exceeding 80/250 bar (hot side/cold side). The program aims to demonstrate 50-kW lab-scale heat exchangers operating in relevant conditions via sCO2 loop testing at the end of the program. HITEMMP projects will enable a revolutionary new class of heat exchangers and innovative approaches to advanced manufacturing with applications for a wide range of commercial and industrial energy producers and consumers.

Dr. Philseok Kim is a Program Director at ARPA-E with a broad interest across functional materials and composites, engineered surfaces and structures, manufacturing, and grid reliability toward accelerated electrification and decarbonization of energy infrastructure. He is currently leading the ULTIMATE (ultrahigh temperature refractory alloy development and manufacturing), HITEMMP (high temperature and high pressure compact heat exchangers), and GOPHURRS (advanced technologies for low-cost, high speed, and safe undergrounding of power lines for grid reliability) programs, as well as several other projects in advanced materials and manufacturing including Direct Air Capture and advanced magnetic materials portfolio

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PANEL SESSIONS

P-2: THERMAL AND MECHANICAL CHALLENGES AND OPPORTUNITIES OF ADVANCED MOBILE/IOT/AUTO/HIGH POWER COMPUTING DEVICES
WEDNESDAY, MAY 31ST, 10:30 AM – 12:00 PM, AMARANTE 2-3 (LOWER LEVEL)

Moderator: Victor Chiriac (Global Cooling Technology Group LLC)

Abstract: 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 leads to significant rise in mobile communication, IoT technology, automotive, space and high-power computing devices, providing the infrastructure needed to carry huge amounts of data, allowing for a smarter and more connected world – enabling Smart Cities, connected roads, advanced transportation (Self-driving cars), AR/VR, AI robotics, Digital healthcare and more. A panel of experts will share their vision on the future of small to large electronics thermal management and other advanced system level thermo-mechanical challenges and solutions.

Panelists:

Raj Pendse
(Meta)

Yogendra Joshi
(DARPA)

Cristina Amon
(U Toronto)

Sreekant
Narumanchi
(NREL)

P-4: ELECTRONICS COOLING AT SCALE – TOWARD A FUTURE OF EFFICIENT COMPUTING
WEDNESDAY, MAY 31ST, 3:30 – 5:00 PM, AMARANTE 2-3 (LOWER LEVEL)

Moderator: Kimberly Saviers (Raytheon)

Abstract: Data centers are estimated to consume 1-3% of electricity consumption globally, a vast majority relying on legacy air-cooled configurations. Looking forward, edge data centers, in particular, are projected to have the most significant growth and nearly triple in number in the next couple of years. By 2025, every person in the developed world will have at least one interaction with a data center every 18 seconds in their lifetime. Therefore, energy efficient data centers are critical to an environmentally conscious future of computing. Key challenges in the industry include not only thermal innovations, but also economic and regulatory hurdles. This panel explores the data center industry from several perspectives toward the goal of maximizing data center energy efficiency.

Panelists:

Al Ortega
(Villanova)

Jackson
Marcinichen
(JJ Cooling)

Peter de Bock
(ARPA-E)

Yin Hang
(META)

Dereje Agonafer
(UT Arlington)

Bahgat Sammakia
(Binghamton)

P-6: CHIPS ACT: OPPORTUNITIES TO INCORPORATE THERMALS AND PACKAGING INTO CHIP FABRICATION AND DESIGN

THURSDAY, JUNE 1ST, 10:30 AM – 12:00 PM, AMARANTE 2-3 (LOWER LEVEL)

Moderator: Vaibhav (VB) Bahadur (UT Austin)

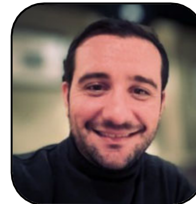
Abstract: The recently passed CHIPS Act will provide $10 billion + worth of funds for R&D in semiconductor fabrication, packaging and related topics. This represents a once-in-a-generation opportunity to re-imagine future microelectronics packages and integrate thermal management, diagnostics & monitoring, and packaging into the chip design and nanofabrication processes. There will be CHIPS-enabled opportunities in a variety of microelectronics platforms related to high performance computing, mobile, power electronics, gaming etc. A panel of experts will share their vision on critical multidisciplinary challenges that need to be addressed and strategies to translate R&D into scalable manufacturing. This panel will include multi-domain experts from industry, academia and government.

Panelists:

Ganesh Subbarayan (Purdue)

Muhannad Bakir (Georgia Tech.)

Hemanth Dhavaleswarapu (AMD)



Raffaele Luca Amalfi (Seguente)

P-10: ARTIFICIAL INTELLIGENCE: INDUSTRY USE CASES AND INVESTMENT TRENDS

FRIDAY, JUNE 2ND, 10:30 AM – 12:00 PM, AMARANTE 2-3 (LOWER LEVEL)

Moderator: Luca Amalfi (Seguente Inc)

Abstract: The use of Artificial Intelligence (AI) has been mainly focused on the development of analytical models to solve complex problems with higher accuracy and lower computational time than conventional mathematical approaches. The advancements in AI-based algorithms and optimization strategies, along with the creation of new startups, are creating new products and business opportunities. AI-based solutions are revolutionizing our digital society allowing for technology developments at a rate that was never seen before. A panel of distinguished industry, government and academia members will share their vision on the future of AI across multiple industry sectors including energy, healthcare, education, manufacturing, and others.

Panelists:

John Kim (Seguente)

Vaibhav Bahadur (UT Austin)

Philseok KIM (ARPA-E)

Paul Paret (NREL)

Milan Dordevic (Proctorio Incorporated)

Yoonjin Won (UC Irvine)

P-11: MECHANICS AND RELIABILITY: PACKAGING CHALLENGES FOR HARSH ENVIRONMENT APPLICATIONS
FRIDAY, JUNE 2ND, 1:30 – 3:00 PM, AMARANTE 2-3 (LOWER LEVEL)

Moderator: Pradeep Lall (Auburn University)

Abstract: Electronics may be required to function in harsh environment applications in several use scenarios, including automotive, downhole, consumer, military, and defense applications. The wide temperature extremes sustained high temperatures, high-g loads, and need for high reliability impose unique constraints on the design, selection of packaging architectures, materials, and processes. The panel will address the unique needs of several application spaces and the technology gaps that need to be surmounted for next-generation packaging applications.

Panelists:

Eric Dede (Toyota Research Institute of North America)	Varughese Mathew (NXP Semiconductor	Vikas Gupta (ASE)	Jaimal Williamson (Texas Instruments)	Dr. Steve Dunford (SLB)

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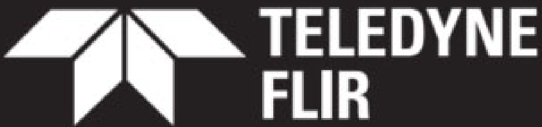

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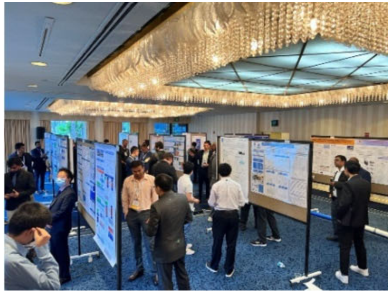
STUDENT POSTER SESSION

THURSDAY, JUNE 1, 5:00-7:00 PM, SEGURA (LOWER LEVEL)

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

Track	Poster #	Student Name	School	Paper #	Paper Title
Thermal-1 Component Level	1	Min Jong Kil	University of California, Los Angeles	67	Direct Solar-Thermal Formation of Graphitic Heat Spreaders on Organic Substrates
	2	Nicholas Morgan	University of Central Florida	137	Fabrication and Testing of Flexible Pulsating Heat Pipes
	3	Mohammad Azarifar	Auburn University	359	Direct Numerical Simulation of Synthetic Jet Coupled to Forced Convection Cooling in a Channel Flow
	4	Carol Caceres	Villanova University	157	Dynamic Modeling of a Refrigerant-Based Cross-flow Heat Exchanger for Close-Coupled Hybrid Cooled Data Centers
	5	Georg Elsinger	KU Leuven	128	Micro-Scale Jet Cooling: A Numerical Study on Improvement Options
	6	Madhu Kasturi	Auburn University	282	Evolution of TIM/Copper Interface under Wide Temperature
	7	Deogratius Kisitu	Villanova University	141	Two-phase flow in compressed copper foam with R134a for high heat flux thermal management: Effects of foam compression ratio and refrigerant operating conditions on thermohydraulic performance
	8	Aniket Ajay Lad	University of Illinois at Urbana Champaign	123	Topology Optimized Fin Designs for Base Plate Direct-Cooled Multi-Chip Power Modules
	9	Shuhang Lyu	Purdue University	133	Hotspot-targeted Cooling Scheme with Hybrid Jet Impingement/Thermal Through Silicon Via (TSV)

Track	Poster #	Student Name	School	Paper #	Paper Title
	10	Shahzeb Mirza	University of Toronto	357	Phase Change Material-Based Cooling Systems Subject to Periodic Heating: Lumped Analysis and Experimental Verification
	11	Arani Mukhopadhyay	University of Illinois Chicago	176	Thermal Performance of a Liquid-cooling Assisted Thin Wickless Vapor Chamber
	12	Aaron Smith	Auburn University	330	Improving fluid-thermal performance of impinging jet arrays with small-scale engineered surface augmentations in the fountain regions
	13	Karthekeyan Sridhar	Auburn University	35	Asymmetric Sawtooth and Cavity-Enhanced Nucleation-driven (ASCENT) Experiment Aboard the International Space Station – Microgravity Outcomes
	14	Piyush Tripathi	Purdue University	149	A New Thermal Management Figure of Merit for Phase Change Materials (PCMs) Selection Considering Geometry
	15	Goksel Yuncu	Middle East Technical University	102	Elliptic Micropillar Wick Evaporators for Thermal Management of High Heat Flux Electronics

Track	Poster #	Student Name	School	Paper #	Paper Title
Thermal-2 System Level	16	Muhammad Ghufran	University of Arkansas	155	Synthesis of ePCMs for thermal management of electronics
	17	Falak Mandali	Purdue University	45	Control Co-Design of a Thermal Management System with Integrated Latent Thermal Energy Storage and a Logic-based Controller
	18	Joshua Palumbo	University of Toronto	358	Implementation of a Topologically Optimized Heat Sink for Non-Uniform Heat Fluxes in an EV Fast-Charger
	19	Chinmay Shingote	Case Western Reserve University	173	Prediction and Flow Visualization of Critical Heat Flux of PF-5060 within a Horizontal Rectangular Channel with Single sided heating

Track	Poster #	Student Name	School	Paper #	Paper Title
Mechanics and Reliability	20	Sufyan Tahat	Auburn University	333	Effects of Multiple Reflows on IMC and Shear Strength of Individual Solder Joints
	21	GOLAM RAKIB MAZUMDER	Auburn University	288	Evolution of the Creep Response of SAC305 Solder Due to Mechanical Cycling
	22	Mohammad Al Ahsan	Auburn University	277	Evolution of the Creep Response of SAC+Bi Lead-Free Solders Subjected to Various Thermal Exposure Profiles
	23	Abdallah Alakayleh	Auburn University	192	Effect of Solder Paste Alloy and Volume on Solder Voiding
	24	Chetan Jois	Purdue University	328	Test device design and test procedure for non-destructive characterization of Bi phase accumulation during electromigration
	25	Sungmo Jung	Auburn University	275	Effect of Chlorine-Bromine pH and Temperature on the Corrosion Propensity of the Cu-Al WB System
	26	Ritwik Vijaykumar Kulkarni	Purdue University	255	In situ Optical Observations of Degradation of Thermal Greases with Thermal Cycling
	27	Debabrata Mondal	Auburn University	284	Size Effects on Overall Deformation Behavior of SAC Samples

	28	Pranay Nagrani	Purdue University	97	Influence of Thermal Cycling on Degradation Behavior of Thermal Greases
	29	Jacek Nazdrowicz	Lodz University of Technology	182	Influence of temperature on the quality of operation of an analog reading system for MEMS structures
	30	Aathi Raja Ram Pandurangan	Auburn University	290	Pad Cratering Evolution With Multiple-Reflows at Resin-Copper Interfaces Under Large Out-of-Plane Deformation
	31	Qais Qasaimeh	Auburn University	224	Predicting the Fatigue Life of the Solder Joints in Electronic Assemblies using Physics-informed Data-driven Methodology
	32	Yunli Zhang	Auburn University	312	Characterization of Aging Effects on Thermal and Mechanical Properties of Magnetically-Oriented ACA for Flexible and Stretchable Electronics

Track	Poster #	Student Name	School	Paper #	Paper Title
Emerging Technologies and Fundamentals	33	Joshua Kasitz	University of Arkansas	165	Phase Transition Behavior of Thin Film Phase Change Materials
	34	Meghavin Bhatasana	Purdue University	331	Deep Learning for Real-Time Chip Temperature and Power Predictions
	35	Sabina Bimali	Auburn University	315	Process Recipes of Additively Printed Sustainable Silver-Ink Using Aerosol Jet Printing
	36	Bivek Bista	University of Connecticut	76	Evaluating the thermal performance of perovskite $SrSnO_3$ field effect transistors
	37	Aalok Gaitonde	Purdue University	153	Feasibility Assessment of Metrologies for Thermal Resistance Characterization of Deeply Buried Interfaces between Bonded Silicon Layers
	38	Daniel Karakitie	Auburn University	318	Realization of Circuits with Additively Printed Water Based Nanoparticle Sustainable Silver-Ink with Ultrasonic Atomization on Aerosol Jet Printer
	39	Shriram Kulkarni	Auburn University, Auburn, AL	304	Prediction of Print Geometry and Electrical Performance of InkJet Printed Electrical Components Using Statistical Models for Closed Loop Control
	40	Juan Lago	Texas A&M University	306	Thermal Impedance and Dynamics of Phase Change Materials under Pulse Train Heating
	41	Fatahi Musa	Auburn University	320	Sustainable Silver Ink Process Studies on Low-Temperature Flexible Substrates.
	42	Jinesh Narangaparambil	Auburn University	298	Performance and Reliability of SMD Interconnections using Low-Temperature Solders and ECAs for FHE Applications
	43	Anish Pal	University of Illinois at Chicago	188	Aluminum Nitride (AlN) Ceramic Surfaces for Enhanced Dropwise Condensation
	44	Qian Qian	Purdue University	53	Experimental investigation of ultra-thin microchannel oscillating heat pipes with submillimeter-scale thickness
	45	Md Golam Sarwar	Auburn University	319	Print Process Development for Ag-Ink Thermoformable Conductive Traces Utilizing Direct Write technique for In-Mold Printed Electronics
	46	Ved Soni	Auburn University	283	SOH Degradation Modeling of Thin Flexible Li-ion Batteries Subjected to Life Cycling with

					Randomized Cycling Depth, C-Rates, and U-Flex-to-Install
	47	Tyler Stamps	Purdue University	107	Temperature-controlled transition boiling at the stagnation zone during confined jet impingement of a dielectric fluid
	48	Diego Vaca	Georgia Institute of Technology	167	Temperature Dependent Thermal Properties of Thin Film Hafnium Oxide
	49	Trevor Whitaker	University of Utah	84	Experimental investigation of boiling heat transfer coefficient in two-phase carbon dioxide in a microchannel with side-view schlieren flow visualization
	50	Yuchi Yang	Peking University	93	Cooling performance study of coplanar counterflow microchannels
	51	Amir Abdolhosseinzadeh	Boğaziçi University	248	Thermal characterization of a silicon wafer utilizing a non-Fourier heat transport equation and Micro-Raman spectroscopy
	52	Pegah Ghanizadeh	Bogazici University	246	Mean Free Path - Thermal Conductivity Relation of AlxGa(1-x)N Alloys

ITherm 2022 WINNING POSTERS

COMPONENT-LEVEL THERMAL MANAGEMENT TRACK

BEST POSTER

Comparison between Direct Winding Heat Exchanger and Slot-liner Confined Evaporative Cooling of Electric Motor

Amitav Tikadar (Georgia Institute of Technology)

OUTSTANDING POSTER

Flow Visualization of Turbulent Jet Impingement with Engineered Surface Modifications through Particle Image Velocimetry

Aaron Smith (Auburn University)

SYSTEM-LEVEL THERMAL MANAGEMENT TRACK

BEST POSTER	OUTSTANDING POSTER
A Dynamic Co-Simulation Framework for the Analysis of Battery Electric Vehicle Thermal Management Systems	**Performance Characterization of a Novel Low-Cost Additively Manufactured PCM-to-Air Polymer Composite Thermal Energy Storage for Cooling Equipment Peak Load Shifting**
Tayler Shelly (Purdue University)	Veeresh Ayyagari (University of Maryland College Park)

EMERGING TECHNOLOGIES AND FUNDAMENTALS TRACK

BEST POSTER	OUTSTANDING POSTER
Circuit-level thermal modelling of Silicon Photonic Transceiver Array using Machine Learning	**The Effect of Fin Array Height and Spacing on Heat Transfer Performance during Pool Boiling from Extended Surfaces**
David Coenen (KU Leuven)	Maureen Winter (Purdue University)

MECHANICS AND RELIABILITY TRACK

BEST POSTER	OUTSTANDING POSTER
Phase Field Simulations of Solder Void Evolution under Thermal Aging	**Influence of Component Interconnect with Printed Copper Circuits on Realized Mechanical and Electrical Characteristics in FHE Applications**
Chetan Jois (Purdue University)	Jinesh Narangaparambil (Auburn University)

PAPER REVIEWERS

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Aaron Wemhoff
Aastha Uppal
Aathi R. R. Pandurangan
Abhijit Dasgupta
Abhishek Deshpande
Adam Wilson
Alicia Medina Garcia
Amir Shooshtari
Amrutha Rachakonda
Anil Yuksel
Anto Barigala
Arani Mukhopadhyay
Arifur Chowdhury
Ashish Gupta
Bahareh Eslami
Beihan Zhao
Bella Amyx
Ben Platt
Bijendra Singh
Bongarala Manohar
Bradly Verdant
Brayden Morse
Caleb Anderson
Chaolun Zheng
Cheng Chen
Chi Zhang
Chuljae Jung
Collin Ruby
Constantine Megaridis
Cristina Amon
Daniel Bacellar
Daniel Juarez Robles
Darin Sharar
Darshan Ravoori
David Huitink
Deogratius Kisitu
Devahdhanush V.S.
Devdatta Kulkarni
Donghua Yang
Edvin Cetegen
Farid Soroush
Fernando Milanese
Gabriel Parent
Galen Jackson
Gargi Kailkhura
Gaurav Chaudhary
Gaurav Patankar
Gautam Gupta
Geoff Wehmeyer
Georg Elsinger
George Damoulakis
George Gogos
Georges Pavlidis
Ghazal Mohsenian
Girish Kini
Harish Ganapathy
Harnoor Singh Sachar
Hassan Azarkish
Herman Oprins
Himanshu Modi
Hongjun Ji
Hung-Yun Lin
Hyoungsoon Lee
Jacek Nazdrowicz
Jacob L.-Dawaghreh
Javed Shaikh
Jayati Athavale
Je-Young Chang
Jia Liu
Jiajun Xu
Jianfei Zhang
Jim Vangilder
Jinesh Narangaparambil
Jinglun Li
Jiu Xu
John Kim
Jorge Alvarado
Jorge Padilla
Joseph Herring
Joshua Palumbo
Juan Pablo Flórez Mera
Jun Zhang
Justin Weibel
Kalyan Dornala
Kanan Pujara
Karsten Meier
Karthekeyan Sridhar
Karthik Kumar
Katerina Reynolds
Ke Pan
Keji Matsumoto
Kenneth Marston
Kimia Montazeri
Krishna Vasanth Valavala
Kuan-Lin Lee
Kunal Ahuja
Kyungjin Kim
Lalit Bansal
Lang Yuan
Li Chen
L. S. R. Chinthaparthy
Luz Belmont
Madhu Kasturi
Mahdi Nabil
Martin Springer
Matthew Clark
Mete Muslu
Michael Fish
Michael Mayer
Michael Shanks
Mohammad Azarifar
Mohammad N. Bakhtiyar
Mohammad Tradat
Mohammed A. Elhashimi
Monali Basutkar
Mrinmoy Saha
Muhammad Ghufran
Muhammad Ikhlaq
Mustafa Ozsipahi
Nakul Kothari
Nicholas Hines
Nicole Cassada
Nitin Karwa
Nurul Azam
Nury Nieto
Okafor G.
Omidreza Ghaffari
Onur Yenigun
Oscar Farias Moguel
Padmanava Choudhury
Pardeep Shahi
Patrick Mccarthy
Patrick Shamberger
Paul Paret
Ping-Chuan Wang
Pratik Bansode
Pruthvik Raghupathi
Przemyslaw Gromala
Qi Feng
Qianying Wu
Quang Nguyen
Rabin Bhandari
Rachel Mcafee
Rajiv Iyer
Rebekah O'Neill
Reza Ghaffarian
Rifat Mahmud
Rinaldo Miorini
Risa Miyazawa
Rohan Kapoor
Saeel Pai
Sai Abhideep Pundla
Sai Sanjit Ganti
S. V. K. Balasubramaniam
Sankarananda Basak
Sathya Raghavan
Satyam Saini
Satyam Saini
Scott Schiffres
Sevket Yuruker
Shadi Mahjoob
Shahzeb Mirza
Shantanu Deshpande
Shitiz Sehgal
Shuhang Lyu
Shuye Zhang
Sina Hossein Zadeh
Sourav Chakravarty
Srivathsan Sudhakar
Stephanie Allard
Suchismita Sarangi
Sushumna Iruvanti
Tanya Liu
Taylor Stoll
Tiwei Wei
Travis Mayberry
Umesh Prasad
Vahid Attari
Ved Soni
Veeresh Ayyagari
Vibin Simon
Vincent Voet
Visakh Vaikuntanathan
Vivek Khaire
Vivek Nair
Wangyun Li
Wei Wang
Wenbin Tian
Whit Vinson
Xianming Dai
Xiaopeng Qu
Xing Qiu
Xu Long
Yaman Manaserh
Yangyang Lai
Yaxiong Chen
Ying Feng Pang
Yingying Wang
Yong Guo
Yong Pei
Young Jong Lee
Yue Xiao
Yueming Li
Yujui Lin
Yun Zhang
Yutai Su
Zane Oligee
Zhaoxi Yao
Zhengda Yao
Zhi Yang
Zubin Padia

CONFERENCE TECHNICAL PROGRAM

TRACKS & SESSIONS

COMPONENT-LEVEL THERMAL MANAGEMENT

- TI-2: Component Level Cooling
- TI-3: Power Electronics and HI Package Cooling
- TI-4: TIMs and Heat Spreaders
- TI-6: Thermal Modeling and Analysis I
- TI-7: Thermal Modeling and Analysis II
- TI-8A: Jet Impingement
- TI-8B: Heat Pipes and Vapor Chambers
- TI-10: Coldplates and Heat Exchangers
- TI-11: Two-phase Cooling

SYSTEM-LEVEL THERMAL MANAGEMENT

- TII-2: Advanced Modeling of Thermal Systems
- TII-3: Air Cooling Techniques and Heat Exchangers
- TII-4: Automotive, Batteries and Thermal Storage
- TII-7: Advanced Cooling Solutions
- TII-8: Immersion Cooling and Refrigeration
- TII-10: Liquid Cooling Solutions II
- TII-11: Thermal Management in Space and Aerospace

EMERGING TECHNOLOGIES & FUNDAMENTALS

- E-2: Additive Manufacturing 1
- E-3: Thermal Management 1
- E-4: Thermal Management 2
- E-6 Thermal Management 3
- E-7: Additive Manufacturing 2
- E-8 Thermal Management 4
- E-10 Special Topics
- E-11: Additive Manufacturing 3

MECHANICS & RELIABILITY

- M-2: Thermal Interface Material Reliability
- M-3: Chip-Package Interactions and Reliability
- M-4: Emerging Package Reliability Methods
- M-6: BGA and Board Level Reliability Mechanics
- M-10: Fatigue of Solders
- M-11: Solder Metallurgy and Process Impacts on Reliability

VIRTUAL

- V-2: Liquid and Immersion Cooling
- V-3: Data Center Cooling
- V-4: Special Topics
- V-5: Manufacturing
- V-7: Liquid and Immersion Cooling

DAY 1: WEDNESDAY, MAY 31

Time					
7:00 AM	**Speakers' Breakfast** — Venue: Palazzo Ballroom				
8:00 AM	**TT-1: Advances in Chiplets and Heterogenous Integration - Packaging, Reliability and Thermal Management** (see pages 26-27) — **Venue:** Amarante 2-3				
9:00 AM	**K-1 Keynote: Transformation of Data Centers from Air to Liquid Cooling** Sandeep Ahuja (Intel Corporation) — Venue: Segura A typical air-cooled datacenter spends 30-40% of its power consumption in cooling. Electricity usage by datacenters crossed 200 TWh in 2021 and crypto mining further adds significant demand to energy needs. It is becoming clear that one needs to look for cooling technologies that can enable the datacenter industry to deliver more performance while spending less on cooling. Liquid cooling technologies such as cold plate and immersion can help achieve sustainability goals of the datacenter industry. The keynote shall cover various liquid cooling technologies being deployed in datacenters. Immersion cooling with single and two-phase options is discussed. Key engineering parameters such as thermal performance, signal integrity, material compatibility and reliability of IT equipment in immersion are discussed. The technology can deliver power savings of 15-38% compared to that for an equivalent air-cooled datacenter. The talk will end with call to action for the industry to accelerate deployment of this technology.				
10:00 AM	**Refreshment Break** — **Venue**: Foyer outside of Del Lago				
10:30 AM	**TECHNICAL SESSIONS**				
	P-2: Thermal and Mechanical Challenges and Opportunities of Advanced Mobile/IoT/Auto/ High Power Computing Devices (see page 37)	**TI-2: Component Level Cooling**	**TII-2: Advanced Modeling of Thermal Systems**	**E-2: Additive Manufacturing 1**	**M-2: Thermal Interface Material Reliability**
Venue	Amarante 2-3	Del Lago 1	Del Lago 2	Del Lago 3	Del Lago 4
12:00 PM	**Luncheon: Richard Chu ITherm Award Presentation** — **Venue**: Palazzo Ballroom				
1:30 PM	**TECHNICAL SESSIONS**				
	TT-3: Impact of Thermal Management on Carbon Neutrality and Sustainability (see page 27-29)	**TI-3: Power Electronics and HI Package Cooling**	**TII-3: Air Cooling Techniques and Heat Exchangers**	**E-3: Thermal Management 1**	**M-3: Chip-Package Interactions and Reliability**
Venue	Amarante 2-3	Del Lago 1	Del Lago 2	Del Lago 3	Del Lago 4
3:00 PM	**Refreshment Break** — **Venue**: Foyer outside of Del Lago				
3:30 PM	**TECHNICAL SESSIONS**				
	P-4: Electronics Cooling at Scale – Toward a Future of Efficient Computing (see page 37)	**TI-4: TIMs and Heat Spreaders**	**TII-4: Automotive, Batteries, and Thermal Storage**	**E-4: Thermal Management 2**	**M-4: Emerging Package Reliability Methods**
Venue	Amarante 2-3	Del Lago 1	Del Lago 2	Del Lago 3	Del Lago 4
5:00 PM	**Student Heat Sink Competition** — Venue: Segura The Student Heat Sink Design Challenge is a team competition in which students design, analyze and optimize an aluminum additively manufactured heat sink. The design from each student team is then evaluated based on a series of design and manufacturing criteria. (see page 24)				
6:30 PM	**ECTC/ITherm Diversity & Career Growth Panel & Reception** (see page 19) — **Venue**: Mediterranean 4&5				
7:30 PM	**ASME K-16 & Journal of Electronic Packaging Meeting** — **Venue**: Amarante				

Session TI-2: COMPONENT LEVEL COOLING — Del Lago 1

Session Chairs: Ryan Enright (Seguente) and Filippo Cataldo (Wieland Provides S.R.L.)

Design and Experimental Verification of Air Cooled Server Enclosure: A Novel Approach for Heat Sink Characterization

Ghazal Mohsenian[1], Yaman Manaserh[1], Mohammad Tradat[1], Srikanth Rangarajan[1], Ayushman Singh[1], Kourosh Nemati[2], Alfonso Ortega[3], Bahgat Sammakia[1], [1]Binghamton University, [2]Future Facilities, [3]Villanova University

Development of Power Law Design Tool for Hotspot Mitigation using Parallel Microchannel Heat Exchanger

Chase McCreary and Stephen Solovitz, Washington State University

Cooling Performance Study of Coplanar Counterflow Microchannels

Yuchi Yang[1], Peijue Lyu[1], Motong Li[2], Zhou Yang[1], Jianyu Du[1], Chi Zhang[1,3], Wei Wang[1,3], [1]Peking University, [2]Tsinghua University, [3]National Key Laboratory of Science and Technology

The Embedded Cooling Silicon 3D Stacking Thermal Test Vehicle

Xiaoliang Zhao[1], Penghuai Shu[1], Wei Li[1], Zhenyu Wang[1], Xiaobin Zhang[2], [1]Peking University, [2]Institute of Microelectronics of the Chinese Academy of Sciences

Characterization of GaN-on-SiC Wafers using a Multi-method Laser-based Pump-probe Technique

Yiwen Song[1], Daniel Shoemaker[1], Kyuhwe Kang[1], Michael Schuette[2], James Tweedie[2], Scott Sheppard[2], Sukwon Choi[1], [1]The Pennsylvania State University, [2]Wolfspeed

Session TII-2: ADVANCED MODELING OF THERMAL SYSTEMS — Del Lago 2

Session Chairs: Lang Yuan and Harish Ganapathy (Intel Corporation)

Control Co-design of a Thermal Management System with Integrated Latent Thermal Energy Storage and a Logic-based Controller

Falak Mandali, Michael Shanks, Neera Jain, Purdue University

Singular Value Decomposition (SVD) based Thermal Resistance Matrix (TRM) Size Reduction for Fast Optimization of On-die Floorplan and Temperature Sensor Placement

Hyungyung Jo, Heeseok Lee, Heonwoo Kim, Youngsang Cho, Jongkyu Yoo, Chigwan Oh, Junso Pak, Samsung Electronics Co.

CFD Analysis of Extracted Fluid Volume for Predicting Pressure Drop in Additively Manufactured Cold Plates with Complex Fin Patterns

Girish Upadhya, Northrop Grumman Mission Systems

Comparison of Time-Splitting and SIMPLE Pressure-Velocity Coupling for Steady-State Data Center CFD

Wei Tian, Jim VanGilder, Michael Condor, Andrew Ardolino, Schneider Electric

Session E-2: ADDITIVE MANUFACTURING 1 — Del Lago 3

Session Chair: Tiwei Wei (Purdue University)

A Numerical Study of Compact Fin Array Geometries to Improve Additively Manufactured Heat Exchanger Performance

Zane Oligee, Roy Knight, Nicholas Tsolas, Auburn University

Sustainable Copper Ink Process Studies on Low-Temperature Flexible Substrates

Pradeep Lall[1], Fatahi Musa[1], Jinesh Narangaparambil[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Influence of Print Parameters on Mechanical and Electrical Properties of Conductive Traces Printed using Water-Based Silver Nanoparticle Ink on Inkjet Platform

Pradeep Lall[1], Shriram Kulkarni[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Investigation of an Additively Manufactured Two-Phase Heat Exchanger with Built-In Thermal Storage

Mehdi Kabir[1], Evan Preller[1], Raid Mohammed[1], Calin Tarau[2], Bao Yang[1], Angel Alvarez-Hernandez[3], Jiajun Xu[1], [1]University of the District of Columbia, [2]Advanced Cooling Technologies, Inc., [3]NASA Johnson Space Center

Session M-2: THERMAL INTERFACE MATERIAL RELIABILITY — Del Lago 4

Session Chair: Madhu Kasturi (Auburn University)

Squeeze Flow and Thermal Resistance Characterization of Thermal Interface Materials

Sukshitha Achar P L, Colin Greene, Ganesh Subbarayan, Purdue University

Reliability of Thermal Interface Materials in Combined Mechanical and Thermal Stress

Danielle Berry, Stephanie Valenzuela, Joseph Sootsman, Dow Chemical Company

***In situ* Optical Observations of Degradation of Thermal Greases with Thermal Cycling**

Ritwik Kulkarni, Pranay Nagrani, Amy Marconnet, Purdue University

Influence of Thermal Cycling on Degradation Behavior of Thermal Greases

Pranay Nagrani, Ritwik Kulkarni, Amy Marconnet, Purdue University

DAY 1: WEDNESDAY, MAY 31 1:30 – 3:00 PM TECHNICAL SESSIONS

Session TI-3: POWER ELECTRONICS AND HI PACKAGE COOLING — Del Lago 1

Session Chairs: John Kim (SEGUENTE) and Nitin Karwa (Honeywell International Inc.)

Liquid Jet Impingement Cooling of High-performance Interposer Packages: A Hybrid CFD–FEM Modeling Study

Herman Oprins[1], Tiwei Wei[1,2], Vladimir Cherman[1], Eric Beyne[1], [1]imec, [2]Purdue University

Numerical Investigation of Silicon-Embedded Microchannel Structures Containing Different Shaped Interior Flow-Splitting Walls and Micro Pin-Fins for Hotspot Mitigation of GaN High-Power Devices

Orçun Yildiz, Aselsan Inc.

Comparative Thermal Analysis of Wide Band Gap Power Module

Guesuk Lee, Jemin Kim, Sungsoon Choi, Byongjin Ma, Korea Electronics Technology Institute

Low Computational Cost Thermal Modelling of High-Frequency Power Transformers using an Admittance Matrix Approach

Anshuman Dey[1], Navid Shafiei[1], Rahul Khandekar[1], Wilson Eberle[2], Ri Li[2], [1]Enersys, [2]University of British Columbia

Session TII-3: AIR COOLING TECHNIQUES AND HEAT EXCHANGERS — Del Lago 2

Session Chairs: Hedan Zhang (Western Digital), Ameya Limaye, Palash Acharya (Qualcomm), and Geoff Wehmeyer

Optimization of Metal Foam Heat Sinks for Electronic Air Cooling: Part I: Porosity

Amir Radmanesh[1], Nihad Dukhan[1], Ming Liang[2], Jonathan Engels[2], [1]University of Detroit Mercy, [2]Ford Motor Company

Experimental Hydraulic Performance Investigation of Fan Enclosure and Competing Effects

Yuanchen Hu, Milnes David, Philipp Buchling, Charles Gary, Michael Fortine, IBM Corporation

Experimental Study of Improved Chassis and Duct Redesign for Air-Cooled Server

Himanshu Modi, Pardeep Shahi, Vibin Simon, Lochan Sai Reddy Chinthaparthy, Gautam Gupta, Akiilessh Sivakumar, Satyam Saini, Pratik Bansode, Dereje Agonafer, University of Texas at Arlington

Session E-3: THERMAL MANAGEMENT 1 — Del Lago 3

Session Chairs: Vibin Simon (The University of Texas at Arlington) and Rick Eiland (Stealth Startup)

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, University of the District of Columbia

Thermal Impedance and Dynamics of Phase Change Materials under Pulse Train Heating

Juan Lago[1], Veronica Gonzalez Fernandez[1], Michael Barako[2], Patrick Shamberger[1], [1]Texas A&M University, [2]Northrop Grumman Corporation

Deep Learning for Real-Time Chip Temperature and Power Predictions

Meghavin Bhatasana, Amy Marconnet, Purdue University

Influence of Cell Dimensions and Number of Tabs on Cylindrical Lithium-ion Cell Sidewall and Bottom Cooling Performance

Heiner Heimes, Christian Offermanns, Moritz Frieges, Nima Ghandily, Ghazi Zamit, Jonas Gorsch, Aachen University

Session M-3: CHIP-PACKAGE INTERACTIONS AND RELIABILITY — Del Lago 4

Session Chair: Przemyslaw Gromala (Bosch)

Effect of Thermal Cycling on the Evolution of Interfacial Fracture Toughness of EMC-Substrate Interface

Pradeep Lall, Madhu Kasturi, Auburn University

Chip-Underfill Interface Damage Model under Fatigue Loading after Sustained High-Temperature Exposure

Pradeep Lall, Aathi Raja Ram Pandurangan, Auburn University

Predictive Cohesive Zone Prediction of Delamination at Potting-PCB Interface under Dynamic Loading and Sustained High-Temperature Exposure

Pradeep Lall[1], Aathi Raja Ram Pandurangan[1], Ken Blecker[2], [1]Auburn University, [2]US Army CCDC-AC

A Simulation Study on SSD PCB Warpage during Reflow: From Understanding to Improvement

Quang Nguyen, Christopher Glancey, Kal Wilson, Mark Tverdy, Micron Technology

A Predictive Model of Wafer-to-Die Warpage Simulation

Quang Nguyen, Christopher Glancey, Wei Chang Wong, Raj Bansal, Micron Technology

DAY 1: WEDNESDAY, MAY 31 3:30– 5:00 PM TECHNICAL SESSIONS

Session TI-4: TIMS AND HEAT SPREADERS — Del Lago 1

Session Chairs: Herman Oprins (imec) and Tiwei Wei (Purdue University)

Phase Change Material-Based Cooling Systems Subject to Periodic Heating: Lumped Analysis and Experimental Verification

Shahzeb Mirza, Cristina Amon, Sanjeev Chandra, University of Toronto

Experimental Study of Cyclically Stable Glauber's Salt-based PCM for Cold Thermal Energy Storage

Veeresh Ayyagari, Andres Paul Sarmiento Cajamarca, Amir Shooshtari, Michael Ohadi, University of Maryland, College Park

A New Thermal Management Figure of Merit for Phase Change Materials (PCMs) Selection Considering Geometry

Piyush Tripathi, Amy Marconnet, Purdue University

Direct Solar-Thermal Formation of Graphitic Heat Spreaders on Organic Substrates

Min Jong Kil[1], Eythan Lam[2], Mostafa Abuseada[1], James Buckwalter[2], Timothy Fisher[1],
[1]University of California, Los Angeles, [2]University of California, Santa Barbara

Demonstration of CTE-Matched Two-Phase Minichannel Heat Sink

Mohammad Reza Shaeri, Chien-Hua Chen, Richard W. Bonner, Maksym Demydovych, Advanced Cooling Technologies, Inc.

Session TII-4: AUTOMOTIVE, BATTERIES AND THERMAL STORAGE — Del Lago 2

Session Chairs : Michael Barako (Northrop Grumman Corporation) and Gargi Kailkhura

Synthesis of ePCMs for Thermal Management of Electronics

Muhammad Ghufran, David Huitink, University of Arkansas Fayetteville

Exhibitor Talk: Advanced High Speed and High Spatial Resolution Infrared Imaging Systems for Crucial Collections

Wes Autran, Joseph Carrock, Benjamin Saute, Mark Norman, Telops

Thermal Management of Lithium-ion Batteries for Electric Vehicles through Immersion Cooling

Niall Williams, Daniel Trimble, Séamus O'Shaughnessy, University of Dublin, Trinity College

Implementation of a Topologically Optimized Heat Sink for Non-Uniform Heat Fluxes in an EV Fast-Charger

Joshua Palumbo, Omri Tayyara, Seyed Amir Assadi, Carlos Da Silva, Olivier Trescases, Cristina Amon, Sanjeev Chandra,
University of Toronto

Session E-4: THERMAL MANAGEMENT 2 — Del Lago 3

Session Chairs: Cheng Chen (Meta), Jayati Athavale (Meta), and Saket Karajgikar (Meta)

Temperature Dependent Thermal Properties of Thin Film Hafnium Oxide

Wenqing Shen, Diego Vaca, Gary Gibson, Satish Kumar, Georgia Institute of Technology

Feasibility Assessment of Metrologies for Thermal Resistance Characterization of Deeply Buried Interfaces between Bonded Silicon Layers

Aalok Gaitonde, Justin Weibel, Amy Marconnet, Purdue University

Aluminum Nitride (AlN) Ceramic Surfaces for Enhanced Dropwise Condensation

Sreya Sarkar, Anish Pal, Arani Mukhopadhyay, Constantine M. Megaridis, University of Illinois Chicago

Phase Transition Behavior of Thin Film Phase Change Materials

Joshua Kasitz, Larry Marshall, David Huitink, University of Arkansas Fayetteville

Development of Gallium Infiltrated Metal Foams for Transient Thermal Management

Rachel McAfee, Michael Fish, Harvey Tsang, US Army Research Laboratory

Session M-4: EMERGING PACKAGE RELIABILITY METHODS — Del Lago 4

Session Chair: David Huitink (University of Arkansas Fayetteville)

Automated Early Damage Detection for Power MOSFETs using On-board Thermal Spectroscopy

Sven Reitz, Jens Warmuth, Fraunhofer Institute for Integrated Circuits

Effect of Chlorine-Bromine pH and Temperature on the Corrosion Propensity of the Cu-Al WB System

Pradeep Lall, Sungmo Jung, Auburn University

Corrosion Kinetics Investigation on Cu-Al Alloy in Sulfate Environment under Various Temperature and pH Values

Pradeep Lall, Yunli Zhang, Sungmo Jung, Auburn University

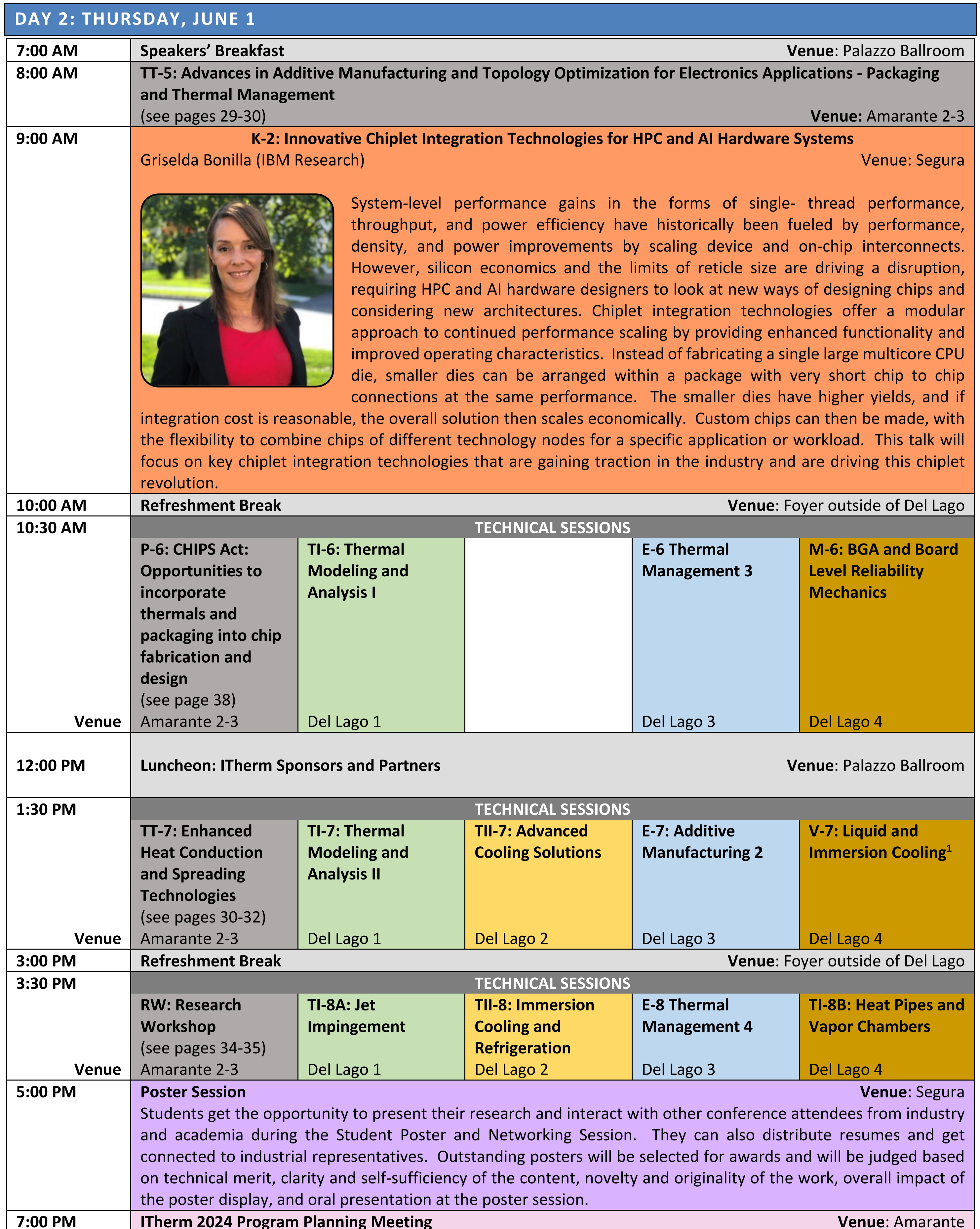
Test Device Design and Test Procedure for Non-destructive Characterization of Bi Phase Accumulation during Electromigration

Chetan Jois, Pei-en Chou, Sudarshan Prasad, Carol Handwerker, Ganesh Subbarayan, Purdue University

Influence of Temperature on the Quality of Operation of an Analog Reading System for MEMS Structures

Jacek Nazdrowicz, Mariusz Jankowski, Lodz University of Technology

DAY 2: THURSDAY, JUNE 1



Time					
7:00 AM	**Speakers' Breakfast** — **Venue**: Palazzo Ballroom				
8:00 AM	**TT-5: Advances in Additive Manufacturing and Topology Optimization for Electronics Applications - Packaging and Thermal Management** (see pages 29-30) — **Venue:** Amarante 2-3				
9:00 AM	**K-2: Innovative Chiplet Integration Technologies for HPC and AI Hardware Systems** Griselda Bonilla (IBM Research) — Venue: Segura System-level performance gains in the forms of single- thread performance, throughput, and power efficiency have historically been fueled by performance, density, and power improvements by scaling device and on-chip interconnects. However, silicon economics and the limits of reticle size are driving a disruption, requiring HPC and AI hardware designers to look at new ways of designing chips and considering new architectures. Chiplet integration technologies offer a modular approach to continued performance scaling by providing enhanced functionality and improved operating characteristics. Instead of fabricating a single large multicore CPU die, smaller dies can be arranged within a package with very short chip to chip connections at the same performance. The smaller dies have higher yields, and if integration cost is reasonable, the overall solution then scales economically. Custom chips can then be made, with the flexibility to combine chips of different technology nodes for a specific application or workload. This talk will focus on key chiplet integration technologies that are gaining traction in the industry and are driving this chiplet revolution.				
10:00 AM	**Refreshment Break** — **Venue**: Foyer outside of Del Lago				
10:30 AM	**TECHNICAL SESSIONS**				
	P-6: CHIPS Act: Opportunities to incorporate thermals and packaging into chip fabrication and design (see page 38)	**TI-6: Thermal Modeling and Analysis I**		**E-6 Thermal Management 3**	**M-6: BGA and Board Level Reliability Mechanics**
Venue	Amarante 2-3	Del Lago 1		Del Lago 3	Del Lago 4
12:00 PM	**Luncheon: ITherm Sponsors and Partners** — **Venue**: Palazzo Ballroom				
1:30 PM	**TECHNICAL SESSIONS**				
	TT-7: Enhanced Heat Conduction and Spreading Technologies (see pages 30-32)	**TI-7: Thermal Modeling and Analysis II**	**TII-7: Advanced Cooling Solutions**	**E-7: Additive Manufacturing 2**	**V-7: Liquid and Immersion Cooling**[1]
Venue	Amarante 2-3	Del Lago 1	Del Lago 2	Del Lago 3	Del Lago 4
3:00 PM	**Refreshment Break** — **Venue**: Foyer outside of Del Lago				
3:30 PM	**TECHNICAL SESSIONS**				
	RW: Research Workshop (see pages 34-35)	**TI-8A: Jet Impingement**	**TII-8: Immersion Cooling and Refrigeration**	**E-8 Thermal Management 4**	**TI-8B: Heat Pipes and Vapor Chambers**
Venue	Amarante 2-3	Del Lago 1	Del Lago 2	Del Lago 3	Del Lago 4
5:00 PM	**Poster Session** — **Venue**: Segura 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.				
7:00 PM	**ITherm 2024 Program Planning Meeting** — **Venue**: Amarante				

[1] Talks in this session will be presented virtually.

DAY 2: THURSDAY, JUNE 1, 10:30 AM – 12:00 PM TECHNICAL SESSIONS

Session TI-6: THERMAL MODELING AND ANALYSIS I — Del Lago 1

Session Chairs: Kevin McCarthy (PCKA) and Prabudhya Roy Chowdhury (IBM Corporation)

Direct Numerical Simulation of Synthetic Jet Coupled to Forced Convection Cooling in a Channel Flow

Mohammad Azarifar[1], Mehmet Arik[1,2], [1]Auburn University, [2]Ozyegin University

Compact Models for Transient Thermal Spreading Resistance in Half-space, Flux Tube, and Flux Channel Regions

Yuri Muzychka[1], Milan Yovanovich[2], [1]Memorial University of Newfoundland, [2]University of Waterloo

Numerical and Analytical Investigation on the Influence of Geometry on Thermohydraulic Performance of Single-phase Split Flow Cold Plates for Data Center Liquid Cooling

Deogratius Kisitu, Alfonso Ortega, Villanova University

Exhibitor Talk: Accelerate Electronics Testing and Design

Desmond Lamont, Teledyne/FLIR

Session E-6 THERMAL MANAGEMENT 3 — Del Lago 3

Session Chairs: Pardeep Shahi (Nvidia, Santa Clara, CA), Satyam Saini (Intel Corporation), and Saket Karajgikar

Performance Comparison of Various Thermal Interface Materials Used with Metal Foams

Ubade Kemerli[1,2], Yogendra Joshi[1], [1]Georgia Institute of Technology, [2]Trakya University

Experimental Investigation of Boiling Heat Transfer Coefficient in Two-phase Carbon Dioxide in a Microchannel with Side-view Schlieren Flow Visualization

Trevor Whitaker, Sameer Rao, University of Utah

Temperature-Controlled Transition Boiling at the Stagnation Zone During Submerged Jet Impingement of a Dielectric Fluid

Tyler Stamps, Justin Weibel, Purdue University

Evaluating the Thermal Performance of Perovskite $SrSnO_3$ Field Effect Transistors

Bivek Bista[1], Prafful Golani[2], Fengdeng Liu[2], Tristan Truttmann[2], Georges Pavlidis[1], Andrea Centrone[3], Bharat Jalan[2], Steven Koester[2], [1]University of Connecticut, [2]University of Minnesota, [3]National Institute of Standards and Technology

Data Center Energy Reduction by Lowering Chip-to-Supply Thermal Resistance

Peter de Bock[1], Thomas Bress[2], Vivien Lecoustre[2], Ashok Gidwani[2], Carlos Noyes[2], [1]Advanced Research Projects Agency – Energy, [2]Booz Allen Hamilton

Session M-6: BGA AND BOARD LEVEL RELIABILITY MECHANICS — Del Lago 4

Session Chair: Paul Paret (National Renewable Energy Laboratory)

Predicting the Life of the Solder Joints in Electronic Assemblies using Physics-informed Data-driven Methodology

Qais Qasaimeh[1], Jia Liu[1], Awni Qasaimeh[2], John Evans[1], Sa'd Hamasha[1], [1]Auburn University, [2]Zebra Technologies

Multiscale, Non-Intrusive Computational Framework for Analyzing Rate-Dependent Deformation of Solder Joints

Sai Sanjit Ganti, Ganesh Subbarayan, Purdue University

Shock and Vibration Simulation for PBGA Board Assemblies with SAC Solder Interconnects using Non-Linear High Strain Rate Properties

Pradeep Lall[1], Vikas Yadav[1], Jeff Suhling[1], David Locker[2], [1]Auburn University, [2]US Army CCDC-AvMC

Pad Cratering Evolution with Multiple-Reflows at Resin-Copper Interfaces under Large Out-of-Plane Deformation

Pradeep Lall, Aathi Raja Ram Pandurangan, Padmanava Choudhury, Auburn University

Study on Evaluation of Durability of Through-Hole Solder Joints

Masahiro Kon, Yu Qiang, Tomohiro Tsuyuki, Yokohama National University

Session TI-7: THERMAL MODELING AND ANALYSIS II — Del Lago 1

Session Chairs: Anil Yuksel (IBM Corporation), Keji Matsumoto (IBM Research-Tokyo), and Aakrati Jain (IBM Corporation)

Dynamic Modeling of a Refrigerant-based Cross-flow Heat Exchanger for Close-Coupled Hybrid Cooled Data Centers

Carol Caceres, Alfonso Ortega, Gerard F. Jones, Villanova University

Model Order Reduction of a Nonlinear Model of an Electronic Component: Application to a Microchip Activated by Four Sources

Fatme Mustapha[1], Frédéric Joly[2], Valentin Bissuel[1], Olivier Quemener[2], [1]Thales, [2]Université Paris Saclay

Topology Optimized Fin Designs for Base Plate Direct-Cooled Multi-Chip Power Modules

Aniket Ajay Lad[1], Eric Roman[1], Yue Zhao[2], William King[1], Nenad Miljkovic[1], [1]U. of Illinois at Urbana Champaign, [2]U. of Arkansas Fayetteville

CFD Simulation Analysis of Inter/Intra Chip Liquid Cooling for 3D Stacked ICs

Risa Miyazawa, Hiroyuki Mori, Aakrati Jain, Mukta Farooq, Takashi Hisada, IBM Research

Micro-Scale Jet Cooling: A Numerical Study on Improvement Options

Georg Elsinger[1,2], Herman Oprins[2], Vladimir Cherman[2], Geert Van der Plas[2], Eric Beyne[2], Ingrid De Wolf[1,2], [1]KU Leuven, [2]imec

Session TII-7: ADVANCED COOLING SOLUTIONS — Del Lago 2

Session Chairs: Aastha Uppal (Intel Co.), Krishna Shah, Jagadeesh Radhakrishnan, Yin Hang, and Shadi Mahjoob (California State University, Northridge)

Thermal Testing of Arrays of PHP Finned Plates for Enhanced Air-Cooling of Electronics

Enzo Minazzo[1], Gautier Rouaze[1], Jackson Marcinichen[1], John Thome[1], Kangnin Xiong[2], L. Winston Zhang[2], Wilhelm Pohl[3], [1]JJ Cooling Innovation SARL, [2]Novark Technologies, [3]HALA Contec GmbH

Thermal Aware Floorplan Optimization of SOC in Mobile Phone

Youngsang Cho, Heonwoo Kim, Kyoungmin Lee, Yunhyeok Im, Heeseok Lee, Minkyu Kim, Samsung Electronics Co.

Self-adaptive Flow Regulation through shape Memory Alloy Valves for Microelectronics Cooling

Montse Vilarrubí[1,3], David Beberide[1,3], Desideri Regany[1], Étienne Léveillé[2], Roger Vila[1], Jaume Camarasa[1], Manel Ibañez[1], Joan I. Rosell[1], Luc G. Fréchette[2,3], Jérôme Barrau[1,3], [1]University of Lleida, [2]Université de Sherbrooke, [3]Universal Smart Cooling

Guidelines and Experimental Hydraulic Performance Evaluation for Single-Phase CDUs under Steady and Transient Events

Ali Heydari[1], Ahmad Gharaibeh[2], Mohammad Tradat[1], Yaman Manaserh[1], Qusai Soud[2], Vahideh Radmard[1], Bahareh Eslami[1], Jeremy Rodriguez[1], Bahgat Sammakia[2], [1]NVIDIA, [2]Binghamton University

Thermal Modeling and Optimization of Mobile Device using Modified LPV ROM

Yunhyeok Im[1], Gyuick Jung[2], Myunghoon Lee[2], Akashdeep Gangrade[2], Seungjoo Kim[2], [1]Samsung Electronics Co., [2]Ansys

Session E-7: ADDITIVE MANUFACTURING 2 — Del Lago 3

Session Chair: Farid Soroush (Apple Inc.)

Packaging and Ergonomic Study of a Body Worn High Energy Microwave Attack Detector

Patrick Loney, Patrick Green, Northrop Grumman Mission Systems

Characterization of Aging Effects on Thermal and Mechanical Properties of Magnetically-Oriented ACA for Flexible and Stretchable Electronics

Pradeep Lall[1], Yunli Zhang[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Process Recipes of Additively Printed Sustainable Silver-Ink using Aerosol Jet Printing

Pradeep Lall[1], Sabina Bimali[1], Ved Soni[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Realization of Circuits with Additively Printed Water Based Nanoparticle Sustainable Silver-Ink with Ultrasonic Atomization on Aerosol Jet Printer

Pradeep Lall[1], Daniel Karakitie[1], Ved Soni[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Print Process Development for Ag-Ink Thermoformable Conductive Traces Utilizing Direct Write Technique for In-Mold Printed Electronics

Pradeep Lall[1], Md Golam Sarwar[1], Jinesh Narangaparambil[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Session V-7 LIQUID AND IMMERSION COOLING — Del Lago 4

Session Chair: Jun Shen (Meta), Anali Soto (Microsoft), Kanan Pujara (Intel Co.), and Jin Hang (Meta)

Thermal Characterization of Single-Phase Immersion Cooling Capability

Suchismita Sarangi, Eric McAfee, Drew Damm, Jessica Gullbrand, Intel Corporation

Numerical Investigation of Influence of Tank Design on Thermal and Flow Performance of a Server in Single-Phase Immersion Cooling

Satyam Saini, Jessica Gullbrand, Suchismita Sarangi, Eric McAfee, Drew Damm, Intel Corporation

Refrigerant to Air Cooling for High Heat Density Two-Phase Cooled Data Centers

Ali Heydari[1], Yaman Manaserh[1], Mehdi Mehrabi[2], Ahmad Abubaker[2], Bahareh Eslami[1], Harold Miyamura[1], Alfonso Ortega[2], Jeremy Rodriguez[1], [1]NVIDIA, [2]Villanova University

Liquid Cooling Pipeline Leakage Prediction and Detection using Reinforcement Learning

Derssie Mebratu, Berhanu Wondimu, Romir Desai, Gaurav Chaudhary, Casey Winkel, Mohammad Hossain, Intel Corporation

Leak Detection and Mitigation for Direct Liquid Cooled Server

Berhanu Wondimu, Zhikui Ren, Devdatta Kulkarni, Yuehong Fan, Intel Corporation

Session TI-8A: JET IMPINGEMENT — Del Lago 1

Session Chairs: Risa Miyazawa (IBM Corporation) and Monali Basutkar (IBM Corporation)

Improving Fluid-thermal Performance of Impinging Jet Arrays with Small-scale Engineered Surface Augmentations in the Fountain Regions

Aaron Smith, Sushil Bhavnani, Roy Knight, Auburn University

Numerical and Experimental Investigation of Multi jet Impingement Cooling System with Optimized Heat Sinks

Pavanrohith Govindaraju, Nikhil Pundir, Jorge Alvarado, Texas A&M University

An Experimental Study on High-pressure Pulsed Sprays for Efficient Management of High Heat Fluxes for Moderate Area Devices

Fernando Soria, Edward Woodruff, Andrew Fordon, Shawn Putnam, Yunjun Xu, University of Central Florida

Hotspot-targeted Cooling Scheme with Hybrid Jet Impingement/Thermal Through Silicon Via (TSV)

Shuhang Lyu[1], Qianying Wu[2], Tiwei Wei[1], [1]Purdue University, [2]Stanford University

Thermal-Fluid Study of Jet-in-Crossflow Cooling in Comparison with Pure Jet Impingement and Pure Crossflow Cooling Methods Applicable in Hotspot Treatment

Christian Corvera, Shadi Mahjoob, California State University, Northridge

Session TII-8: IMMERSION COOLING AND REFRIGERATION — Del Lago 2

Session Chairs: Solomon Adera (University of Michigan) and Xiang Zhang (Oregon State University)

A Novel Cost-effective Liquid Assisted Air Cooling Solution for High TDP Server System

Allen Liang[1], Jiahong Wu[1], Jialiang Xu[1], Jun Zhang[1], Carrie Chen[1], Pinyi Xiang[2], Guoping Wu[2], [1]Intel Corporation, [2]Inventec Corporation

A Novel Scalable Modular Immersion Cooling System Architecture for Sustainable Data Center

Carrie Chen, Jiahong Wu, Jun Zhang, Ying-Shan Lo, Allen Liang, Checa Hung, Nishi Ahuja, Qing Qiao, Intel Corporation

Study on Boiling Cooling Characteristics of Immersion Cooling Motors

Kohei Hotta[1], Hirotsugu Aoyama[1], Yu Qiang[1], Aoi Fukuda[2], Kazutoshi Matsuda[2], [1]Yokohama National University, [2]NIDEC Corporation

Session E-8 THERMAL MANAGEMENT 4 — Del Lago 3

Session Chairs: Tiwei Wei (Purdue University) and Zhe Cheng (Peking University)

Saturated and Superheated Water Vapor Condensation on a Custom Micro-Textured Surface

Mete Budakli[1], Mehmet Arik[2], [1]Ozyegin University, [2]Auburn University

Experimental Investigation of Ultra-thin Microchannel Oscillating Heat Pipes with Submillimeter-scale Thickness

Qian Qian[1], Xin Zhang[2], Shurong Tian[2], Justin Weibel[1], Liang Pan[1], [1]Purdue University, [2]IBM T. J. Watson Research Center

Experimental Investigation of Heat Transfer to a Dual Jet Flow with Varying Velocity Ratio

Paula Murphy[1], Sajad Alimohammadi[2], Séamus O'Shaughnessy[1], [1]University of Dublin Trinity College, [2]Technical University Dublin

Impact of Oxidation on Pool Boiling Heat Transfer Performance over Flat Plates Exposed to Extended Operating Conditions

Tolga Emir[1], Mete Budakli[1], Mehmet Arik[1,2], [1]Ozyegin University, [2]Auburn University

Session TI-8B: HEAT PIPES AND VAPOR CHAMBERS — Del Lago 4

Session Chair: Rinaldo Miorini (GE Research) and Rachel McAfee (U.S. Army Research Laboratory)

Evaluation of Thermal Performance of a Wick-free Vapor Chamber in Power Electronics Cooling

Arani Mukhopadhyay, Anish Pal, Congbo Bao, Mohamad Jafari Gukeh, Sudip K. Mazumder, Constantine Megaridis, University of Illinois at Chicago

Thermal Performance of a Liquid-cooling Assisted Thin Wickless Vapor Chamber

Arani Mukhopadhyay, Anish Pal, Mohamad Jafari Gukeh, Constantine Megaridis, University of Illinois at Chicago

Characterization of Ultra-thin Vapor Chambers for Notebook Computer Applications

Ravishankar Srikanth, MChethan Holla, Intel Corporation

Fabrication and Testing of Flexible Pulsating Heat Pipes

Nick Morgan, Damian Hundley, Maya Baron, Matthew Pichardo, Shawn Putnam, University of Central Florida

Elliptic Micropillar Wick Evaporators for Thermal Management of High Flux Electronics

Goksel Yuncu[1,3], Yigit Akkus[2], Zafer Dursunkaya[3], [1]Aselsan Inc, [2]Ericsson, [3]Middle East Technical University

DAY 3: FRIDAY, JUNE 2

Time					
7:00 AM	**Speakers' Breakfast**				Venue: Palazzo Ballroom
8:00 AM	**TECHNICAL SESSIONS**				
		V-2: Liquid and Immersion Cooling[2]	**V-3: Data Center Cooling[2]**	**V-4: Special Topics[2]**	**V-5: Manufacturing[2]**
Venue		Del Lago 1	Del Lago 2	Del Lago 3	Del Lago 4
9:00 AM	**K-3: Space Mission Thermal Control and Protection Challenges – Past, Present, and Future** Steve Rickman (NASA) — Venue: Segura Space missions must operate in extreme thermal environments whether they are orbiting a planet, on an interplanetary trajectory, or undergoing atmospheric entry. However, electronic equipment, batteries, scientific instruments, and crewed spacecraft require thermal control over a relatively narrow temperature range. Thermal control and protection strategies for past, present, and future missions are presented to show how missions can be accomplished in extreme environments over a temperature range extending from near absolute zero up to 14000 K.				
10:00 AM	**Refreshment Break**				Venue: Foyer outside of Del Lago
10:30 AM	**TECHNICAL SESSIONS**				
	P-10: Artificial Intelligence: Industry use cases and investment trends (see page 38)	**TI-10: Coldplates and Heat Exchangers**	**TII-10: Liquid Cooling Solutions II**	**E-10 Special Topics**	**M-10: Fatigue of Solders**
Venue	Amarante 2-3	Del Lago 1	Del Lago 2	Del Lago 3	Del Lago 4
12:00 PM	**Luncheon: ITherm Awards & Organizer Recognitions**				Venue: Palazzo Ballroom
1:30 PM	**TECHNICAL SESSIONS**				
	P-11: Mechanics and Reliability: Packaging Challenges for Harsh Environment Applications (see page 39)	**TI-11: Two-phase Cooling**	**TII-11: Thermal Management in Space and Aerospace**	**E-11: Additive Manufacturing 3**	**M-11: Solder Metallurgy and Process Impacts on Reliability**
Venue	Amarante 2-3	Del Lago 1	Del Lago 2	Del Lago 3	Del Lago 4

[2] Talks in these sessions will be presented virtually

Session V-2: Liquid and Immersion Cooling — Del Lago 1

Session Chair: Ashish Gupta (Intel)

Advanced Cold Plate Liquid Cooling Solution for Hyper-scale Data Center Application

Chenglong Gui[1], Yulong Wang[1], Chen Shen[1], Shifeng Wang[1], Ruidong Wang[1], Zhichao Lv[1], Bin Lin[1], Wenbin Tian[2], Zhiming Li[2], Xu Zhang[2], Ken Zhang[2], Lihui Wu[2], Nishi Ahuja[2], [1]Bytedance Technology, [2]Intel Corporation

Investigation on Immersion Cooling Solution for Hyper-scale Data Center Application

Yulong Wang[1], Chenglong Gui[1], Pengfei Cheng[1],Chen Shen[1], Ruidong Wang[1], , Zhichao Lv[1], Bin Lin[1], Wenbin Tian[2], Zhiming Li[2], Xu Zhang[2], Ken Zhang[2], Lihui Wu[2], Nishi Ahuja[1], [1]Bytedance Technology, [2]Intel Corporation

Investigation on Advanced Cold Plate Liquid Cooling Solution for Large Scale Application in Data Center

Xianguang Tan[1], Hongmei Liu[1], Jiajun Zhang[1], Wenbin Tian[2], Jiang Yu[2], Xingping Ruan[2], Baolin Wang[2], Lihui Wu[2], Jun Zhang[2], Nishi Ahuja[2], [1]Kuaishou Technology, [2]Intel Corporation

Session V-3: Data Center Cooling — Del Lago 2

Session Chair: Raffaele Luca Amalfi (Seguente)

Data Center Power Density Rack Evolution with 54V for Sustainable Computing

Sheng Li[1], Guofeng Chen[1], Guilin Wang[1], Yuehlin Tsai[1], Jun Zhang[2], Jialiang Xu[2], Hongxing Zhou[2], Ming Gao[2], Nishi Ahuja[2], Qing Qiao[1], [1]JD Technology, [2]Intel Corporation

A Novel Cost Efficient Cold Plate Liquid Cooling Solution for Data Center Deployment

Zhenghui Wu[1], Younzhan He[1], Jianwu Zheng[1], Bing Cheng[1], Jun Zhang[2], Wenqing Lv[2], Min Wu[2], Ying He[2], Pengfei Yue[2], Nishi Ahuja[2], Qing Qiao[2], [1]Baidu, [2]Intel Corporation

High Power Density Rack Design Optimal for Hyper Scale Data Center Carbon Emission Reduction

Zhenghui Wu1, Yongzhan He1, Jianwu Zheng1, Bing Cheng1, Jun Zhang2, Min Wu2, Wenqing Lv2, Ying He[2], Pengfei Yue[2], Nishi Ahuja[2], Qing Qiao[2], [1]Baidu, [2]Intel Corp.

Session V-4: Special Topics I — Del Lago 3

Session Chair: Jimil Shah (Stealth Startup) and Amir Shooshtari (University of Maryland, College Park)

Ab-initio Multiscale Thermal Modeling of 5 nm Stacked Nanosheet Field Effect Transistor for Thermal Hotspot Optimization Inside the Channel

Vivek Kumar[1,2], Arnab Datta[1], Sudeb Dasgupta[1], [1]IIT Roorkee, [2]National Institute of Technology Uttarakhand

Thermal Solution Study of 51.2T Near-packaged Optics Switch

Yaoyin Fan, Mingqing Luo, Chengzhi Liu, Sheng Zhang, Celestica Corp.

Session V-5: Special Topics II — Del Lago 4

Session Chair: David Huitink (University of Arkansas Fayetteville)

Digital Twin in Manufacturing: Reflow Soldering Process

Alireza Ameli[1], Henri Jutila[1], Jari Huttunen[1], Sami Markus[1], Matt Milne[2], Kelly Cordell-Morris[2], [1]Nokia Solutions and Networks, [2]Siemens

Thermal Characterization of a Silicon Wafer Utilizing a Non-Fourier Heat Transport Equation and Micro-Raman Spectroscopy

Amir Abdolhosseinzadeh, Emine Göktepe, Taher Meydando, Nazli Donmezer, Bogazici University

The Effect of Aluminum Fraction on the Phonon Mean Free Path - Thermal Conductivity Relation of $Al_xGa_{1-x}N$ Alloys

Pegah Ghanizadeh, Nazli Donmezer, Bogazici University

DAY 3: FRIDAY, JUNE 2, 10:30 AM – 12:00 PM TECHNICAL SESSIONS

Session TI-10: COLDPLATES AND HEAT EXCHANGERS — Del Lago 1

Session Chairs: Michael Fish (US Army Research Laboratory) and Omidreza Ghaffari (Sherbrooke University)

Manifold Integrated Cold Plate for Single-phase and Two-phase Liquid Cooling

Yuehong Fan, Jimmy Chuang, David Shia, Mohanraj Prabhugoud, Intel Corporation

Double-Side Manifold Micro-Channel Cold Plate for High Power Density Composite DC-DC Converter

Feng Zhou, Yuqing Zhou, Tianzhu Fan, Ercan Dede, Toyota Research Institute of North America

Pushing the Limits of Air Cooling with Novel Two-Phase Prototypes for High Power Microprocessors

Omidreza Ghaffari[1], Manuel Vincent[1], Francis Grenier[2], Yaser Nabavi Larimi[1], Simon Jasmin[2], Luc G. Fréchette[1], Julien Sylvestre[1], [1]Sherbrooke University, [2]Systemex Energies. Inc.

Measuring the Surface Flatness of Heaters and Cold Plates and Estimating its Effect on Heat Transfer

Ali Heydari[1], Najmeh Fallahtafti[2], Mohammad Tradat[1], Vahideh Radmard[1], Qusai Al-Soud[2], Uschas Chowdhury[1], Pardeep Shahi[1], Bahgat Sammakia[2], [1]NVIDIA, [2]Binghamton University

Session TII-10: LIQUID COOLING SOLUTIONS II — Del Lago 2

Session Chairs: Neera Jain (Purdue University), Sevket Yuruker, Adam Wilson (US Army Research Laboratory), Yingying Wang

An Investigation of Multi-parameters Effects on the Performance of Liquid-to-liquid Heat Exchangers in Rack Level Cooling

Ali Heydari[1], Qusai Soud[2], Mohammad Tradat[1], Ahmad Gharaibeh[2], Najmeh Fallahtafti[2], Pardeep Shahi[1], Jeremy Rodriguez[1], Bahgat Sammakia[2], [1]NVIDIA, [2]Binghamton University

Thermosyphon Simulation of High Heat Flux Density Server Racks with 84 CPU-Evaporators in Parallel Operation André Seuret, Jackson Marcinichen, John Thome, JJ Cooling Innovation SARL

High Power Advanced Package with Water Cooling System Evaluation and Optimization

Shane Lin, Dan Lin, Vito Lin, Teny Shih, Andrew Kang, Y.P. Wang, Siliconware Precision Industries Co. Ltd.

Session E-10 SPECIAL TOPICS — Del Lago 3

Session Chairs: Georges Pavlidis (University of Connecticut), Jorge Padilla (Google), and Todd Bandhauer (Colorado State University)

Automated Design-for-Reliability of a Power Electronics Module

Paul Paret, Andrew Glaws, Gilberto Moreno, Joshua Major, Faisal Khan, Sreekant Narumanchi, National Renewable Energy Laboratory

Performance and Reliability of SMD Interconnections using Low-Temperature Solders and ECAs for FHE applications

Pradeep Lall[1], Jinesh Narangaparambil[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

SOH Degradation Modeling of Thin Flexible Li-ion Batteries Subjected to Life Cycling with Randomized Cycling Depth, C-Rates, and U-Flex-to-Install

Pradeep Lall[1], Ved Soni[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Process Recipes for SMD Interconnection on Aqueous Conductive Inks using Direct-Write Printing

Pradeep Lall[1], Jinesh Narangaparambil[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Process Recipes and Performance of Printable Formable Inks for In-Mold Electronics Applications

Pradeep Lall[1], Jinesh Narangaparambil[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Session M-10: FATIGUE OF SOLDERS — Del Lago 4

Session Chair: Okafor G. (University of Arkansas, Fayetteville)

Reliability of BGAs and Mixed Low Temperature Solder Assemblies

Reza Ghaffarian[1], Michael Meilunas[2], [1]Jet Propulsion Laboratory, [2]Universal Instruments Corporation

Evolution of TIM/Copper Interface under Wide Temperature Excursions

Pradeep Lall, Madhu Kasturi, Auburn University

Evolution of the Creep Response of SAC305 Solder due to Mechanical Cycling

Golam Rakib Mazumder, Souvik Chakraborty, Jeffrey Suhling, Pradeep Lall, Auburn University

***In Situ* Monitoring of Creep Deformation in Single Crystal SAC305 Solder Joint at Different Temperatures**

Aniket Bharamgonda, Abhishek Deshpande, Abhijit Dasgupta, University of Maryland, College Park

The Effects of Thermal Exposure on the Creep Behavior of SAC+Bi Lead-Free Solders

Mohammad Al Ahsan, Kamrul Hasan, Jeffrey Suhling, Pradeep Lall, Auburn University

DAY 3: FRIDAY, JUNE 2, 1:30 – 3:00 PM TECHNICAL SESSIONS

Session TI-11: TWO-PHASE COOLING — Del Lago 1

Session Chairs: Adam Wilson (US Army Research Laboratory) and Travis Mayberry (Raytheon)

Flow Boiling Heat Transfer Enhancement using Novel Dual-Channel Design with Femtosecond Laser Surface Processed Stainless Steel Surfaces

Logan Pettit, Justin Costa-Greger, Andrew Reicks, Suchit Sarin, Jeffrey Shield, Craig Zuhlke, George Gogos, University of Nebraska-Lincoln

Augmented Pool Boiling Heat Transfer of PF-5060 Using Femtosecond Laser Surface Processed Aluminum: Effects of Laser Fluence

Justin Costa-Greger, Logan Pettit, Andrew Reicks, Suchit Sarin, Chase Pettit, Jeffrey Shield, Craig Zuhlke, George Gogos, University of Nebraska-Lincoln

Capillary-activated Scalable Microporous Copper Microchannels for Two-phase Thermal Management of Semiconductor Materials

Sujan Dewanjee[1], Gaurav Singhal[1], Jiaqi Li[1], Danny Lohan[2], Shailesh Joshi[2], Paul V. Braun[1], Nenad Miljkovic[1], University of Illinois, Urbana Champaign, [2]Toyota Research Institute of North America

Two-phase Flow in Compressed Copper Foam with R134a for High Heat Flux Thermal Management: Effects of Foam Compression Ratio and Refrigerant Operating Conditions on Thermohydraulic Performance

Deogratius Kisitu[1], Alfonso Ortega[1], Metodi Zlatinov[2], Denver Schaffarzick[2], [1]Villanova, [2]ERG Aerospace Corporation

Asymmetric Sawtooth and Cavity-Enhanced Nucleation-driven Transport (ASCENT) Experiment Aboard the International Space Station – Microgravity Outcomes

Karthekeyan Sridhar[1], Vinod Narayanan[2], Sushil Bhavnani[1], [1]Auburn University, [2]University of California, Davis

Session TII-11: THERMAL MANAGEMENT IN SPACE AND AEROSPACE — Del Lago 2

Session Chairs: Ratnesh Tiwari and Andres Sarmiento (University of Maryland, College Park)

Prediction and Flow Visualization of Critical Heat Flux of PF-5060 within a Horizontal Rectangular Channel with Single Sided Heating

Chinmay Shingote, Cho-Ning Huang, Chirag Kharangate, Case Western Reserve University

Bi-Modal Thermal Design of a Spacebourne Rotorcraft Avionics Unit

Christopher Kim, Allison Orr, Amelia Cherian, Johns Hopkins Applied Physics Lab

Novel Thermal Packaging Approach for an Airtight Electronic Chassis without Card Retainer-I

Murat Parlak[1], Ahmet Sahin Sen[1,2], Vedat Yagci[1,3], [1]Aselsan Inc, [2]Yildiz Technical University, [3]Istanbul Technical University

Novel Thermal Packaging Approach for an Airtight Electronic Chassis without Card Retainer-II

Murat Parlak[1], Ahmet Sahin Sen[1,2], Vedat Yagci[1,3], [1]Aselsan Inc, [2]Yildiz Technical University, [3]Istanbul Technical University

E-11: ADDITIVE MANUFACTURING 3 — Del Lago 3

Session Chair: Kanan Pujara (Intel Corporation)

Evaluation of Additively Printed Sustainable Aqueous Silver Inks using Aerosol Jet Printing and Investigation of Circuit Repairability

Pradeep Lall[1], Ved Soni[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Demonstration of Functional Circuits with Surface Mount Devices on Sustainable Water-Based Inkjet Printed Metallization

Pradeep Lall[1], Kartik Goyal[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Prediction of Print Geometry and Electrical Performance of InkJet Printed Electrical Components using Statistical Models for Closed Loop Control

Pradeep Lall[1], Shriram Kulkarni[1], Kartik Goyal[1], Scott Miller[2], [1]Auburn University, [2]NextFlex

Session M-11: SOLDER METALLURGY AND PROCESS IMPACTS ON RELIABILTY — Del Lago 4

Session Chair: Farid Soroush (Apple Inc.)

Effect of Solder Paste Alloy and Volume on Solder Voiding

Abdallah Alakayleh[1], Mohamed El Amine Belhadi[1], Sufyan Tahat[1], Ehab HMasha[1], Andrii Shmatok[1], Ali Alahmer[1,2], Sa'd Hamasha[1], [1]Auburn University, [2]Tafila Technical University

Size Effects on Overall Deformation Behavior of SAC Samples

Debabrata Mondal, Jeffrey Suhling, Pradeep Lall, Auburn University

Effects of Multiple Reflows on IMC and Shear Strength of Individual Solder Joints

Sufyan Tahat[1], Abdallah Alakayleh[1], Mohamed El Amine Belhadi[1], Ali Alahmer[1,2], Alyssa Yaeger[3], Sa'd Hamasha[1], [1]Auburn University, [2]Tafila Technical University, [3]Universal Instruments Corporation

Abstracts Due: September 4, 2023

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

May 28 – 31, 2024

Important Dates

Abstract Deadline:	**Sept. 4, 2023**
Notification of Acceptance:	Oct. 16, 2023
Draft Paper Submission:	Dec. 18, 2023
Reviews Returned:	Feb. 5, 2024
Final Paper Submission:	Mar. 4, 2024

Call for Abstracts

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 2024 will be a physical conference held along with the 74th 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 2024 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 & Reliability

- Thermo-Mechanical Modeling and Simulation
- Mechanics and Reliability of Solder Joints and Interconnects
- Materials Characterization, Processing, and Models
- Failure Mechanics, Fatigue, and Damage Modeling
- Measurement of Deformations, Strains and Stresses
- Shock, Drop and Vibrational Analysis
- TSV / 3D Reliability and Packaging
- Mechanics in Assembly and Manufacturing
- Applied Reliability and Failure Analysis
- Process-Structure-Property Relations / Multi-Scale Analyses
- 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
- Measurement and Diagnostic Techniques
- Numerical Methods, Nano-to-Macro Scale
- Experimental Methods, Nano-to-Macro Scale
- Prognostic Health Management and Reliability Analysis
- Wearable, Flexible, and Printed Electronics
- Additive Manufacturing
- Silicon Fabrication for Thermal Management Devices
- Predictive Analytics and Machine Learning

ITherm provides an opportunity for industrial and university participation in the form of financial support to ITherm 2024.
All contributors will be given strong recognition both onsite and in the conference materials.

Join the ITherm LinkedIn Group
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CONFERENCE PROGRAM OVERVIEW

ITherm 2023: Program Overview

	7:00 - 8:00	8:00 - 9:00	9:00 - 10:00	10:00 - 10:30	10:30 - 12:00	12:00 - 1:30	1:30 - 3:00	3:00 - 3:30	3:30 - 5:00	5:00 - 6:00	6:00 - 7:00	7:00 - 8:00	8:00 - 9:00
Day-0: Tuesday, May 30, 2022		ECTC/ITherm Joint Professional Development Courses (PDC)				Luncheon for PDC Course Attendees	ECTC/ITherm Joint Professional Development Courses (PDC)						
		HIR Workshop											
Day-1: Wednesday, May 31, 2023	Speakers' Breakfast	TT-1	K-1 Keynote	Coffee Break	E-2 TI-2 TII-2 M-2 P-2	Luncheon Richard Chu ITherm Award Presentation	E-3 TI-3 TII-3 M-3 TT-3	Coffee Break	E-4 TI-4 TII-4 M-4 P-4	Student Heat Sink Design Challenge 5:00 - 6:30	ECTC / ITherm Diversity & Career Growth Panel and Reception 6:30 -7:30	ASME K-16 and Journal of Electronic Packaging 7:30 - 9:00 pm	
		ITherm Sponsors & Exhibits					ITherm Sponsors & Exhibits						
Day-2: Thursday, June 1, 2023	Speakers' Breakfast	TT-5	K-2 Keynote	Coffee Break	E-6 TI-6 M-6 P-6	Luncheon ITherm Sponsors and Partners	E-7 TI-7 TII-7 V-7 TT-7	Coffee Break	E-8 TI-8A TII-8 TI-8B Research Workshop	Student Poster Networking Session and Reception 5:00 - 7:00		ITherm 2024 Program Planning 7:00 - 8:00	ITherm Organizers' Dinner (by Invitation)
			ITherm Sponsors & Exhibits				ITherm Sponsors & Exhibits						
									ExCom				
Day-3: Friday, June 2, 2023	Speakers' Breakfast	V-2 V-3 V-4 V-5	K-3 Keynote	Coffee Break	E-10 TI-10 TII-10 M-10 P-10	Luncheon ITherm Best Paper Awards & Organizer Recognitions	E-11 TI-11 TII-11 M-11 P-11						
			ITherm Sponsors & Exhibits										

Emerging	Tech Talk
Thermal I	Panel
Thermal II	Meeting
Mechanics	Meal
Keynote	Special Event
PDC	**Legend**