SEMI-THERM®

Seventeenth Annual

Semiconductor Thermal Measurement and Management Symposium and Exposition

March 20-22, 2001 – San Jose, California
DoubleTree Hotel San Jose, California

The Institute of Electrical and Electronic Engineers, Inc.

IEEE Components, Packaging and Manufacturing Technology Society

NIST

The National Institute of Standards and Technology

SESSIONS

Tuesday, March 20
- Simulation in Thermal Management
- Novel Measurement Techniques
- Poster Session

Wednesday, March 21
- Advances in Compact Models
- Active Cooling Technology

Thursday, March 22
- Thermal Enhancement Technology
- Component Thermal Performance

EVENING WORKSHOP

Tuesday, March 20, 7:30 – 9:00 pm.
Panel: Optoelectronic Packaging–Thermal Aspects and Challenges
PANEL CHAIR: Jeff Montgomery, Electronicast

Significant Contributor Thermi Award Presentation

Thursday, March 22, 8:15 - 9:00 am
RECIPIENT: **Clemens J. M. Lasance**, Philips Research
“Capita Selecta in Electronics Cooling”

OPTIONAL 2-DAY SHORT COURSE *(In Advance of Regular Sessions)*

Sunday & Monday, March 18-19, 2001, 9 am – 5 pm
Thermal Design for Electronics Cooling Applications
Robert E. Simons, IBM

Register On-line: **www.semi-therm.org**

EXHIBITS & WORKSHOPS

FREE ATTENDANCE

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SEMI-THERM provides attendees the opportunity to view the latest equipment and services related to thermal management and measurement on the afternoons of March 20 and 21. Vendor workshops provide either basic technical information or specific applications information regarding an exhibiting company's product.

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SHORT COURSE

Thermal Design for Electronics Cooling Applications

Sunday–Monday, March 18–19

Instructor: **Robert E. Simons, IBM**

TELEPHONE: 845-433-5262 • FAX: 845-432-9805 • E-MAIL: resimons@us.ibm.com

Introduction

This intensive short course is designed to provide an appreciation and understanding of the important role of thermal design in the development and operation of electronic equipment, as well as the basic techniques for estimating thermal performance of electronic packages and systems. Fundamental principles of thermal conduction for heat transport within an electronic package, and convection (natural and forced) for heat removal from the package are presented. Methods to estimate heat transfer coefficients and thermal spreading resistance are covered, as well as radiation and liquid immersion heat transfer.

The use of heat sinks to augment air cooling performance is discussed along with simple methods to predict heat sink performance. Flow and pressure drop characteristics in air-cooled systems are also covered. The use of fan performance and system flow impedance curves to determine total air flow rate and flow distribution in a system is presented. Easy-to-use methods of package cooling analysis utilizing the junction temperature equation, thermal resistance concepts, and simple network models are included.

Many annotated numerical examples are provided throughout the course to illustrate the application of basic concepts and equations to model heat flow in electronic packages from the chip level to system level.

This course will be of interest to electrical and mechanical engineers with a need to understand thermal design. The course is presented at a level which will be understandable even to those with no prior heat transfer background. The course also provides information of interest and of use to experienced thermal engineers.

Topic Outline

- **Introduction**
  Objectives
  Power Dissipation Trend(s)
  Temperature and Reliability
  Thermal Design Objectives
  Thermal Design Variables
  Thermal Management Options
- **Conduction**
  Fourier's Law
  Electro-Thermal Analog
  Series and Parallel Conduction
  Thermal Spreading Resistance
  Thermal Contact Resistance
- **Convection**
  Newton's Rate Equation
  Heat Transfer Coefficient
  Relative Cooling Capability
  Dimensionless Groups
  Fluid Properties
  Natural Convection Heat Transfer
  Forced Convection Heat Transfer
- **Radiation**
  Planck's Law
  Stefan-Boltzman Law
  Emissivity
  Radiation Equation
  Radiation Heat Transfer Coefficient
- **Immersion Cooling**
  Single Phase
  Pool Boiling
  Flow Boiling
- **Extended Surfaces and Heat Sinks**
  Typical Extended Surfaces
  Fin Efficiency Concept
  Straight Fin Heat Sink Analysis
  Radial Fin Heat Sink Analysis
  Effect of Air Bypass
- **Air Flow and Pressure Drop**
  Fan Curves and System Flow Resistance
  Pressure Drop Equation
  Electro-Flow Analog
  Flow Network Modeling
- **Package Cooling Analysis**
  Junction Temperature Equation
  Internal and External Resistance
  Thermal Network Modeling

Instructor

Robert Simons has been engaged in the development and application of cooling technologies for electronic equipment for more than 30 years at IBM. While at IBM he participated in the thermal design and development of cooling technologies for the IBM 3033, 3081 and 3090 Processors, as well as direct liquid immersion cooling techniques. He holds 30 cooling patents and has published many papers and articles related to cooling electronics. He has conducted many lectures and seminars on cooling electronic equipment around the world.

Cost: $525.00

Advanced Program

TUESDAY, MARCH 20, 2001

MORNING

Symposium Opening and Welcome 8:00-8:15
GENERAL CHAIR: Bruce Guenin . . . .Amkor Technology, Inc.

Technical Session I: Simulation in Thermal Mangement 8:15-9:55
SESSION CHAIR: Bill Maltz . . . .Electronic Cooling Solutions

I-1 Characterization of Laminar Jet Impingement Cooling in Portable Computer Applications
John R. Guarino, Vincent P. Manno
. . . . .Raytheon Systems Co / Tufts University

I-2 Optimisation of Thermal Resistance in Quasi Monolithic Integration Technology (QMIT) Structure
M. Joodaki, G. Kompa, H. Hillmer, R. Kassing
. . . . .Dept. of High Frequency Engineering, University of Kassel, Germany

I-3 Thermal Design of a Desktop Computer System Using CFD Analysis
C. W. Yu, R. L. Webb
. . . . .The Pennsylvania State University

I-4 Thermal Analysis of IGBT and Hybrid Power Modules with the Boundary Element Method
Zoubir Khatir, S. Lefebvre . . . . .INRETS, France

I-5 Dynamic Electro-Thermal Physically Based Compact Models of the Power Devices for Device and Circuit Simulations
P.M. Igic, P.A. Mawby, M.S. Towers
. . . . .University of Wales, Swansea

Coffee Break 9:55-10:15

Technical Session II: Novel Measurement Techniques 10:15-11:15
SESSION CHAIR: Savithri Subramanyam, Texas Instruments

II-1 A High-Speed Thermal Imaging System For Semiconductor Device Analysis
A. Hefner, D. Berning, D. Blackburn, C. Chapuy, S. Bouche . . . . .National Institute of Standards and Technology

II-2 Design Issues of a Multi-Functional Intelligent Thermal Test Die
A. Poppe, G. Farkas, M. Rencz, Ys. Benedek, L. Pohl, V. Székely, K. Torki, S. Mir, B. Courtois . .MicReD Ltd, Hungary

II-3 Thermoreflectance Imaging of Superlattice Micro Refrigerators
J. Christofferson, D. Vashaee, A. Shakouri
. . . . .University of California, Santa Cruz
P. Melese . . . . .SRI International
X. Fan, G. Zeng, C. Labounty, J. E. Bowers
. . . . .University of California, Santa Barbara
E. T. Croke III . . . . .HRL Laboratories, Inc.

Session III: Poster Session Preview 11:15-12:00
SESSION CHAIR: Seri Lee . . . . Intel

III-1 Thermal - Mechanical Measurement and Analysis of Advanced Thermal Interface Material Construction
Farhad Raiszadeh . . . . .INCEP Technologies, Inc.

III-2 Fully Physical, Time-Dependent Thermal Modelling of Complex 3-Dimensional Systems for Device and Circuit Level Electro-Thermal CAD
W. Batty, S. David, A.J. Panks, R.G. Johnson, C.M. Snowden . . . . .University of Leeds, UK
C.E. Christoffersen, M.B. Steer
. . . . .North Carolina State University

III-3 Revising the Goals and Means for the Base-to-Air Cooling Stage for Semiconductor Heat Removal– Experiments and Their Results
V.S. Travkin, K. Hu, M. Rizzi, I. Catton
. . . . .University of California, Los Angeles

III-4 Thermal Management for High Performance Integrated Circuits with Non-Uniform Chip Power Considerations
T.D. Yuan, Bor Zen Hong . . . . IBM Microelectronics
Howard Chen, Li-Kong Wong . . . . IBM Research Division

III-5 Thermal Comparison of Plate, Extrusion Heat Sink, and Skive Heat Sink
Michael C. Yang . . . . .Motorola

III-6 The Development of a Natural Graphite Heat-Spreader
Julian Norley, Jim J.-W. Tzeng, George Getz, Jeremy Klug, Brian Fedor . . . . .Graftech Inc

III-7 Thermal Characterization of Fan-Heat Sink Systems in Miniature Axial Fan and Micro Blower Airflow
C.K. Loh, Dan Nelson, D.J. Chou . . . . .Enertron, Inc.

III-8 Multi-Objective Placement Optimization of Power Electronic Devices on Liquid Cooled Heat Sinks
Deepak Gopinath,Yogendra K. Joshi, Shapour Azarm
. . .CALCE Electronic Products and Systems Consortium, University of Maryland

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SEMI-THERM 2000: General Chair Marcelle Ibrahim honors Finance Chair Al Angevine at Awards Luncheon.

SEMI-THERM 2000: Mike Boyle and General Chair Marcelle Ibrahim present Kaveh Azar with the Significant Contributor Thermi Award.

Luncheon 12:15–1:30
SPEAKER: **Thermal Management Challenges of Third Generation Telecommunication Devices**
Jukka Rantala . . . . .Nokia Research Center, Finland

A F T E R N O O N

Exhibits Open 1:30–6:00

Vendor Workshops 2:00–5:15

Poster Session 1:30–3:00

E V E N I N G

Dinner 6:15–7:15

Evening Workshop 7:30–9:00

PANEL SESSION – **Optoelectronic Packaging: Thermal Aspects and Challenges**
PANEL CHAIR: Jeff Montgomery . . . . .Electronicast

WEDNESDAY, MARCH 21, 2001

M O R N I N G

Announcements 8:00-8:15

Technical Session IV: Advances in Compact Models 8:15-10:15
SESSION CHAIR: Wendy Luiten . . . . .Philips

IV-1 The European Project PROFIT: Prediction of Temperature Gradients Influencing the Quality of Electronic Products
Clemens J.M. Lasance . . .Philips Research Laboratories, The Netherlands

IV-2 Creating Compact Models Using Standard Spreadsheet Software
Gerhard Noebauer . . . . .Infineon Technologies, Germany

IV-3 A Simple Analytic Method for Converting Standardized IC-Package Thermal Resistances (θ_{JA}, θ_{JC}), into a Two-Resistor Model (θ_{JB}, θ_{JT})
Yaniv Tal, Aharon Nabi
. . . . .Heat and Mass Transfer Group, RAFAEL, Israel

IV-4 A Generic Method for Thermal Multiport Model Generation of IC Packages
M. Rencz, V. Székely . . . . .MicReD Ltd., Hungary

Coffee Break 10:15-10:35

LUNCHEON SPEAKER

Tuesday, March 20, 2001

Thermal Management Challenges of Third Generation Telecommunication Devices

Jukka Rantala, Nokia Research Center

In telecommunication, data transfer is gaining more importance and the relational part of voice calls is decreasing. Related to this, digital convergence is taking place: telecommunication devices and data transfer devices are going to have more and more features in common.

The third generation of telecommunication products, that will be first taken into public use in Japan in 2001, will offer high data transfer rates for mobile users, making possible for example convenient internet browsing, videoconferencing, and truly mobile office with access to all data bases, to name a few applications. However, this means that in the hand held products more power consuming processors and memories are needed, the RF amplifiers will have longer on-times, and the operation frequencies of digital circuits will increase. Simultaneously, the miniaturization of consumer telecommunication devices puts more functions to smaller volume. This brings us a relation where the dissipated heat intensities are increasing tremendously.

In thermal management this brings new challenges: previously the main task was to transfer the heat from the component, but now it will be at least as important to dissipate the heat from the system and to keep the enclosure surface cool enough for convenient and safe use. To reach the optimum solution, thermal management has to be taken into account in different areas of electronics design, with different means towards the common target.

EVENING WORKSHOP

Tuesday, March 20, 2001

Panel Session: Optoelectronic Packaging:Thermal Aspects and Challenges

PANEL CHAIR: **Jeff Montgomery,** Electronicast

Optical telecommunications components are the future of high-bandwidth communications. As internet traffic increases, traditional electrical signals are limited by the medium in which they travel. Using light to move information has incredible benefits in terms of speed and density, but there are drawbacks especially in packaging and thermal management of optical devices. Optical packaging is a specialty which is drawing from many other industries such as microelectronics, aerospace and medical, but new territories are emerging that require fresh thinking and new ideas.

A group of experts on optical components will discuss thermal issues and challenges associated with this vital segment of the telecom industry. The main theme is packaging with emphasis on thermal management. Panelists include participants from suppliers as well as end-users. The session is being moderated by Jeff Montgomery of Electronicast, a well known expert on the optics industry.

LUNCHEON SPEAKER

Wednesday, March 21, 2001

"The Arte of Fyshing with an Angle —in the 21st Century"

Dr. Robert J. Moffat, Stanford University/Moffat Thermosciences, Inc.

Fly fishing goes back hundreds of years, long before Dame Juliana Berners wrote the first book on the subject. The first few hundred years were all about developing gear and techniques. We've gone from fishing in the local brooks with braided horse-hair fishing lines on willow poles to flying thousands of miles to fish for the "Biggest Rainbows in the World" using hydrophobic-plastic-encased fly lines cast with boron composite fly rods designed by aero-elasticians.

The biggest change, however, has come in our husbandry of the streams: "How do we keep clean water flowing?"

We'll start with Dame Berners' description of the joys and benefits of fishing, written in 1421 and still true! She'll advise us on where and when to fish, how to braid horse-hair fishing lines, and how to tie her favorite fly patterns.

I'll demonstrate the equipment worn by the modern "well-dressed fisherman," show some still-pictures and videos of the fish we are trying to catch, and talk a bit about the technical and political problems involved in re-building our sport fisheries.

Technical Session V: Active Cooling Technology . . . 10:35-12:15

SESSION CHAIR: Alan Claassen . . . IBM

V-1 An Electrokinetic Closed-Loop Micro Cooler for High-Power VLSI Chips
L. Jiang, J. Koo, S. Zeng, L. Zhang, S. Banerjee, P. Zhou, J. Santiago, T. Kenny, K. Goodson . . . Stanford University

V-2 Current and Future Miniature Refrigeration Cooling Technologies for High Power Microelectronics
Patrick E. Phelan . . . Arizona State University
Victor Chiriac, Tien-Yu Tom Lee . . . Motorola, Inc.

V-3 Microprocessor-Based Adaptive Thermal Control for an Air-Cooled Computer CPU Module
Carin Lundquist, Van P. Carey . . . University of California at Berkeley

V-4 Tool for Fast Modelling Active Heat Sinks
Piotr Dziurdzia, Andrzej Kos . . . University of Mining and Metallurgy, Poland

SEMI-THERM 2000: Robert Simons, recipient of the Best Paper Award.

Panel Discussion:

Thermal Modeling Challenges/Issues
PANEL CHAIR: Roger Schmidt . . . IBM
PANELISTS: Clemens J. M. Lasance . . . Philips Research
Bill Maltz . . . Electronic Cooling Solutions
ADDITIONAL PANELISTS: TBA

AFTERNOON

Luncheon . . . 12:20–1:30
SPEAKER: The Arte of Fyshing with an Angle —in the 21st Century
Dr. Robert J. Moffat . . . Stanford University
Moffat Thermosciences, Inc.

Exhibits Open . . . 1:30–6:00

Vendor Workshops . . . 2:00–5:15

Vendor Reception . . . 5:15–6:30

THURSDAY, MARCH 22, 2001

MORNING

Announcements . . . 8:00-8:15

Significant Contributor Thermi Award Presentation . . . 8:15–9:00

Capita Selecta in Electronics Cooling
Clemens J. M. Lasance . . . Philips Research Laboratories, The Netherlands

Technical Session VI: Thermal Enhancement Technology . . . 9:00-10:00

SESSION CHAIR: Alfonso Ortega . . . University of Arizona

VI-1 Design Considerations of High Heat Flux Heat Pipe Evaporators
Jon Zuo . . . Thermacore

VI-2 Biporous Heat Pipes for High Power Electronic Device Cooling
Jinliang Wang, Ivan Catton . . . University of California, Los Angeles

VI-3 The Study of Micro-Fins Heat Sink for Electronic Cooling Application
Heng-Chien Chien, Chih-Yao Wang, Ming-His Tseng, Chun-Hsun Chu . . . Industrial Technology Research Institute, Taiwan

Coffee Break . . . 10:00-10:20

Technical Session VII: Component Thermal Performance . . . 10:20-12:00

Session Chair: Paul Hundt . . . Texas Instruments

VII-1 Effect of Flag Design on Thermal Performance of PBGA Packages
Bennett Joiner . . . Motorola

VII-2 Linear Models for Temperature and Power Dependence of Thermal Resistance in Si, InP and GaAs Substrate Devices
David J. Walkey, Tom J. Smy, Michael Maliepaard, Tom MacElwee . . . Carleton University, Canada

VII-3 Analysis of Manifold Fluid Flow Networks for Cooling Air and Liquid Flow-Through Modular Electronics
Scott T. Johnson . . . Raytheon Sensors and Electronics Systems

VII-4 Temperature Sensors Placement Strategy for Fault Diagnosis in Integrated Circuits
Piotr Bratek, Andrzej Kos . . . Institute of Electronics, University of Mining and Metallurgy, Poland

VII-5 Wiring Statistics and Printed Wiring Board Thermal Conductivity
Richard D. Nelson . . . Teravicta Technologies

Awards Luncheon . . . 12:15–1:30

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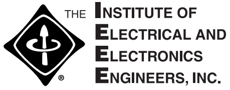

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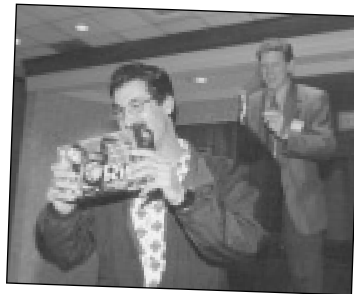

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