

# message

## FROM THE TECHNICAL CHAIR

Greetings from Colorado!

I would like to take this opportunity to tell you about the technical conference at IMAPS 2002. We have seen an unprecedented number of abstracts submitted from all over the world; which has allowed us to put together one of the strongest technical programs in recent years. Add to that a full line up of Professional Development Courses and you have the makings of the 35th International Symposium on Microelectronics in Denver, CO. IMAPS continues to provide the critical information to expand one's knowledge and understanding of the ever-changing world of microelectronics.

Year after year, IMAPS delivers unmatched quality of papers and presentations on new and emerging technologies from leading industry professionals. This year's conference has a strong line-up of papers focusing on well-established topics such as thick film and thin film hybrid applications and surface mount, but we also have the new and emerging areas covered such as: lead-free soldering, precision opto-electronic assembly and packaging, the state-of-the-art in MEMS technologies, wireless applications, high density interconnection, integrated passives and much, much more.

So, come and join us at the technical conference and exhibition in Denver. We've got a gold mine of information for you to sharpen your skills. Along with the exceptional technical program, take advantage of the networking opportunities and spend some quality time with your peers. You never know when you might score with that one tidbit of information that you can only get by attending. We look forward to seeing you here in September!

Best regards,

*Richard Charbonneau*  
StorageTek  
rick\_charbonneau@stortek.com

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### What Your 2002 Full Symposium Registration Includes

Your registration includes the Awards Ceremony, Technical Sessions, Marketing Forum, Exhibits, Welcome Reception, Exhibit Hall Lunches, 2002 Proceedings (printed & CD-ROM Versions), and an automatic one-year IMAPS membership renewal for individual and student members in good standing at the time of registration. For an additional fee you can register for the Professional Development Courses (PDC), Golf Tournament, and the Spouse/Guest Program.

### IMAPS 2002

#### Registration Hours

Tuesday	Sept. 3	8:00 AM – 4:00 PM
Wednesday	Sept. 4	7:00 AM – 6:00 PM
Thursday	Sept. 5	7:00 AM – 5:00 PM
Friday	Sept. 6	7:00 AM – Noon

#### Exhibit Hours

Wednesday	Sept. 4	9:00 AM – 6 PM
Thursday	Sept. 5	9:00 AM – 5 PM
Friday	Sept. 6	9:00 AM – Noon

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## The Paymaster would like to See You at the IMAPS 2002 Welcome Reception!

*Paymaster image courtesy of Kinecta Federal Credit Union formerly Hughes Aircraft Employees FCU*

Denver is a clean, young and green city with over 200 parks and dozens of tree-lined boulevards. The architecture reflects the city's three boom periods: Victorian, when silver was discovered in Leadville; turn-of-the-century, when gold was discovered in Cripple Creek; and contemporary, when the energy boom added 16 skyscrapers to the downtown skyline in a three year period, 1980-1983. Lower Downtown (called "LoDo" by locals) is on the northern edge of downtown Denver and offers one of the nation's greatest concentrations of Victorian buildings and warehouses, many of which have been refurbished to house restaurants, art galleries, offices and shops. This is the center of the city's brew pubs, with six large brew pubs and micro breweries, each brewing six to eight exclusive beers, all within easy walking distance of each other.

Denver is one of the few cities in history that was not on a road, railroad, lake, navigable river or body of water when it was founded. Denver just happened to be where the first few flakes of gold were found in 1858 and it was here that the first camp was made. The first permanent structure was a saloon. The Indians warned early settlers not to build there, but no one listened. In its first few years, Denver was destroyed twice, by fire and flood.

The dome of the State Capitol in Denver is covered with 200 ounces of 24K gold, but the really priceless building material was used inside as wainscoting. It is Colorado onyx ("Beulah red"), a rare red marble found near Beulah, Colorado. "Beulah red" gives the Colorado State Capitol its distinctive splendor. The entire world's supply was used in this building and no more of it has ever been found. Cutting, polishing, and installing the marble in the Capitol took six years, from 1894 to 1900. It cannot be replaced, at any price.

The State is blessed with the Colorado Rockies a part of the North American Cordillera, which stretches 3,000 miles from Alaska, through western Canada and the United States, into northern Mexico. The centerpieces of this dramatic uplift are the peaks over 14,000 feet, or "Fourteeners," as climbers affectionately refer to them. There are 52 Fourteeners in Colorado. Leadville is the highest incorporated city in the United States at 10,430 feet elevation. Because there was lots of "silver" named towns at the time, the founding fathers suggested Leadville. The World's First Rodeo was held on July 4th, 1869, in Deer Trail.

In hopes of gaining political favors, local boosters named the frontier mining camp on the South Platte River "Denver" after Kansas Territorial Governor James Denver. They never received any favors — by the time they named the town, Denver had already resigned. There were originally three separate towns on the current site of Denver, with three different names. In 1859, in return for a barrel of whiskey to be shared by all, the other names were dropped and the tent and log cabin city officially became "Denver."

It was on top of nearby Pikes Peak in 1893 that Katherine Lee Bates was inspired to write the words to "America the Beautiful." Denver, the city that flourished in spite of fire and flood, is looking forward to welcoming you to The Microelectronics Gold Rush - IMAPS 2002, the 35th International Symposium on Microelectronics. We are particularly proud to welcome our international guests and encourage everyone to enjoy the many historical and cultural attractions that Colorado and Denver have to offer including a chance to play cowboy at a Dude Ranch, a CART race and the Taste of Colorado. Bring the family and enjoy all that Colorado has to offer. The weather should offer a pleasing climate and colorful palette for all activities.

Then, **please join us** for the **Microelectronics Gold Rush Welcome Reception** as we prepare to **Mine Denver 2002** and experience all the latest developments in Microelectronics and Packaging. You will be able to enjoy an evening of excellent food and refreshments, meet friends and colleagues, make new acquaintances, and carry on quiet conversations in an atmosphere that we promise will be low-key. **May** the **paymaster** visit you often throughout the next year!

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## Welcome Reception

Tuesday, September 3

6:30 – 8:00 PM

at the

The Adam's Mark Hotel

Come have something to eat,

something to drink,

meet your colleagues, and

"take a chance" for the benefit of the

Sidney J. Stein Educational Foundation!

EARLY-BIRD DISCOUNTS END JULY 12, 2002. REGISTER EARLY • WWW.IMAPS2002.ORG

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## 8<sup>th</sup> Annual IMAPS Golf Classic to benefit the Sidney J. Stein Educational Foundation

Tuesday, September 3, 2002

The IMAPS 2002 Golf Classic will be held at Arrowhead Golf Club - Littleton, Colorado, on Tuesday, September 3, 2002. The tournament will feature a shotgun start with prizes awarded to the overall winners, as well as those closest to the pin and with the longest drive.

This Robert Trent Jones, Jr. course built in 1974 has towering red sandstone rocks throughout its design, providing for some beautiful settings. Many varieties of wildlife make this course their home, so if you enjoy animal watching this is an excellent facility to visit. The greens are undulating and several are elevated. Several tees are elevated too, plus there are several changes in elevation throughout the course, so expect some uneven lies. "Golf Digest" rated this as the 18th "Best in State" course for 1995-96, and under the 1990 category of "Top 75 Public Courses" it was ranked 53rd.

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Cost is \$125 before July 12, 2002, and \$150 after. The cost includes transportation, lunch, greens fees, cart, and use of the range and practice facilities.

Please Note: Proper golf attire is required. Men's shirts without collars, gym shorts, and jeans are not permitted. The Golf Course also requires that all players wear soft-spiked golf shoes.

Hole sponsorships are available: \$400 & \$600. Please contact John Wood, National Foundation Golf Chair ([john.wood@nstarch.com](mailto:john.wood@nstarch.com)) or Doug Paul, IMAPS HQ ([dpaul@imaps.org](mailto:dpaul@imaps.org)) for details.

### Hole Sponsors:

Accu-Tech Laser Processing, Inc.  
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Metalor Technologies USA  
Presidio Components, Inc.  
Technic, Inc.

### Raffle and Auction

to benefit the  
Sidney J. Stein Educational Foundation

New this year at IMAPS 2002 will be a Raffle at the Welcome Reception. Attendees will buy tickets for \$1 and place them in a basket in front of the item they wish to take a chance on. A drawing will be held for each item and the person with the corresponding numbered ticket will take that item home. Items in the Raffle will have a top value of \$50. A "live" Auction will take place at the Symposium and will feature items with a value in excess of \$50 with the item going to the highest bidder.

SAVE \$50 OFF FULL-SYMPOSIUM REGISTRATION BY REGISTERING ON-LINE: [WWW.IMAPS2002.ORG](http://WWW.IMAPS2002.ORG)

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# Student Program

Students, no relaxing at this symposium! This is the chance to jumpstart your career in microelectronics and/or optical networking. We've got exciting, mind-stretching activities lined-up from Tuesday through Friday, September 3 - 6. Plus, you'll experience the culture and hospitality of the real Rocky Mountain West.

## Reduced Symposium Registration

IMAPS offers students a greatly reduced symposium registration fee. Students' cost to attend the Full Technical Symposium is \$10.00 for IMAPS members and \$15.00 for Non-members (before July 12, 2002); \$20.00 for members and \$25.00 non-members after the deadline. Your registration includes all Technical Sessions, Awards Ceremony, Marketing Forum, Exhibits, Welcome Reception, Exhibit Hall Lunches, 2002 Proceedings (hard copy and CD-ROM) and an automatic one-year IMAPS Membership renewal.

IMAPS is also offering a **free students-only** half-day Professional Development Course (PDC). The course, entitled *Microelectronics Systems Packaging: Careers, Technologies and Markets (F9)* will be presented on Friday, September 6 from noon to 3 pm. **See page 15 for more details.**

## Professional Development Course (PDC) Monitors

Again this year students will have the opportunity to serve as PDC monitors. One student monitor will be assigned to each of the 17 PDCs during the Symposium. The PDCs are scheduled for Tuesday, September 3 from 9 am to 5 pm and Friday, September 6 from 11 am to 6 pm. Course monitors assist the PDC instructors (distribute handouts, monitor lights, collect evaluations, etc.). In return monitors may attend the course at no charge and receive free course materials (not including textbooks) and lunch on the day of their PDC. PDC monitors will receive no financial compensation. Monitors are assigned on a first-come, first-served basis. So, sign up early to get the PDC of your choice by emailing Doug Paul, [dpaul@imaps.org](mailto:dpaul@imaps.org), with your top three choices.

## Student Chapter Booth Competition

IMAPS Student Chapters are encouraged to exhibit a Chapter booth on the Exhibit Floor. These booths are free to Student Chapters and provide the opportunity to display and discuss its microelectronics research projects and activities. On Wednesday morning, a panel of judges will evaluate the Student Chapter booths on several criteria, including general appearance, display diversity (curriculum, activities, and projects), technical knowledge, and overall exhibit professionalism. The *Best Student Chapter Booth* will be recognized at the Student/Industry Reception that evening.

## Best Student Paper

A review committee will attend all technical presentations by student authors to evaluate and determine the *Best Student Paper*. The student papers will be evaluated on technical knowledge, presentation skills, written manuscript, and audience interaction. The winning student will receive a certificate and recognition in *Advancing Microelectronics*.

## Student/Industry Panel

The Student/Industry Panel is your chance to learn career development insights from top-level industry professionals. **The Panel will be conducted on Wednesday afternoon from 3 pm to 4:30.** Professionals from the electronics and optical networking equipment industries, industry recruiters, and engineering educators will describe and discuss how their education, interests and career experiences led to their current positions. Students will also learn current industry expectations and what they should be doing now for their long-term career development. Invited panel participants include: Andrew Goldstein, *Network Photonics*; Keith Baumgardner, *Intel*; Dr. Roop Mahajan, *University of Colorado at Boulder*; Dr. Jennie S. Hwang, *H-Technologies Group*; and others. Each panelist will speak for 10 - 15 minutes, followed by a Q & A session.

## Student/Industry Reception

The Student/Industry Reception will immediately follow the Student/Industry Panel. Students will have the opportunity to network one-on-one with the industry panelists and each other. Refreshments will be served. The *Best Student Chapter Booth* will be announced at the reception.

## Student Plant Tour

On Thursday morning students will hop on a bus and head for Boulder and Longmont to get a look at the Colorado photonics industry. We'll tour the Colorado Advanced Photonics Technology [CAPT] Center and one or more optical network equipment companies, to be determined.

With all this planned for students, it would be a shame if you missed out on the excitement! For more information, please visit [www.IMAPS2002.org](http://www.IMAPS2002.org)

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## 2001 - 2002

### Sidney J. Stein Educational Foundation Graduate Grant Recipients

**Steven C. De Blasio**, The Pennsylvania State University  
*Student Advisor: Michael T. Lanagan*  
Paper title: Debinding Low Temperature Cofired Ceramic Components

**Randy Klein**, Florida International University  
*Student Advisor: W. Kinzy Jones*  
Paper title: Characterization of Thick Film Resistor Formulations Compatible with LTCC Ceramics

**Hua Ye**, State University of New York at Buffalo  
*Student Advisor: Douglas C. Hopkins*  
Paper title: Reliability of BGA Solder Joints Operating under High Current Density

**Wang Yu**, University of Pennsylvania/Moore School of Electrical Engineering  
*Student Advisor: Jorge J. Santiago-Aviles*  
Paper title: Process Development and Characterization for the Fabrication of 3-D Meso-Scale Structures Utilizing Low Temperature Co-Fired Ceramic Tapes

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# Spouse/Guest Program

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Wednesday, September 4, 2002  
10 AM - 4 PM

**A Tour of Boulder!** Today you will visit the Little Town nestled between the mountains and reality.

A short ride will lead you into the foothills of the Rocky Mountains where the first stop will be the **Red Rocks Amphitheater**. A magnificent natural geologically formed open-air theater. The allure of the two three-hundred-foot monoliths combined with a naturally occurring theatre set on a mountain stage is not duplicated anywhere in the world. It provides perfect acoustics for hundreds of famous artists who perform here. You will be one of the first to visit the **Amphitheater's** newly renovated Visitor's Center.

You will then continue on to the charming college town of **Boulder**. There you will be our guest at the **Celestial Seasonings headquarters**, where 45 different herb and black teas are created. You will learn all about the fine art of tea during a 45-minute tour of the facilities. After the tour stop by the Celestial gift shop where ancient proverbs and new-age art blend into unusual gifts; you'll head to tea-lovers paradise in the **Tea Room** where you will enjoy the perfect opportunity to put your brand new appreciation for herbal teas to work. Afterwards, you will enjoy a refreshing lunch in the **Celestials Café**.

You will then continue on to the **Leaning Tree Museum** - Voted the "Best Small Museum in the United States" by museum lovers. There you will have the opportunity to view the extraordinary private collection of traditional and contemporary Western art and sculptures. The Leaning Tree Museum is part of the Leaning Tree greeting card world headquarters. Next you will take a 45-minute tour where you will see the production facility and witness for yourself how the artisans create these award-winning cards.

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On your way back to Denver you will drive through the historic neighborhood of **Mapleton Hills** or the **University of Colorado**, ranked one of the most beautiful campuses in the United States. You will return to the hotel at approximately 4:00 p.m.

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Thursday, September 5, 2002  
9 AM - 5 PM

**Silver and Gold!** You will enjoy a beautiful, scenic drive through the mountains into the heart of the historic mining district to the town of Idaho Springs. Your guide will describe various sights passed en route, as well as historical information about Idaho Springs. You will be led to a small family operated working gold mine, which is known the world over for its educational and entertainment features. The **Phoenix Mine** has been a prolific gold producer since the 1880s and is still the site where gold can be found. You will take a 30-minute tour into the mine and gain "hands-on" mining experience, where you will be invited to try mining and keep what you find!

Then it is onwards to the city of **Georgetown**. Here you will enjoy lunch in one of Georgetown's historical buildings. Afterwards you will board the Georgetown Loop train in the historic station for the ride to **Silver Plume** and back. This portion of the track has been rebuilt and recreates the original line. The track loops over itself in order to climb the steep mountain grade in the six-mile trip. The rest of the afternoon you will spend on a guided tour, walking through historical Georgetown. You will have the opportunity to visit one of Georgetown's museums like the Hamill House, the Hotel de Paris or the Energy Museum. The Hamill House is a beautiful Gothic Revival style building that was once home of the town's most famous silver baron, William A. Hamill. The Hotel de Paris was opened in 1875 and built by a Frenchman who came to Georgetown to seek his fortune in mining. Georgetown's Victorian streets also host several charming antique and geological interest shops where you can browse and shop before boarding the bus at 3:30 pm to head back to the hotel. You will return to the hotel at approximately 5:00 pm.

Wednesday & Thursday only: \$190 – Advance; \$220 – On-site.  
*\*Please note that lunch is included on both days. No breakfast will be provided.*

Exhibit Hall Luncheon  
sponsored by:  
**Laserage Technology Corp.**

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## professional development courses

Do you want to broaden and strengthen your skills and knowledge, optimize your manufacturing processes, and integrate the latest advances in materials and technologies to maintain your strength in today's competitive global market? The Technical Committee of IMAPS is pleased to present a comprehensive offering of professional development courses that provide detailed information on topics of immediate interest to the Microelectronics and Packaging community. So please be sure to choose from the fifteen full day and two half-day in-depth technical workshops taught by recognized industry experts. You will discover the following key ways you will benefit...

- **Better understand the industry's fundamental skills and knowledge.**
- **Be exposed to the rapid expanding developments in new materials and technologies.**
- **Consult with renowned authorities about your current R&D or manufacturing problems and challenges.**
- **Learn new ways to identify, think about, and address your problems and opportunities.**
- **Great opportunities to interact with industry experts and other course attendees.**
- **Certificate of Attendance and much more...**

### T1

#### Wire Bonding in Microelectronics

*Instructor:*

*George G. Harman, National Institute of Standards and Technology*

**Course Description:**

Wire bond manufacturing defects range typically from about 1000 to 100 ppm, with exceptions to >10,000 and <50 ppm. In order to achieve the lower numbers in production, one must understand all of the conditions that affect both bond yield and reliability (since they are interrelated). This course will discuss many large- and small-wire bonding problems, as well as subjects of specific interest to hybrid/MCM device bonding. In addition, a number of advanced topics, such as high yield, fine pitch, and flex bonding will be covered. New developments (e.g., high frequency ultrasonic bonding), are included along with a major discussion of wire bonding to multichip modules and other soft substrates.

Wire bond testing and metallurgy (covering both aluminum and gold bonds); intermetallic compounds; cleaning for yield and reliability; failures resulting from electroplating; mechanical problems in wire bonding; new bond technologies and developments; how ultrasonic bonds are formed, and the metallurgy of gold and aluminum wire. It concludes with methods of implementing TAB and Flip Chip by using wire bonding techniques.

**Who should attend?**

Engineers in R&D, QA, QC, manufacturing, process development, and advanced technicians. It is assumed that participants have some familiarity with wire bonding and general device assembly technologies.

**Special Course Materials:**

All attendees will receive a complimentary copy of Wire Bonding in Microelectronics, by George Harman, McGraw Hill, NY, 1997 (List price \$65), as well as course notes and explanations.

*Mr. Harman is a Fellow of the National Institute of Standards and Technology (NIST), Department of Commerce. He received a BS in Physics from Virginia Polytechnic Institute & State University and a MS in Physics from the University of Maryland. Mr. Harman has published 50+ papers, two books on wire bonding, and holds four U.S. Patents. He was the 1995 President of ISHM and is a Fellow of IMAPS and the IEEE. He has received numerous awards for his work from IMAPS, IEEE, DVS and others. He has presented numerous talks, and has taught courses for the University of Arizona and IMAPS for over 15 years, as well as the IEEE, to name a few. He has presented many papers and given courses in the USA, Europe, and Asia.*

### T2

#### Metal Plating for Electronics

*Instructor:*

*Michael McChesney, McChesney, Inc.*

**Course Description**

Electroplated finishes provide environmentally sound and cost effective contacts and coatings for most electronic components and systems. Plating also plays a role in hybrid fabrication and assembly and semiconductor bonding. This course will provide a foundation in electrolytic and electroless plating of precious metals, copper, tin and tin/lead. Also covered will be plating for corrosion protection and testing of electro-deposited coatings.

**Who should attend?**

This course is appropriate for design, process and applications engineers and technicians as well as sales personnel and those who specify, purchase or inspect plated components. Newcomers to the field or those who wish to broaden their knowledge of plating terminology, process specifications or the surface finishing processes involved in component manufacturing will find the course worthwhile.

*Mike McChesney has worked in the surface finishing field for 33 years as both a production engineer and in process development and retired from the Avionics Division of Honeywell Inc. He has a BS in Chemistry and MS in Physics. He is a*



certified electroplater/finisher and a specialist in electronic finishing. He is an instructor for the American Electroplating and Surface Finishing Society and the College of St. Thomas. He now works as an independent consultant in the area of surface finishing.

### T3 Technology of Screen Printing

**Instructors:**  
Art Dobie, SEFAR America & Rudy Bacher, DuPont

#### Course Description:

The purpose of this course is to increase the understanding of the screen printing process thereby improving production yield and quality. The critical and integrated components for screen, such as frames, screen mesh and emulsion are presented. Presented are some of the latest advancements in the screens, the compositions and the printing process that enable screen printing to meet future circuits density requirements.

The course is applications-oriented in terms of how to optimize the screen printing process; how to specify and use screens; rheology properties that affect the print; minimizing printing defects and trouble-shooting problems related to the screens and the printing process.

#### Who Should Attend?

This course is intended for production and process engineers, and others interested in learning how to optimize and increase the uses of the screen printing process.

*Art Dobie is Manager of Technical Service and Marketing and a member of the senior management team of SEFAR America (MEC) in Mount Holly, NJ. He has been with MEC more than 18 years since receiving his BS in Screen Printing Technology in 1980 from California University of Pennsylvania's School of Science and Technology. Art is an original instructor of IMAPS' Technology of Screen Printing Professional Development Course, and has delivered many technical papers and presentations relating to screen printing technology to the microelectronics industry at the local, National and International levels. He is a Senior Member of IMAPS and has held numerous offices in the Keystone Chapter, including*

*president. Art Dobie was Co-Chair of Exhibits for ISHM '97 and initiated the IMAPS Educational Foundation Silent Auction. On October 7, 1998, Art was inducted into the Academy of Screen Printing Technology, a body of 50 technical authorities representing the highest plane of technical expertise in the screen printing industry.*

*Rudy Bacher has worked 37 years in Thick Film Technology for DuPont Research and Development as a Ceramic Engineer and currently as a Development Associate. He is a recipient of the ISHM Technical Achievement Award-1984; Corporate Marketing Excellence Award-1994; and is an IMAPS Instructor "Technology of Screen Printing" 1990-1998.*

### T4 Implementing Microvias and Embedded Passives

**Instructor:**  
Rolf E. Funer, Funer Associates

#### Course Description:

New PCB designs are increasing in density and requiring more and more component placements, more I/Os, tighter dimensions. Microvias can dramatically reduce board size, increase I/O count and reduce layer count. The numbers of passives (resistors and capacitors) are increasing dramatically. By embedding the passives directly in the circuit board, valuable surface area can be saved. Performance, particularly at high frequency, can be improved. These new technologies can work together to cut weight and size and therefore enable high density substrates. But can these concepts be implemented today? Or are they future technologies? This workshop addresses these issues, reviews all the currently available materials and processes to make microvias and embed passives. Design and testing issues, performance, reliability, applications and economics are all covered. The design and project managers attending this course will come away with an informed view if their designs are ready for microvias and embedded passives and if microvias and embedded components are ready for them. PCB manufacturing and development engineers will learn what they will need to do to implement these technologies.

#### What You Will Learn:

- Major microvia processes: their capabilities, costs, reliability and availability
- Applications of microvias to reduce size, layer count and cost
- Suppliers: US and worldwide
- Embedded passives: currently available materials. How to process, capabilities, benefits and limitations
- New and emerging passive materials: their status and potential
- Applications and how they are working out

#### Who should attend?

This course will be valuable to those considering the use of microvia in their product or are contemplating manufacturing microvia boards. It is also valuable to hybrid engineers as microvia technology is considered an alternative or complement to traditional hybrid circuitry.

*Rolf Funer has over 20 years experience in interconnect materials development, printed circuit and hybrid fabrication. Dr. Funer is the principal consultant for Funer associates. His clients include leading OEMs, circuit and electronic materials manufacturers. Previously, he was Chief Technologist, Circuits and Packaging for AMP, Inc. and prior to that served as AMP Circuits' Technical Director, responsible for development of new and advanced circuit technologies including installation of one of the first microvia plants in the US.*

### T5 Advanced Organic Substrate Package Design & Manufacturing for RF & Broadband Applications

**Instructor:**  
Hassan Hashemi, Rockwell Semiconductor

#### Course Description:

The objectives of this course are to review design and manufacturing practices and tradeoffs affecting current and next generation RF & GHz Packaging using laminated substrate technologies in single or multiple die packaging format. The course material is primarily based upon the instructor's experience on current practices used for Wireless & GHz IC packaging for Internet infrastruc-

# professional development courses

ture applications. The course is designed for engineers or engineering managers who want to understand more about laminate single or multichip modules, and the unique requirements for assuring that packages can be manufactured in a high volume commercial application and meet stringent electrical and thermal performance requirements.

## Who should attend?

The course is intended for both the packaging expert (Electrical and Mechanical Engineers) as well as persons new to the field. The course will concentrate on extending the existing organic substrate infrastructure capability to GHz high volume packaging applications. The information presented will include the theoretical background with practical methods for implementing a design. These same techniques can be applied to other high frequency single or multichip designs.

*Hassan Hashemi is Director of Advanced Packaging at Conexant Systems, Inc. in Newport Beach, California. He is currently managing design and development of single and multi-chip packages for broadband digital, mixed-signal, and RF devices used in personal communication applications. He holds a Masters degree in electrical engineering from the University of Texas at Austin, and has over 16 years of experience in microelectronics package design, manufacturing, and product development. Prior to joining Conexant, he was a senior member, technical staff at Microelectronics and Computer Corp. and Advanced Micro Devices. He holds 10 US patents, has authored three book chapters and over 40 technical papers in the areas of high speed package electrical and thermal design and implementation.*

## T6

### Fundamentals of Fabrication and Packaging of MEMS and Related Micro Systems

#### Instructor:

*Ajay P. Malshe, Ph.D., University of Arkansas - HiDEC*

#### Course Description:

MEMS and related micro systems are typically divided into two application areas, sensors and actuators for range of applica-

tion such as automotive, biomedical, optical, RF, etc. Fabrication and packaging of microelectromechanical systems (MEMS) is the subject of immense interest. Their packaging with other components is challenging and unlike IC packaging, have different set of demands from releasing, dicing to interconnection at chip-scale and manufacturing at wafer-level. This course will address fabrication and packaging of silicon and non-silicon MEMS and related microsystems. The course will use examples of various novel applications to elaborate the use of various fabrication and packaging processes.

## Who should attend?

The course is meant for industry and academic leaders in science and engineering with interest in MEMS and related micro systems. Graduate students with special interest in the above areas will also find it useful. Highly recommended for R&D scientists, engineers and managers involved in sensors, actuators, instrumentation and systems related to microsystem technology.

*Ajay P. Malshe, is an Associate Professor at the Department of Mechanical Engineering and an adjunct faculty member at the High Density Electronics Center (HiDEC), Department of Electrical Engineering, University of Arkansas, USA. His three distinct fields of research and educational interest are integration and advanced packaging of micro and nanosystems, surface engineering of materials for advanced manufacturing, and human-machine interfaces. He has edited two proceedings, and authored one book chapter, over one hundred refereed publications and holds four patents. He is currently an active member of International Microelectronics and Packaging Society (IMAPS) through the organization of Advanced Technology Workshops (ATW) on MEMS Packaging. Currently, he is Chairman of Thermal Management Technical Sub-committee and also, National Chair of Topical Technology Workshops for IMAPS.*

## T7

### Flip Chip and CSP Technologies – Constructions, Materials, Assembly and Reliability

#### Instructor

*R. Wayne Johnson, Ph.D., Auburn University*

#### Course Description:

The increasing number of I/O per semiconductor chip combined with the product driven requirements of thinner, smaller and lighter weight have lead the electronics packaging and assembly industry to chip scale packages and flip chip (Flip Chip in Package (FCiP) and Flip Chip on Laminate (FCoL)) technologies. In fact, many CSPs use FCiP constructions. This course will begin by examining the drivers for flip chip and CSP technologies then examine the options, their construction and trade-offs. 3-D CSPs will also be examined. Substrate design requirements will be discussed including routing, and pad design. Major assembly issues are flux selection for flip chip, solder paste printing for CSPs, underfilling, if necessary, and inspection. Underfilling which is not a traditional SMT assembly process is required for flip chip and often for CSPs. The underfill process and material options for flip chip and CSP will be examined. Recently, wafer applied underfill material concepts for FCoL assemblies have been discussed and this new technology concept will be explored. The replacement of leads by solder spheres impacts reliability, particularly in thermal cycling and bending, and must be considered prior to implementing these technologies. The course will conclude with a discussion of reliability.

#### Who Should Attend?

This course is intended for those individuals soon to be responsible for implementing flip chip assembly, suppliers of materials and equipment for flip chip assembly and others interested in flip chip implementation.

*Dr. Johnson is an Alumni Professor of Electrical Engineering at Auburn University and Director of the Laboratory for Electronics Assembly and Packaging (LEAP). At Auburn, he has estab-*

## professional development courses

lished teaching and research laboratories for advanced packaging and electronics assembly. Research efforts are focused on materials, processing, and reliability for electronics assembly. He has worked in MCM design, MCM-L, -C and -D substrate technology as well as advanced SMT, wire bond and flip chip assembly techniques. He has published and presented numerous papers at workshops and conferences and in technical journals. He has also co-edited one IEEE book on MCM technology and written two book chapters in the areas of silicon MCM technology and MCM assembly. He received the 1997 Auburn Alumni Engineering Council Senior Faculty Research Award for his work in electronics packaging and assembly. Dr. Johnson is the current Technical Vice President of IMAPS and was the 1991 President of the Society. He received the 1993 John A. Wagnon, Jr. Technical Achievement Award from ISHM, was named a Fellow of the Society in 1994 and received the Daniel C. Hughes Memorial Award in 1997. He is also a member of IEEE, SMTA, and IPC. Dr. Johnson received the B.E. and M.Sc. degrees in 1979 and 1982 from Vanderbilt University, Nashville, TN, and the Ph.D. degree in 1987 from Auburn University, Auburn, AL, all in electrical engineering. He has worked in the microelectronics industry for DuPont, Eaton, and Amperex.

### What You Will Learn

This course will provide you with the ability to:

- Keep abreast of current lead restriction legislation activity
- Be informed about the Pb-free roadmap of major industrial manufacturers
- Review the options of lead-free replacement
- Realize the strengths and limitations of each option
- Recognize the challenges in implementing lead-free soldering
- Understand the defect mechanisms encountered at lead-free soldering
- Determine the proper move toward lead-free soldering

### Who Should Attend?

This course is intended for engineers, supervisors, managers, directors, safety staff, scientists, technologists, and technicians who are involved in implementing lead-free solder selection, soldering process work, or in guiding corporate safety and corporate major directions.

Dr. Lee is the Vice President of Technology of Indium Corporation of America. He has been with Indium since 1986. Prior to joining Indium, he was with Morton Chemical and SCM. Dr. Lee has more than 17 years of experience in the development of fluxes and solder pastes for SMT industries. In addition, he also has very extensive experience in the development of high temperature polymers, encapsulants for microelectronics, and adhesives. Dr. Lee has given numerous presentations and short courses worldwide on those subjects at many international conferences. Dr. Lee received his PhD in polymer science from the University of Akron in 1981 and a BS in chemistry from the National Taiwan University in 1973.

### T9

#### Design Failure Mode Effects Analysis for Reducing Design Defects

*Instructor:*  
Mary McDonald, ISO/QS, Inc.

#### Course Description:

Failure Mode Effects Analysis, or FMEA, is a widely used tool for determining, before the design is finalized, whether the design can be improved (more robust,

more cost effective, etc.). This is accomplished by analyzing the design to determine where improvements can be made, or by understanding the risk of the current design.

Course setup: The concept will be taught, then attendees will break into small groups to implement a generic Design FMEA problem, to learn the mechanics first hand. A second example, relating to Electronic Packaging, will be given to demonstrate how the technique can be applied in their facilities.

This course can be taken alone, or in conjunction with Process FMEA.

### Who Should Attend?

All areas of a facility use this technique, so anyone involved in preventing problems (or solving them) would find this technique useful. Engineers involved in Design, Reliability, Process, New Product Introduction, Product, etc. as well as employees involved in material specifications, testing, warranty, and end of life determination.

Mary McDonald is President/Principal of Individual Solution Options/Quality Services, Inc., a full service consulting and training enterprise located in Austin, Texas. Since 1995, ISO/QS has been serving the hi technology, automotive, and service industries by providing money-saving techniques to improve the bottom-line. Mary is a Project Management Master; IMAPS Fellow; Past President, Malcolm Baldrige Examiner; and Quality and Environmental Management Systems Certified Auditor. Prior to opening her own company, she was Director of Quality, Environmental, Safety, and Health at Electrosources in San Marcos, TX; and a Senior Engineer at IBM's upstate NY facilities, where she worked as a NPI engineer, Quality Assurance/Reliability Engineer, Engineering Manager, and coordinator for their ISO 9001 registration. She has presented over 20 papers at IMAPS and other conferences, and is a frequent invited speaker.

### T8

#### Lead Free Soldering – Status Review and Process Challenges

*Instructor:*  
Ning-Cheng Lee, Indium Corporation of America

#### Course Objectives:

In this course, all current vital options for lead-free solder replacement will be reviewed and compared, with strengths and limitations for each option well analyzed. In particular, the major challenges encountered in implementing lead-free soldering will be presented, including defect mechanisms analysis. With the information provided by this course, the users will be able to decide when and what to do with lead-free soldering implementation according to each specific situation.

PROFESSIONAL DEVELOPMENT  
COURSES (PDCs)  
held on Friday, September 6, 2002  
are located at the:  
  
ADAM'S MARK HOTEL  
NOON - 6 PM  
LUNCH AT 11 AM

## professional development courses

### F1 Process Engineering Fundamentals

*Instructor:*  
Thomas J Green, National Training Center for Microelectronics

#### Course Description:

The objective of this course is to teach the fundamental process engineering tools and techniques needed for the microelectronics packaging industry. The focus of this course is to provide an overview of the skill sets required to effectively control and optimize a microelectronics manufacturing process flow. The course begins with a review of the common materials and manufacturing processes used in the hybrid microelectronics industry including common assembly processes for RF MMIC modules and optoelectronic devices. Next, process characterization and statistical methodologies are introduced with a focus on practical applications. The basic concepts of Design of Experiments (DOE) including set up and analysis of a simple industry fractional factorial experiment is covered. Statistical Process Control (SPC) techniques and sample charts are also reviewed with a special emphasis on Cp and Cpk calculations. Finally, industry accepted Defect Recognition and Workmanship Standards are presented. Clear color photos of excessive probe marks, chipouts, air bridge damage, die attach and wirebond defects along with numerous other defects will be presented to the class and discussed in detail.

#### Who Should Attend?

This PDC is intended as an introduction to intermediate level course for process engineers, designers, quality engineers, and experienced technicians responsible for microelectronics materials and process development and manufacturing process improvements.

*Tom is a Technical Director at the National Training Center for Microelectronics. At NTCm he designs curriculum and teaches industry short courses relating to advanced microelectronics manufacturing processes. He has over twenty years experience in the microelectronics industry at Lockheed Martin Astro Space and USAF Rome*

*Laboratories. During that time period he was a staff engineer responsible for the materials and manufacturing processes used in building custom high reliability space qualified microcircuits (Hybrids, MCMs and RF modules) for military and commercial communication satellites. Tom has demonstrated expertise in wirebonding, component attach, and seam sealing processes. He has conducted and analyzed numerous statistically designed experiments, which increased first pass yield, reduced costs and improved product quality. At Rome Labs he worked as a senior reliability engineer and analyzed component failures from AF avionics equipment. Tom is an active member of the IMAPS at both the regional and national level, he is currently serving as the Keystone chapter president. He has published seven technical papers and is a member of the IMAPS National Technical Program Committee. Tom earned a B.S. in Metallurgy and Materials Engineering from Lehigh University and a Masters in Engineering from University of Utah.*

### F2 Advanced Materials for Microelectronics, Optoelectronic and MEMS/MOEMS Packaging and Thermal Management

*Instructor:*  
Dr. Carl Zweben, Advanced Packaging Materials and Composites Consultant

#### Course Description:

Materials selection impacts performance, reliability, manufacturing yield and cost. Increasingly, traditional packaging materials are failing to meet the requirements of new microelectronics, optoelectronic and MEMS/MOEMS packaging designs. In response, numerous advanced composites and monolithic materials have been, and are continuing to be developed. Property improvements include:

- Thermal conductivities ranging from extremely high (over four times that of copper) to very low
- Low, tailorable coefficients of thermal expansion
- Electrical resistivities ranging from very low to very high
- Extremely high strengths and stiffnesses
- Low densities
- Low cost, net shape fabrication processes

Payoffs include:

- Improved thermal performance
- Reduced thermal stresses and warpage
- Improved fiber alignment
- Simplified thermal design
- Possible elimination of heat pipes
- Weight savings up to 80%
- Size reductions up to 65%
- Increased reliability
- Reduced electromagnetic radiation emissions
- Increased manufacturing yield
- Potential cost reductions

Advanced materials, such as Al/SiC metal matrix composites and carbon fiber-reinforced polymer matrix composites, are now being used in a growing number of high volume commercial and aerospace production applications at the rate of millions of piece parts annually. Components include optoelectronic packages, carriers, heat spreaders, microprocessor and PWB heat sinks, solid and flow-through PWB cold plates, microwave modules, power semiconductor modules, and heat pipe overmolds. Products using these materials include servers, DSPs, cellular telephone handsets and base stations, laptop computers, hybrid vehicles like the Toyota Prius, trains, wind turbine generators, data storage drives and aircraft and spacecraft electronic systems.

We cover traditional packaging materials and the large and increasing number of advanced materials, including: silicon carbide particle-reinforced aluminum (Al/SiC) and copper; carbon fiber-reinforced polymer matrix composites; aluminum and copper reinforced with discontinuous and continuous carbon fibers; diamond particle-reinforced aluminum, copper and silicon carbide; beryllia particle-reinforced beryllium; discontinuous carbon-graphite-reinforced aluminum; silicon-aluminum; silver/“Invar;” carbon/carbon composites; pyrolytic graphite; thermal pyrolytic graphite; “ThermalGraph;” silicon carbide/silicon and others.

This course provides an in-depth discussion of the materials, their properties, the processes by which they are made, and where they are being used. We also look at future directions.

#### Who Should Attend?

Engineers, scientists and managers in-

involved in microelectronics, optoelectronic and MEMS/MOEMS packaging design, production and R&D, packaging material suppliers.

*Dr. Zweben, an independent consultant, has directed development of advanced packaging materials for over 30 years. For many years he was Advanced Technology Manager and Division Fellow at GE Astro Space, later acquired by Lockheed Martin, where he directed the Composites Center of Excellence. Other affiliations have included Du Pont, Jet Propulsion Laboratory and the Georgia Institute of Technology NSF Packaging Research Center. Dr. Zweben was the first, and one of only two winners of both the GE One-in-a-Thousand and Engineer of the Year awards. He is a Fellow of ASME, ASM and SAMPE, an Associate Fellow of AIAA, and has been a Distinguished Lecturer for AIAA and ASME. He has published and lectured widely on advanced packaging materials and composites.*

cessing technologies, particularly thick and thin film, suitable for RF/microwave hybrids will be reviewed. The relation of processing strategies to their applicability to high frequency requirements will be discussed. The effect of processing on passive and transmission line components in the context of RF/Microwave hybrids will be explored and packaging, especially with respect to inductance will be explored.

#### Who Should Attend?

This course will benefit all those with entering the RF and microwave arena. In particular this course will benefit those with responsibility for design and manufacturing of RF/microwave hybrids. Supervisors, engineers and technicians involved in product development, design and manufacture should plan to attend.

*Richard Brown is a technical and engineering consultant in hybrid manufacturing, with more than 30 years experience, encompassing thin and thick film, electroplating and substrate technologies. He began his career at Bell Telephone Laboratories working on substrate materials and tantalum based thin film circuitry. After joining RCA Solid State in 1968, he worked on all phases of high density, air-insulated interconnect, multi-chip substrates, including vapor deposition, electroplating, laser scribing and beam lead assembly. At the RCA Microwave Technology Center in Princeton, NJ, he developed new process technologies for microwave hybrids, including the development of unique high density interconnect technologies. In 1991, Mr. Brown joined an Alcoa Electronic Packaging technology team as program manager to implement thin film on high temperature co-fired ceramic for MCMs. Work for one of his major clients involved the development of a multilayer manufacturing technology on clad, polymer substrates for high frequency communication and radar applications. He holds seven US patents and is the author or co-author of numerous publications including a recent chapter titled, "Thin Film for Microwave Hybrids" in "Handbook of Thin Film Technology," A. Elshabani-Riad, ed, McGraw-Hill, 1997. Since 1983, Mr. Brown has presented short courses on-site and at various technical societies on RF and microwave hybrids. His text, "Materials and Processes for Microwave Hybrids" was published in 1991 by ISHM.*

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### F3 RF/Microwave Hybrids: Basics, Materials and Processes

**Instructor:**  
Richard Brown, Richard Brown Associates, Inc.

#### Course Description:

In recent years, the development of wireless communications systems and products has been growing at a rapid pace. Coupled with this is the development of monolithic integrated circuits, MMICs. As a result, system and product designers are faced with the choice between hybrids and MMICs; i.e., complete system on a chip vs. hybrids with discrete devices, or more often, somewhere in-between.

This course will begin with a comparison of MMICs and hybrids. It will then cover some of the basic concepts necessary to appreciate the materials and processing demands placed on manufacturing high frequency circuits. The need for impedance matching as operating. The three basic planar waveguides will be discussed, illustrating how fields determine trace geometry and impedance. The basic materials (conductors and substrates) and their properties will be reviewed, and their effect on circuit properties and performance will be discussed. Pro-

### F4 Integrated Circuit Packaging Trends and Assembly Options - Issues and Concerns

**Instructor:**  
William J. Greig, Greig Associates

#### Course Description:

This course addresses the impact of both the Integrated Circuit, and End Product requirements ("smaller, better, cheaper"), on packaging, assembly, and substrate interconnects. It focuses on packaging trends, namely, the Ball Grid Array (BGA) and the Chip Scale Package (CSP), Multichip Packaging (MCP) and alternative formats, Chip On Board (COB) and 3-D initiatives at both the chip and package levels. Assembly options available for attachment of the IC in each case will be discussed with major emphasis on Flip Chip. The course also covers the High Density Interconnect (HDIs) substrates. The various substrate technologies (Thick Film, Co-fired Ceramic, and Thin Film) that are employed in the manufacture of packages and component assemblies for MCPs will be reviewed. Finally, the latest developments in PWBs, with high density, fine lines, and microvias employing sequential processing (Build Up Technology – BUT) will be reviewed. Through out the course the technical issues will be emphasized and reliability concerns addressed where appropriate.

#### Special Course Materials:

All attendees will receive a complimentary copy of the book, Hybrid Microcircuit Technology Handbook, J. Licari, L. Enlow, 2nd Edition, Noyes Publications, 1998 (List price \$125).

#### Who Should Attend?

The course provides an overview of microelectronic packaging and assembly and is intended for individuals in any way involved with electronics manufacturing. While introductory in nature, it discusses current status and future trends, it is directed towards both the experienced or inexperienced engineer and technician, and management personnel with the "need to know." It

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should be of particular interest to those in support activities such as procurement, quality assurance, marketing and sales, and program office by providing a technology base in support of strategic planning and implementation.

*Bill Greig is currently an independent consultant specializing in microelectronic packaging and assembly. His previous work experiences include RCA Semiconductor, General Electric Co., Lockheed Electronics, and NASA. His areas of expertise covers semiconductor wafer processing and assembly, hybrid circuit manufacture, and printed wiring board fabrication. He is experienced in assembly technologies such as chip & wire, TAB, and flip chip. He has been granted 6 patents and has published or presented numerous papers at the various technical symposia. He has developed and presented courses at national symposia and participated in CEE programs at U. of Wisconsin, Lehigh University and Rutgers University. He is a member of SMTA and IMAPS in which he is a Fellow, and Past President of the Garden State Chapter.*

## F5

### Low Temperature Cofired Ceramics (LTCC)

#### Instructors:

*Aicha Elshabini and Fred D. Barlow, University of Arkansas*

#### Course Description

This course is a one-day PDC focusing on the materials, processes, design, and applications of Low Temperature Cofired Ceramics (LTCC). The course will begin with a brief history and background of the technology. A detailed discussion of the process flow and processes will cover each step used in the fabrication of LTCC substrates. A discussion of the material properties and design guidelines and considerations will also be covered in detail. Finally, a discussion of the technical advances and the technical applications of the technology will outline the relative strengths of LTCC for a number of target markets.

#### Who should attend?

Engineers, managers, and technicians, that desire to expand their background or strengthen their understanding of the tech-

nology. The course will not assume any prerequisite background.

*Aicha Elshabini is a Professor of Electrical and Computer Engineering. She obtained a B.Sc. in Electrical Engineering at Cairo University, 1973, in both Electronics and Communications areas, a Master in Electrical Engineering at University of Toledo, 1975, in Microelectronics, and a Ph.D. Degree in Electrical Engineering at the University of Colorado, 1978 in Semiconductor Devices and Microelectronics. Currently, she is serving the position of Professor and Department Head for the Electrical Engineering Department at University of Arkansas (since July 1, 1999), and Interim Department Head for Computer Science & Computer Engineering Department (since July 1, 2000). She has been serving as the faculty advisor for IMAPS student society at both institutions since 1980 to present time. Elshabini is a Fellow member of IEEE/CPMT Society (1993) Citation for 'Contribution to The Hybrid Microelectronics Education and to Hybrid Microelectronics to Microwave Applications,' a Fellow member of IMAPS Society (1993), The International Microelectronics and Packaging Society, Citation for 'Continuous Contribution to Microelectronics and Microelectronics Industries for numerous years.' Dr. Elshabini was awarded the 1996 John A. Wagnon Technical Achievements Award from IMAPS. She has served as the Editor of the IMAPS International Journal of Microcircuits & Electronic Packaging for 10 years.*

*Fred Barlow earned a Bachelors of Science in Physics and Applied Physics from Emory University in 1990, a Masters of Science in Electrical Engineering from Virginia Tech in 1994, and a Ph.D. in Electrical Engineering from Virginia Tech in 1999. He is currently working as an Assistant Professor in the Electrical Engineering Department at University of Arkansas. Dr. Barlow has published widely on electronic packaging and electronic materials evaluation and is Co-Editor of The Handbook of Thin Film Technology (McGraw Hill, 1998). In addition, he has written several book chapters including two chapters on thin films and one on components and devices. He has achieved the Outstanding Contribution Award with IMAPS society in recognition of his efforts in developing and implementing the CD-ROM project for IMAPS publications, IMAPS home page on the Internet, and for his technical contributions. He currently serves on the IMAPS national technical committee for power packaging. His research interests include electronic packaging for power electronic and microwave applications as well as RF and microwave design.*

## F6

### Microelectronic Thermal Management

#### Instructor:

*Al Krum, Consultant*

#### Course Description:

This course will provide an introduction into the thermal management of microelectronic components and assemblies. It will address the various packaging approaches available - single chip, hybrid, MCM and circuit card assemblies.

This course starts off with the selection of the materials used in various components. Semiconductors, die attach, substrates, packages, package attach and circuit cards are covered in detail. Tradeoffs in cost, performance and producibility are addressed.

Quantitative methods for determining heat generation in both active and passive components will be presented.

Complete thermal analysis is both time consuming and CPU intensive. This course will provide techniques for doing first order thermal modeling without the need for heavy math. In this rapid modeling technique, the material choices and heat path design can be narrowed down so that subsequent detailed thermal analysis can be more productive.

Techniques for decreasing junction temperatures will be presented with an eye on cost and producibility. Heat spreaders, thermal vias, fans and blowers will be covered. Methods of measuring thermal resistances and thermal conductivity will be presented.

For extremely high power density components, exotic cooling techniques are required to minimize junction temperatures. Micro-channel cooling, thermoelectric coolers and heat pipes are some of the techniques that will be discussed.

The trends in thermal management of microelectronics will be addressed with an emphasis on new materials and processes.

#### Who should attend?

This course is recommended for engineers, physical designers, project managers,

manufacturing personnel, and quality and reliability engineers who are interested in obtaining a firm understanding of the thermal design of microelectronic assemblies without the rigor of the heavy math usually associated with thermal analysis.

**Special Course Materials:**

Each student will receive a copy of Thermal Management Handbook for Electronic Assemblies by Jerry Sergent and Al Krum, McGraw Hill, 1998 (List price \$90).

*Al Krum is a consultant to the microelectronic packaging industry. Previously he was a manager at Raytheon Electronic Systems (formerly Hughes Aircraft Company) with over 30 years of experience in the design, test and manufacture of microelectronic modules. He has lead the design and development of over 200 hybrid circuits including over 50 power hybrids. A much sought after lecturer, Mr. Krum is the author of numerous papers in the field of hybrids and holds four patents. He is an author and coeditor of the Thermal Management Handbook for Electronic Assemblies. In addition, Mr. Krum has written the thermal management chapter in the 3<sup>rd</sup> edition of Electronic and Packaging Interconnection Handbook. He teaches classes on power hybrids for the University of California Extension and at the IMAPS national symposium. He received his B.S.E.E. and M.S.E.E. from Newark College of Engineering.*

**1/2 Day Courses**

**F7 runs Noon - 3 pm; F8 runs 3 pm - 6 pm**

**F7 - Noon - 3 pm**

**Lead-Free Solders – Technology, Selection and Applications**

*Instructor*

*Dr. Jennie S. Hwang, H-Technologies Group, Inc.*

**Course Description:**

This course is to provide the attendees a good understanding of the full spectrum of Lead-free applications and to facilitate the selection of the lead-free compositions, targeting to help the industry implement lead-free electronics. The course covers all of the important aspects and technologies with a practical treatment, ranging from legislation status and alloy selections to manufactur-

ing processes and production issues and to reliability and cost analysis. As a result of 12-year sustained research, a performance comparison of the viable alloy systems in basic materials properties will be presented. Pb-free PCB surface finish and component lead coatings will be separately discussed. The course will be concluded with a slate of recommendations and application tips. Information is applicable to all types of packages and assemblies including QFP, BGA, flip chip and CSP.

**Topics covered:**

- Driving forces
- Pb use and concerns
- Legislation status—US, EU, Japan
- Review of the role of Pb in electronics
- Differentiation of solder joint failure modes between SnPb and Pb-free
- Potential elements and general consideration in place Pb
- Pb-free base technology
- Development of Pb-free solder
- Selected alloys and performance
- Example of OEM implementations
- Tin Whisker
- Black pad and fillet lifting issues and solutions
- Pb-free component leads coating
- Pb-free PCB surface finish
- Pb-free reflow process key criteria
- Manufacturing factors - cost vs. performance
- Summary of Pb-free alloys and selections
- Recommendations to manufacturers
- Future perspectives

**Who should attend?**

The course will benefit those who are interested in the development and use of lead-free solders for electronics manufacturing, including researchers, manufacturing engineers, design engineers, quality assurance and materials and safety personnel as well as the management in implementing manufacturing strategies through a general understanding of lead-free electronics.

**Special Course Material:**

Each participant will receive a complimentary copy of the newly released book Environment-friendly Electronics: Lead-Free Technology, by Dr. Jennie Hwang, Electro-

chemical Publications, Great Britain, 2001 (List price \$238.00).

**F8 - 3 pm - 6 pm**

**Solder Joint Reliability - Manufacturing Perspectives**

*Instructor:*

*Dr. Jennie S. Hwang, H-Technologies Group, Inc.*

**Course Description:**

This course is to provide attendees a proper level of understanding of solder interconnection reliability in material basics, manufacturing know-how, and real-world performance, as well as the interrelation between them. This understanding is important to every step of manufacturing, from design and material selection, to the establishment of production process, and to the overall quality and performance of end-use packages and assemblies. Information is applicable to all types of interconnections including fine pitch QFP, BGA, flip chip, CSP, and passive components.

**What you will learn:**

- Improved processes to achieve solder joint reliability
- How to avoid potential problems of solder assemblies
- Solder joint reliability factors
- Solution or recommendation to the specific problems or concerns; attendees are encouraged to bring along their production floor problems for discussion and solution. For those problems requiring a lab-examination, a complimentary preliminary assessment report will be provided to the attendee after the lecture (limit one per company)
- Future demands on solder interconnections

**Topics:**

- What does it take to derive a universal life-prediction model
- Basic level of material fundamentals in solder alloys, alloy in response to temperature changes during service life, and solder alloy selection parameters
- Bulk solder vs. solder joint properties and the key factors that affect solder joint in-

# professional development courses

tegrity

- Reliability factors of BGA array and QFP peripheral solder joints
- The role of gold, intermetallics, solder mask, palladium
- Basic failure process and principle in creep, fatigue, thermal fatigue
- Effects of large voids and reflow process parameters
- Microstructure vs. reflow profile vs. solder joint behavior
- Common failure modes of QFP, PBGA, CBGA, CSP and other types of solder joints
- Approaches to further strengthen solder materials in improving creep-fatigue resistance

### Who should attend?

This course provides a working knowledge to all who are involved with or interested in surface mount/fine pitch/BGA assembling. The course will provide new personnel to the industry with the necessary understanding of the solder joint reliability issues and provide experienced personnel with insights into future technology advances.

### Special Course Material:

Each attendee will receive a copy of the book Modern Solder Technology for Competitive Electronics Manufacturing, by Dr. Jennie Hwang, McGraw-Hill 1996 (List price \$85.95).

*Dr. Jennie S. Hwang received her Ph.D. in Materials Science and Engineering from Case Western Reserve University, two M.S. degrees in Liquid Crystals and Chemistry from Kent State University and Columbia University, respectively. She has been a major contributor to the Surface Mount Technology since its inception. Serving as an advisor to major OEMs, U.S. government and electronics contract manufacturers, she has provided solutions to many challenging problems in SMT manufacturing for the last 20-year of SMT establishment. Among her many honors and awards, Dr. Hwang is elected to the National Academy of Engineering and has received Distinguished Alumni Award from her alma maters. She also received the U. S. Congressional Certificate of Recognition and Achievements and YWCA Women of Achievement Award. She was inducted to the WITI Hall of Fame and named R&D-Star-to-Watch.*

*She is an invited lecturer/keynote speaker worldwide. Holding ten patents, she is the author of over 200 publications including the sole authorship of five textbooks and a co-author of several books. She also authored many articles related to trade, business, educational and social agenda. Contributing to corporate governance, education and community, she serves on various trade, civic*

*and corporate boards. Dr. Hwang has held senior managerial positions with Lockheed Martin, Hanson, PLC, and IEM Corp., and is currently president of H-Technologies Group, Inc. The firm specializes in providing business and manufacturing solutions to electronics/microelectronics interconnection industry.*

## Included in Your PDC Registration Fee:

- Lunch on the day of your course
- Refreshment breaks
- All course materials
- PDC Reception on Tuesday evening (for Attendees & Instructors only)
- Certificate of Attendance

F9

FOR STUDENTS ONLY! - FREE

Microsystems Packaging: Technologies, Markets and Careers  
1/2 Day Course • Noon - 3:00 PM

*Instructors: Prof. Rao R. Tummala, Petit Chair Professor, Director NSF-PRC, GRA Scholar, Georgia Institute of Technology; Janet K. Lumpp, University of Kentucky; Leyla Conrad, Georgia Institute of Technology*

Information technology involves hardware, software, applications and services. This industry has become the largest industry surpassing agriculture that lasted more than a millennium and steel that lasted more than a century. It is becoming the driving engine for science, technology, manufacturing and services paving the way for unparalleled prosperity of people and countries that participate in it. Better than 80% of all millionaires in the U.S. during the last five years have been attributed to this industry.

Microelectronics systems packaging involves all the technologies in forming electronic systems for consumer, telecom, computer, automotive, aerospace and medical industries. These technologies typically involve all the components and their interconnections to form system level boards to provide system level functions. Microelectronics packaging is the ultimate cross-disciplinary technology that involves engineers from various backgrounds. For example: electrical design typically performed by Electrical or Electronic and Computer Engineers; thermo-mechanical design by Mechanical Engineers; development of new materials that provide the required functions by Materials Engineers; fabrication of components by Chemical Engineers; electrical test by Electrical or Electronic Engineers; IC and board assembly by Mechanical or Materials Engineers; thermal management and reliability by Mechanical Engineers; and so on. Working together as a team from all these disciplines, packaging engineers design, fabricate, integrate, test, cool and assure reliability of the entire microelectronic system.

This four-hour course will present the global microelectronics market, past and future technologies that constitute this market, the educational opportunities that are available and career prospects for a lifelong career around the world in various industries.

## New Sponsorship Opportunity at IMAPS 2002!

### The IMAPS 2002 Internet Cafe

IMAPS 2002 will inaugurate the first "IMAPS Internet Cafe" and we are offering Sponsorship opportunities for this exciting new high traffic area that will feature:

- ◆ Four PC stations with high-speed (Fiber) Internet Connection so people can check the web and their e-mail within seconds.
- ◆ A convenient location in the Convention Center adjacent to other high traffic areas.

\*As a Sponsor at \$1,000 per Sponsorship you will receive:

- ◆ Your company logo or advertisement as the wallpaper/screen saver on a PC. Also, your company web site as the default web page on the PC. Multiple Sponsorships are available. PCs will be allotted on a first-come, first-served basis.
- ◆ Your company name will appear on signage throughout the Convention Center and will be listed as a Sponsor in the *Final Program* and *Advancing Microelectronics*.

\* **OR**, your company can be the sole Sponsor of the "IMAPS Internet Cafe" for \$4,000.

Please call Ann Bell at 202-548-8717 or e-mail: [abell@imaps.org](mailto:abell@imaps.org) if you have any questions or wish to sign-up as a Sponsor for the "IMAPS Internet Cafe."

## Refreshment Breaks

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Wednesday - Friday

All breaks will be in the Exhibit Hall

# technical program

Wednesday, September 4, 2002

## WA1

### High Density Substrates & Boards

Chairs: Rajen Chanchani, Sandia National Laboratories; Andrew Strandjord, IC Interconnect

8 am - 11:25 am

Several advanced, high density substrate and board technologies will be presented. Some of the innovative technologies that will be included are advanced boards with liquid crystal polymer dielectric, a new stacked via technology, a new organic laminate technology for better electrical performance at over GHz frequencies, high interconnect density organic boards for UNIX servers, copper nano-composites for PWBs and polymer based photo-imageable dielectric.

### Assembly on Liquid Crystal Polymer (LCP) Substrates for Advanced Packaging

R. Wayne Johnson, Tan Zhang, Auburn University; Brian Farrell, Foster Miller

### High-Performance Flip-Chip BGA based on Multi-Layer Thin-Film Packaging Technology

Tadanori Shimoto, Katsumi Kikuchi, Hirokazu Honda, Keiichiro Kata, Kazuhiro Baba, Koji Matsui, NEC Corporation

### A New Stacked-Via Formation Technology for High-Density Build-Up Packages

Tomoyuki Abe, Nobuyuki Hayashi, Motoaki Tani, Yasuhiro Yoneda, Fujitsu Laboratories Ltd.

### Over GHz Signal Transmission of the Simultaneous Curing Multilayered Substrate

Takuji Seri, Shigeru Kamoi, Kenji Kume, Katsura Hayashi, Masahiro Fukui, Kyocera Corporation

### Packaging Technology for High Performance UNIX Server

Masateru Koide, Fujitsu Limited

### PAMAMOS Copper Nanocomposite Coatings for the Fabrication of Printed Wiring Boards

David A. Dalman, Petar R. Dvornic, M. Frederick Hoover, Dendritech, Inc.

### Cardo Polymer Based Photo Imageable Dielectric

Masahiko Takeuchi, Hironobu Kawasato, Shinji Inaba, Kazuhiko Mizuuchi, Takero Teramoto, Nippon Steel Chemical Co., Ltd.

## WA2

### LTCC Manufacturing Issues

Chairs: Ken Kuang, Kyocera America, Inc.; Aziz Shaikh, Ferro Electronic Materials

8 am - 11:25 am

The continuous drive of making LTCC products better and cheaper has challenged many engineers and scientists alike to address manufacturing issues. This session discusses two pioneering ways to achieve high-density circuit traces, three novel LTCC material systems, one new process monitoring technique and an innovative manufacturing method to make LTCC monolithic transformers.

### Cold Low Pressure Lamination of LTCCs

Andreas Roosen, University of Erlangen-Nuremberg

### Fine Line LTCC-RF-Circuits by Direct Gravure Printing (DGP) Method

Juha Hagberg, Marko Kittilä, Eino Jakku, Seppo Leppävuori, University of Oulu

### CaRuO<sub>3</sub> Thick Film Resistor Formulations Compatible with LTCC Co-Firing

Randy Klein, W. Kinzy Jones, Florida International University

### Characterization of Unrestrained Zero Shrink LTCC Material System for Volume Production of RFLTCC Modules

Michael R. Ehlert, Barbie Spenser, National Semiconductor LTCC Foundry; Frans Lautzenhiser, Edmar Amaya, Heraeus Inc. - CMD

### High K and Magnetic Materials for Buried Components

Alvin Feingold, S.J. Stein, C.Y.D. Huang, M. Heinz, R.L. Wahlers, Electro-Science Labs, Inc.

### Optical Dilatometer for Insitu Measurements of Warpage Effects during Firing of LTCC Multilayer Structure

Matthias Wagner, Alfons Stiegelschmitt, Andreas Roosen, Franz Bechtold, Dieter Schwanke, Department of Materials Science, Glass and Ceramics

### Low Profile Transformers using Low Temperature Co-fire Magnetic Tape

John Bielawski, George Slama, A.H. Feingold, C.Y.D. Huang, M.R. Heinz, R.L. Wahlers, Midcom Inc.

## WA3

### MEMS & MEMS Applications

Chairs: David Galipeau, South Dakota State University; Janet Lumppp, University of Kentucky

8 am - 11 am

The focus of this session is on advancements in MEMS including pressure sensing, GaAs structures and MEMS packaging.

### Design by Analysis of a MEMS Pressure Sensor

Ryszard J. Pryputniewicz, Cosme Furlong, Emily J. Pryputniewicz, Worcester Polytechnic Institute

### Mechanically Fixed and Thermally Isolated Micromechanical Structures for GaAs Heterostructure Based MEMS Devices

Tibor Lalinsky, Milan Drzik, Martin Tomaska, Stefan Hascik, Zelmira Mozolova, Ivan Kostic, Ladislav Matay, Slovak Academy of Sciences

### Laser-Assisted Selective Bonding for Wafer-Level & Chip-Scale Vacuum Packaging of MEMS

Yi Tao, Ajay P. Malshe, W. D. Brown, University of Arkansas

### Reliability Testing of Flexible Circuit-Based RF MEMS Switches

Simone Lee, Nasun Na, Ramesh Ramadoss, Victor Bright, K.C. Gupta, Y.C. Lee, University of Colorado at Boulder

### One Packaging Technique of Exposed MEMS Sensors

Zhigang Lin, Rick Yoon, IJ Research, Inc.

### Strategies for Successfully Integrating MEMS Die onto Laminate

Robert Dean, R. Wayne Johnson, Holly Garrison, Nicole Schutz, Auburn University; Mike Kranz, Morgan Research Corporation; Bill Bowers, Bill Payne, ITRI; Ron Legowik, AMRDEC-U.S.Army

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# technical program

## WA4

### Area Array Interconnects

Chair: Roupen Keusseyan, DuPont  
Microcircuit Materials

8 am - 11:25 am

*Surface mount technologies rely heavily on solder interconnect methods. To achieve acceptable service life, both materials properties and the application environment must be factored into packaging of electronics for specific applications. These papers present some of the significant aspects of packaging using solder interconnections.*

### Design and Characterization of a 10GHz Organic BGA Package

Richard R. Lynn, Maxtek Components Corp.

### Qualification of Plastic Ball Grid Array Packages for Space Flight Applications

Thomas Estes, Yoshio Saito, TRW

### A Study of Solder Joint Reliability of TFBGA Assemblies with Fresh and Reworked Solder Balls

Po Jen Zheng, J.Z. Lee, K.H. Liu, J.D. Wu, S.C. Hung, Advanced Semiconductor Engineering, Inc.

### Long Time Reliability of Flip Chip Interconnections on Flexible Substrates

Barbara Pahl, Christine Kallmayer, Rolf Aschenbrenner, Herbert Reichl, Fraunhofer Institute of Reliability and Microintegration IZM

### Placement and Reflow of Solder Balls for FC, BGA, Wafer-Level-CSP, Optoelectronic Components and MEMS by using a Mew Solder Jetting Method

Thomas Oppert, L. Titerle, G. Azdasht, E. Zakel, Pac Tech - Packaging Technologies GmbH

### Measurements and Simulation of SMT Components

Ryszard J. Pryputniewicz, David Rosato, Cosme Furlong, Worcester Polytechnic Institute

### SMT: Modeling and Uncertainty Analyses of a J-Lead Attachment

Ryszard J. Pryputniewicz, Cosme Furlong, Dariusz R. Pryputniewicz, Worcester Polytechnic Institute

## WA5

### System Packaging

Chair: Christian M. Val, 3DPlus  
8 am - 11 am

*The dictionary defines a system as "a group of things or parts connected in some form to make a whole." Systems Packaging is essentially the electromechanical process or technique of connecting the parts of the system together. These papers demonstrate various examples of the latest thinking in systems packaging that allow for high density integration.*

### SiP Design for Higher Integration

Nozad Karim, Amkor Technology; Tania Van Bever, Alcatel Microelectronics

### Wafer Level Batch Transfer Process of RF MEMS Passive Devices using PDMS

Sang Won Park, Kabseog Kim, Jeong-Bong Lee, University of Texas at Dallas

### High Density Packaging for Wrist Wearable Medical Devices

Etienne Hirt, Michael Scheffler, Art of Technology

### Very High Speed 3D "System in Package"

Christian M. Val, 3DPlus

### System-on-Package (SOP): A Solution for Next Generation Convergent Microminiaturized Microsystems

Rodolfo L. Gacusan, Intel Technology Philippines, Inc.

### Modular Systems for Sensor Integration

Matthias Klein, H. Oppermann, R. Aschenbrenner, H. Reichl, Fraunhofer IZM - Berlin

## IMAPS Awards Ceremony

Wednesday, September 4, 2002

11:40 AM - 12:15 AM

Colorado Convention Center

Daniel C. Hughes, Jr. Award

William D. Ashman Award

Corporate Recognition Award

John A. Wagon Technical Achievement Award

IMAPS Fellows of the Society

Best Paper 2001

Come say "Thanks" to those who contributed so much to the IMAPS Society over many years. **ALL WELCOME!**

## WP1

### Recent Developments in Wafer Level CSPs

Chairs: Curtis Zwenger, Amkor Technology; Li Wetz, Motorola SPS

2:30 pm - 5:30 pm

*Wafer Level CSP (WLCSP) technologies hold tremendous promise for reducing the form factors of small integrated circuits and other passive devices with I/O counts typically below 50 I/O. Since low I/O leadframe based SMT packages are not particularly space efficient, the migration of these modest components to wafer scale can have quite a dramatic influence on product miniaturization. This session will outline advancements that are being made in the development of wafer scale solutions including traditional ICs and MEMS to name a few as well as to highlight recent developments in process development and WLCSP reliability.*

### Assembly Process for High Brightness LEDs using the AuSn Metallurgy

Gordon Elger, Rafael Jordan, Maria v. Suchodoletz, Hermann Oppermann, Fraunhofer Institut for Reliability and Microintegration

### Materials for 300 mm Wafer Level Packaging

Michael J. Toepper, Fraunhofer IZM; A. Achen; Dow-Chemical Company; Ch. Lopper, K. Hauck, K. Samulewics, V. Glaw, H. Reichl, Fraunhofer Institute for Reliability & Microintegration IZM

### Design and Reliability of a New WL-CSP

Li Wetz, Beth Keser, Jerry White, Motorola, SPS

### Wafer Scale CSP

Joe Smetana, Alcatel, USA; Deborah Patterson, Flip Chip Technology; Dennis Krizman, Celestica; David Love, Sun Microsystems; Theo Ejim, Lucent

### Experimental and Analytical Study on Large Passivation Opening to Improve Solder Joint Reliability for microSMD Packages

Vivek Arora, Li Zhang, Luu Nguyen, Nikhil Kelkar, National Semiconductor Corporation

### Cost Effective, High Reliability, Low Profile WLP

Hirohisa Matsuki, Masamitsu Ikumo, Mario Aguirre, Yoshitaka Aiba, Mitsutaka Sato, Fujitsu Limited

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**WP2**

**Packaging Materials**

Chairs: Herbert J. Neuhaus, NanoPierce Connection Systems, Inc.; Michael E. Wernle, NanoPierce Card Technologies, GmbH

**2:30 pm - 5:30 pm**

*This session presents cutting-edge developments at the intersection of the two most dynamic areas of packaging. Previously wafer-level packaging and lead-free solders have been generally considered separately. Now, as these emerging areas mature, their interactions come to the fore as critical issues for study.*

**Wafer-Level Underfill Materials and Processes for Pb-free Flip-Chip Applications**

Claudius Feger, Nancy LaBianca, Hosadurga Shobha, Gareth Hougham, Peter Gruber and Steve Buchwalter, IBM T. J. Watson Research Center; Mike Gaynes, Miguel Jimarez, IBM Interconnect Products; Allison Xiao, Gyan Dutt, Stanley Kong, Don Herr, Quinn Tong, National Starch and Chemical

**Effects of Flexibilizers on the Properties of Liquid Microelectronic Encapsulation Materials**

Shaoqin Gong, Michael Todd, Loctite Corporation

**Thermal Characterization of High Temp Reflow (HTR) Compatible Epoxy Molding Compound for Lead Free PBGA Packaging**

Dennis Prem Kumar Chandran, Yi He, Intel Technology Sdn., Bhd

**Investigation of Electroplated Ni and Ni-Cu Alloy UBM (Under bump Metallurgy) with Lead-Free Solders for Flip Chip Packages**

Su-Hyeon Kim, Jong Yeon Kim, Jin Yu, KAIST

**Development of Single Pass Reflow Encapsulant for Lead Free Solder Bump**

Lin Xin, Rich Kraszewski, Jin Liu, Chad Showalter, Jennifer Allen, SH Goh, Linda Wong, Northrop Grumman Component Technologies – Kester

**Phase Transformation and Residual Stress Evolution in Electroless Ni-P UBM used in Low Cost Flip Chip Technology**

J. Y. Song, Jin Yu, KAIST

**WP3**

**RF Design and Measurements & Wireless Applications**

Chairs: F. D. Barlow, University of Arkansas; John Gipprich, Northrop-Grumman

**2:30 pm - 5:30 pm**

*This session addresses design and measurements of RF and wireless applications. These applications include RF MEMS, LMDS, RF radio links, LTCC and embedded passives, multiplexer/demultiplexer package, and T/R modules.*

**RF MEMS: Modeling and Simulation of Switch Dynamics**

Ryszard J. Pryputniewicz, Patrick W. Wilkerson, Andrzej J. Przekwas, Cosme Furlong, Worcester Polytechnic Institute

**LMDS Applications and RF Radio Links go for SMD Based Module Technology - Reality, Experience and Future Trends**

Martin Oppermann, EADS Deutschland GmbH

**Multiple Conductor Gridded Ground Planes for Enhanced Manufacturability and RF Performance LTCC Passive Components**

George Passiopoulos, Kevin Lamacraft, Nokia Networks

**Microwave Module Design with HeraLock™ 2000 LTCC**

Frans Lautzenhiser, Edmar Amaya, Peter Barnwell, Brent Smith, Jim Wood, Heraeus Inc. - Circuit Materials Division

**Simulation and Design Methodology for a 50Gb/s Multiplexer/Demultiplexer Package**

Lei Shan, Mounir Meghelli, Joong-Ho Kim, Jean Trehwella, Modest Oprysko, IBM Corp., T. J. Watson Research Center

**Embedded Passives and T/R Module for Millimeter-Wave Fabricated by the Photoimageable Thick Film Process**

Seong-Dae Park, Y. S. Lee, C. S. Yoo, and J. C. Park, Erick Kim, Korea Electronics Technology Institute

**WP4**

**Thermal Management**

Chairs: Ajay P. Malshe, University of Arkansas; Matt Gordon, University of Arkansas

**2:30 pm - 5:30 pm**

*Demands and advances in the thermal management area are highlighted in this session through various presentations by leading researchers on topics such as miniaturized heat pipes, reliability of high power optical devices, analysis and modeling.*

**Thermal Modeling and Measurement of Large High-Power Silicon Devices with Asymmetric Power Distribution**

Jeffrey Deeney, Hewlett Packard Company

**Thermally Enhanced PBGA: Thermal Performance and Reliability at High Temperatures (Pb-free)**

Swaminath Prasad, Flynn Carson, Bret Zahn, TK Lee, ChipPAC Incorporated

**Packaging and Thermal Management for kW/cm<sup>2</sup> Microwave Amplifiers**

Zhigang Lin, Rick Yoon, IJ Research, Inc.

**Development of a Re-workable Film in High Performance Thermal Management Applications**

Chih-Min Cheng, Andrew Collins, Emerson & Cuming

**Manufacturing and Heat Transfer Characteristics of the Flat Micro Heat Pipe**

Seok Hwan Moon, Sang Choon Ko, Gunn Hwang, ETRI

**Heat Sink Design Optimization for Optical Transponders**

Zhaofeng Shi, Albert Lu, Yeow Meng Tan, Kar Hwee Ang; Eric Tan, Roson Tan, E2O Communications Pte Ltd.

**WP5**

**Marketing Forum**

*The MMRC (Microelectronics Marketing Research Council) will offer a free-of-charge Marketing Forum to all IMAPS 2002 attendees who wish to participate. The Forum will feature four presentations with a panel discussion at the end that will allow for audience participation in this not to be missed event! See page 26 for more information.*

**Student Reception**  
 Wednesday, September 4, 2002  
 4:30 pm - 5:30 pm

# technical program

## THA1

### 3D and High Performance Packaging in Japan (Japanese Translated Session)

Chairs: Yuzo Shimada, NEC Corporation;  
Charles E. Bauer, TechLead Corporation

8 am - 11 am

*Building on the road map for high density packaging presented in the first paper, this session demonstrates the significant advances in three dimensional semiconductor packaging concepts and technology taking place in Japan. These innovations range from the high density substrate technologies necessary to accomplish three dimensional packaging through the intricate design concepts under consideration to the complex assembly processes required.*

**High Density Packaging Technology Research & Development Roadmap in Japan**  
Manabu Bonkohara, ASET-Association of Super-Advanced Electronics Technologies

**High-Density System-On-Film (SOF) using Two-Metal Layer Tape**  
Yasuhisa Yamaji, Sharp Corporation

**Investigation of Fundamental Technology for 3D Assembly**  
Kei Murayama, Shinko Electric Co., Ltd.

**Ultra-high-density Interconnection Technology of 3-dimensional Packaging**  
Kenji Takahashi, ASET-Association of Super-Advanced Electronics Technologies

**Thermosonic Flip Chip Bonding for Low Cost Packaging**  
Taizo Tomioka, Toshiba Corporation

**Ultra Thin & High Density Packaging Using Both Sides Flip Chip Technology**  
Kazuto Nishida, Matsushita Electric Industrial Co., Ltd.

## IMAPS 2002 PROCEEDINGS

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## THA2

### RF and Microwaves Components Realization

Chairs: A. Elshabini, University of Arkansas; Daniel Amey, Dupont Microcircuit Materials

8 am - 11:25 am

*This session describes RF and Microwaves components realization for MEMS switch, MEMS variable capacitor, LTCC filter, a slit cavity resonator, and microwave power amplifier. Impact of fine line technique and processing parameters on electrical properties and accurate prediction of these properties are covered in the session.*

**Gold Stud Bump Bonding for High Frequency Packaging: Impact of Gang Coining and other Process Variables on Electrical Properties**

Taekyeong Lee, Alan M. Lyons, Sean Shih, Andy Becker, Carsten Metz, Lucent Technologies, Bell Labs

**Mechanical and Electrical Design of a Novel RF MEMS Switch for Cryogenic Applications**

Huantong Zhang, Victor M. Bright, YC. Lee, K.C. Gupta, University of Colorado

**Frequency Tunable Half-wave Resonator using a MEMS Variable Capacitor**

Patrick Bell, Nils Hoivik, Victor M. Bright, Zoya Popovic, University of Colorado at Boulder

**Accurate Prediction of Microstrip Impedance and Attenuation at MM-Wave Frequencies**

Didier Cottet, Janusz Grzyb, Gerhard Troester, ETH Zurich, Electronics Laboratory

**The Fine-line Technique in the Fabrication of LTCC Filter**

W. S. Lee, Y.J. Lin, F.T. Shiao, C.W. Tang, J.S. Hsieh, Phycomp Taiwan Ltd.

**Dielectric Constant and Loss Tangent Measurement for 2-Layer Dielectric Samples using a Slit Cavity Resonator**

Zhengrong Tian, Middlesex University; Charles Free, Colin Aitchison, University of Surrey; Peter Barnwell, Heraeus Circuit Materials Division

**A High Performance 5.8 GHz Power Amplifier Design Enabled by a New Microwave Power Package**

John W. Roman, Steven C. Evangelista, SatCon Technology - Film Microelectronics Incorporated

## THA3

### Power Packaging Technologies

Chairs: Douglas C. Hopkins, University at Buffalo; Dave Kellerman, Material Solutions

8 am - 11 am

*This session provides applications and techniques starting with a 55kW automotive power module, followed by an update on polyimide flex to interconnect power chips in a very high density module. Ceramic is still a major development area with new characterizations reported in thermal vias imbedded into LTCC and new resistor formulations to combat cost increases. Finally, two papers provide detailed technical analysis of degradation due to high power effects.*

**Packaging and Thermal Management of AIPM**

Yuejian Chen, John Mookkeen, Victor Temple, Silicon Power Corporation

**A High Performance Polymer Thin Film Power Electronics Packaging Technology**

Raymond A. Fillion, Eladio Delgado, Paul McConnell, Richard Beaupre, GE Global Research Center

**High Density Thermal Vias in Low Temperature Cofire Ceramic (LTCC)**

W. Kinzy Jones, Marc Zampino, Ravindra Kandukuri, Yanquin Liu, Florida International University

**A New Generation of Low Cost Surge Resistor Materials**

Michael Moroz, Aziz Shaikh, Ferro Electronic Materials

**Measurement and Effects of High Electrical Current Stress in Solder Joints**

Hua Ye, Douglas C. Hopkins, Cemal Basaran, Alex Cartwright, University at Buffalo, SUNY

**Thermal Hot Spots under Low Duty Cycle High Power Applications**

Kenneth Rispoli, Raymond Fitzsimmons, Lee Gould, Jason Leandro, Raytheon Company

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**THA4**

**Sensors Packaging**

Chairs: David Galipeau, South Dakota State University; Richard Gehman, Honeywell, Inc.

**8 am - 11 am**

*This session covers advancements in thick film sensors as well as new packaging methods for sensor arrays, MEMS and IR detection.*

**A Study of Factors Affecting Characteristics of Thick Film NTC Thermistors**

David J. Nabatian, KOARTAN Microelectronic Interconnect Materials

**An Evaluation of Materials and Processes Employed in the Construction of Novel Thick Film Force Sensors**

Yulan Zheng, University of Southampton; John Atkinson, Russ Sion, C-Cubed Limited

**Investigations of Thick-Film Resistors on different Substrates for Strain Gauge Applications**

Darko Belavic, HIPOT; Marko Hrovat, Andreja Bencan, Jozef Stefan Institute; Walter Smetana, Heinz Homolka, Roland Reicher, Vienna University of Technology; Leszek Golonka, Andrzej Dziedzic, Jaroslaw Kita, Wroclaw University of Technology

**Fluxless High-Vacuum Packaging of MEMS and IR Sensors**

Cory Jenkins, SST International

**A Novel Flex Circuit Area-Array Interconnect System for a Catheter-Based Ultrasound Transducer**

Scott Corbett, Jeff Strole, Warren Lee, Stephen Smith, Duke University

**The Package and Thermal Management of Infrared (IR) Sensors**

Zhigang Lin, Rick Yoon, IJ Research, Inc.

**International Reception sponsored by:**  
**Nanopierce Technologies, Inc.**

**THA5**

**Advanced Interconnect and Wire Bonding**

Chair: Lee Levine, Process Solutions Consulting

**8 am - 11:25 am**

*Interconnections have greatly broadened in scope of late. Wire bonds continue to be the most used interconnection method, but new methods and non-traditional applications continue to appear. This session gives recent advancements in both wire bonding and in some less traditional means of interconnection.*

**Anisotropic Conductive Adhesive for Flip Chip on Paper Assembly**

Jad Rasul, Bill Olson, Motorola Inc.

**Comparison of 60-kHz and 100-kHz Wirebonding on Organic and Inorganic Substrates**

Harry K. Charles, Jr., K.J. Mach, S.J. Lehtonen, A.S. Francomacaro, J.S. DeBoy, R.L. Edwards, The Johns Hopkins University/APL

**Elevated Temperature Failure Mechanisms in Au-Al Ball Bonds**

Narendra J. Noolu, Mark Klossner, Kevin Ely, William Baeslack, John Lippold, Palomar Technologies

**Process Solutions for Technological Challenges in Assembly of Hybrid and MCM Packages**

Ivy Wei Qin, Guy Frick, Bob Wise, Kulicke and Soffa Industries Inc.

**TiN Coating - A Solution for High Temperature Interconnects**

H. Ryu, R.A. Saravanan, Rishi Raj, University of Colorado at Boulder

**Laser Processing of Flexible Substrates**

Peter Gordon, Richard Berenyi, Budapest University of Technology and Economics

**Potential of Flip Chip Technologies for Chip Stacking Applications**

Holger Woerner, Infineon Technologies

**THP1**

**Automotive Electronics**

Chair: D. H. R. Sarma, Delphi

**2 pm - 3:15 pm**

*According to Global Information, Inc., worldwide demand for OEM automotive electronics will expand 6.8 percent per year to \$97.5 billion in 2005. This specially designed session explores some of the latest technical developments in methods for micro machining sensor arrays; contains information about new polymeric materials used for environmental protection of sensitive electronics in severe operating environments and provides a comprehensive look at developments in lead-free packaging for automotive electronics.*

**A Study of a Micromachined Sensor Array for Automotive Emissions**

Jason D. Sternhagen, Kraig D. Mitzner, Eric J. Berkenpas, Wade Kempf, David W. Galipeau, South Dakota State University

**An Evaluation of Materials for the Environmental Protection of Automotive Sensors**

Kate Pearce, Elizabeth Walker, Jiazhong Luo, RoseAnn Schultz, Emerson & Cuming

**Packaging Technology for Automotive Electronics in the Lead-free Era**

Hans Danielesson, MIKROELEKTRONIK KONSULTAB

**THP2**

**Thick Film I**

Chair: Richard Sigliano, Kyocera America, Inc.

**2 pm - 5:25 pm**

*This session discusses topics from high temperature semiconductor materials for packaging of MEMS devices to a variety of thick film printing materials for AlN substrates and fine line processing. Also of interest to the thick film and quality engineer is a paper on Lead-free thick film resistor materials and characterization. Rounding out the session is a study of microvia fabrication in conjunction with LTCC materials.*

**SiCN Ceramic - A High Temperature Semiconductor Material for MEMS Applications**

R. A. Saravanan, Li-Anne Liew, Victor M. Bright, Rishi Raj, University of Colorado at Boulder

# technical program

## New Lead-Free Thick Film Resistors

Jacob Hormadaly, Ben-Gurion University

## MCM-D/C Based on Cu/BCB Thin Film and LTCC; Lessons Learned

Fred D. Barlow, Errol Porter, Jeff Mincy, Len Schaper, Aicha Elshabini, University of Arkansas

## Thick-Film Printable Polymer Insulator Paste: Development, Testing and Results

Khalil Arshak, David Egan, University of Limerick

## Structural Optimization for Ultra Fine Pad Pitch LDI Devices

Jin-Hyuk Lee, Sa Yoon Kang, Dae-Woo Son, Kwan-Jai Lee, Se-Yong Oh, Samsung Electronics, Co. Ltd.

## Novel Thick Film System on AlN Substrates

Yueli Wang, Alan Carroll, Jerome Smith, Yong Cho, John Crumpton, Dave Anderson, Rudy Bacher, Christopher Needes, DuPont iTechnologies

## A Mixed Metal Low Loss Dielectric Materials System for High Frequency Applications

Christopher R. Needes, Michael A. Smith, DuPont Company

### THP3

#### Passive Integration in PWB, Thin Film and On Chip Technologies

Chairs: Dr. Robert Heistand II, AVX Corporation; Richard Charbonneau, StorageTek

**2 pm - 5 pm**

*Passive component integration is a very active packaging development area to increase performance, increase system yields, miniaturize systems and reduce system costs. Presentations on three very different vehicles for passive integration will be presented. These include continuing developments from thin film technology and PWB embedded components/materials along with the new thrust in thin film integrated passives on active chip.*

## Embedded Passives Technology for PCBs: Materials, Design, and Process

Jiming Zhou, John Myers, Delphi Delco Electronics Systems; John Felten, DuPont; Richard Snogren, Coretech/SAS; Kim Fjedsted, ESI; Bob Greenlee, Merix; Joel Peiffer, 3M

## Composite Dielectric Laminate for Integrated Capacitors

Kirk Slenes, Tuqiang Chen, Erik Luther, TPL Corp.

## Novel Structure of Integral Passive Substrate and the High Frequency Characteristics

Shigeru Utsumi, Hirofumi Fujioka, Hideki Tsuruse, Mitsubishi Electric Corp.

## High-Q RF Inductors Fabricated using WLP Redistribution Technology

Quan Tran, Qing Ma, Intel Corporation

## High-Q inductors on Low Resistivity Silicon through Wafer Post-Processing

Geert Carchon, W. De Raedt, E. Beyne, IMEC-MCP/HDIP

## Integrated Capacitors for Multichip Module Packaging Applications

Allen C. Keeney, A. Shaun Francomacaro, Richard L. Edwards, Harry K. Charles, Jr., Johns Hopkins University/APL

### THP4

#### Novel Manufacturing Technology

Chairs: Nicole Cavanah, Rockwell International; David Virissimo, Hi-Q Materials, Inc.

**2 pm - 5 pm**

*The pursuit for smaller, higher density and affordable assemblies increases the challenges for robust manufacturing. This session highlights techniques developed to achieve robust manufacturing and integrated testing processes with ever-increasing challenges facing microelectronics packaging and assembly. New manufacturing developments include die pick and place, wire bonding, area array assembly, RF modules and optoelectronic assemblies.*

## Thick and Thin Film Materials

Kevin Blakelock, Motorola Inc.

## System Considerations for Active Laser Trimming of Bluetooth Modules

Joe Lento, Yun Chu, Bruce Couch, GSI Lumonics

## Ultrasonic Bonding: Understanding How Process Parameters Determine the Strength of Au-Al Bonds

Michael Mayer, ESEC; Juerg Schwizer, ETH Zurich

## Yield Improvement Methodologies for Flip Chip Assemblies Using Solder On Pad (SOP) Substrates

Sarathy Rajagopalan, Mukul Joshi, Kishor Desai, LSI Logic Corp.

## Fully Integrated Solution for CBGA Inspection: A New Approach to meet High Mix and High Volume Challenges

Nicolas Tessier, IBM Canada

## Automated, In-Line Leak Testing of Hermetic Optoelectronic Packages

John W. Newman, NorCom Systems Inc.

### THP5

#### Reliability

Chairs: James T. Cook, Microelectronic Business Associates; Greg Caswell, Xetel Corporation

**2 pm - 5:25 pm**

*The papers in this session focus on the design and reliability of interconnect materials and processes. Specific interest will be in the SMT and Flip Chip interconnect reliability concerns. The targeted audience for this session are for packaging, reliability and process engineers and technicians.*

## Impact of Under Bump Metallurgy on Solder Joint Reliability of Flip Chip on Low Temperature Co-Fired Ceramic Substrate

Ning Duan, J. Scheer, J. Bielen, M. van Kleef, Royal Philips Electronics B.V.

## Effect of the Al Pad Surface Morphology on the Flip-Chip Solder Joint Reliability

Esther W.C. Yau, Simon P.C. Law, Philip C.H. Chan, Hong Kong University of Science and Technology

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**Electromigration in WLCSP Solder Bumps**  
Glenn A. Rinne, Krishna K. Nair, Julia Roe, Unitive, Inc.

**Materials Characterization and Finite Element Analysis of the Effect of Mechanical Bending on Area Array Package Interconnects**  
Daniel T. Rooney, Dongji Xie, N. Todd Castello, Doug Abbott, Flextronics

**Material Set Comparison in Moisture Sensitivity Classification of Nonhermetic Organic Packages**  
William Schildgen, Cameron Murray, 3M

**A Case Study in Test Vehicle Design for Real-Time Reliability Characterization**  
Dennis Krizman, Scott Waters, Alex Chen, Celestica International Inc.

**Solder Joint Reliability Testing of Back-to-Back Assembled BGA Components**  
Joyce E.S. Taylor, Dave Peters, Hewlett Packard

**THP6**

**Interactive Forum (Poster Session)  
1 PM – 4 PM**

**Evaluation of Two Novel Lead-Free Surface Finishes**  
Ning-Cheng Lee, Richard Ludwig, Chonglun Fan, Yun Zhang, Indium Corporation of America

**Improved Long-Term Stability of Solder Joints through Rapid Reflowing**  
Fritz Herbert, Lutz Dorn, Technical University Berlin

**Beyond Periodic Pulse**  
Enrique Gutierrez, TecNu, Inc.

**WASPP Program: Advanced Passivation and near Hermetic Seals for Advanced Packages and Harsh Environments**  
Chuck Reusnow, Lockheed Martin Missiles and Fire Control - Dallas

**An Investigation of the Properties of Newly Developed LTCC Materials for their use in Microwave Circuit**

Hiroshi Usui, Kazunari Watanabe, Shotaro Watanabe, Kastutoshi Nakayama, Asahi Glass Co., Ltd.

**Thermal Properties of New Composites of Diamond and Copper**

Katsuhito Yoshida, Hideaki Morigami, Takahiro Awaji, Tetsuo Nakai, Sumitomo Electric Industries, Ltd.

**Technical Challenges of Stencil Printing Technology for Ultra Fine Pitch Flip Chip Soldering**

Dionysios Manassis, R. Patzelt, U. Oestermann, S. Nieland, A. Ostmann, R. Aschenbrenner, H. Reichl, Technical University of Berlin

**Evolution of the SWIFT CZT Detector Module**

Phillip A. Goodwin, Swales Aerospace

**The New Thick - Film Hybrid High Frequency Electronic Ballasts for Low Power Discharge Lamps**

Janusz J. Gondek, Private Institute of Electronic Engineering; St. Kordowiak, W. Mysinski, Cracow University of Technology; B. Kawa, J. Kocol, Technical School of Communications; P. Gebik, P.P.U.H 'GECO' Ltd.; P. Sztatynski, Cracow Electronics Works 'TELPOD'

**Challenge of Flip Chip Encapsulation Technologies**

Kevin Chai, Eddy Wu, Roger Hsieh, J. Y. Tong, Siliconware Precision Industries Co., Ltd.

**Flip-Chip Packaging Solution for CMOS Image Sensor Device**

Jong-heon Kim, In-Soo Kang, Hak-Nam Kim, Esdy Baek, C-Cube Digital Corp., Ltd.; Tae-Jun Seo, Samsung Electro-Mechanics

**Power Cycling Reliability of the First and Second Level Interconnections of Modules**

Ning Duan, J. Scheer, J. Bielen, M. van Kleef, Royal Philips Electronics B.V.

**Electroplated Micro-inductors and Micro-transformers for Wireless Applications**

Jae Y. Park, Young Jun Chang, Jong Uk Bu, LG Electronics Institute of Technology

**Structure of Cantilever with Implanted Strain Gauge**

Miroslav Husak, Pavel Kulha, Jiri Jakovenko, Zdenek Vyborny, Technical University of Prague

**A New High Resolution Process for Passives in Hybrid Packaging**

Charles D.E. Lakeman, Patrick F. Fleig, TPL Inc.

**Implementation of Integrated Packaging of DC/DC Converter and PFC IPEMs using Bumpless Interconnected Embedded Chip Technology**

Zhenxian Liang, J. D. Van Wyk, Fred C. Lee, Virginia Tech

**Investigations of the Effects of Gamma-Radiations on the Optical and Electrical Properties of Nickel Phthalocyanine (NiPc) Thick Film**

A. Arshak, S. Zleetni, K. I. Arshak, J. Harris, University of Limerick

**High Dose Optical and Electrical Sensor Dosimeter using Cobalt Phthalocyanine (CoPc) Thick Film**

A. Arshak, S. Zleetni, K. I. Arshak, J. Harris, University of Limerick

**Prediction of Shrinkage and Deformation During LTCC Device Production**

Aravind Mohanram, Gary L. Messing, David J. Green, Pennsylvania State University

**An Experimental Study of the Thermal Performance of Heat Pipe Embedded Cold Plate for Satellite Electronic Cooling**

David Sarraf, Devarakonda Angirasa, Thermacore International

**New Microcontact for Separable, Reusable, High Digital Speed Level-2 Interconnections**

Ryszard J. Pryputniewicz, Dimitry G. Grabbe, Dariusz R. Pryputniewicz, Worcester Polytechnic Institute



# technical program

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## Materials for Ultrafine Printing of Conductors

Christopher Wargo, David Richard, Yvonne Kunz, Parelec Inc.

## New Materials for High Performance No-Flow Underfill

Kathleen M. B. Gross, Steve C. Hackett, Donald G. Larkey, William J. Schultz, Wendy Thompson, 3M

## Design and Reliability Study for Flip Chip Applications on Ultra-Thin Flexible Substrates Using NanoPierce Connection System Technology

Bin Zou, M. Kober, F. Blum, S. Mieslinger, L. Gaherty, W. Steinberg, B. Bahn, M. Wernle, H. Neuhaus, NanoPierce Technologies, Inc.

## Backside Silicon Thinning Techniques for Failure Mode Analysis

Huixian Wu, James Cargo, Barry Dutt, Albert Seier, Joe Serpiello, James McGinn, Agere Systems

## Wire Bonding Study of Gold Conductors for LTCC Applications

Liang Chai, Cristina Lopez, Aziz Shaikh, Vern Stygar, Ferro Corporation

## Multilevel Digital Micromirror Array with Enhanced Fill Factor by Flip-Chip Transfer

Jianglong Zhang, Y.C. Lee, Yu-Chen Lin, John Neff, University of Colorado at Boulder

## Patternable Compliant Silicone Materials for Advanced Packaging Applications

Brian R. Harkness, James Alger, Stanton Dent, Geoffery Gardner, Lyndon Larson, Robert Nelson, Dow Corning Corporation

## Technology of Group Assembly in Microelectronics based on Contact Units with Capillary Connecting Elements (Capillary Connection Technology™)

Alexander I. Taran, Andrew A. Belov, Microelectronics Assembly Innovations; Charles E. Bauer, TechLead Corporation

## A Study of the Conduction Mechanisms of Screen-Printed Thick Films of MnZn Ferrite

Khalil Arshak, Karen Twomey, University of Limerick

## Flip Chip Technologies of Direct Bump-on-Copper/low-k

Jamin Ling, Tony Pan, Pete Elenius, KNS - Flip Chip Division

## Rapid Analysis of Power/Ground Plane Decoupling using New Solution Methods

Richard T. Remski, Ansoft Corporation

## Biomedical Sensors: New Application Horizons? - A Review

Gabor Harsanyi, Budapest University of Technology and Economics

### FA1

## High Density Packaging

Chairs: R. Wayne Johnson, Auburn University; Scott Popelar, IC Interconnect

**8 am - 11:25 am**

*Several innovations in high density packaging technologies including fine pitch packages and their assemblies, surface mount and flip-chip technologies will be presented.*

## High Density Stacked Packaging Solution for SiP Applications

Vern Solberg, Tessera Technologies

## Very-Very Thin Profile Small Outline Package for Memory Card

In-Ku Kang, Sang-Ho An, Jae-Min Kim, Se-Yong Oh, Samsung Electronics

## Wirebondability of Electroless Ni/Au Plated Semiconductor Package Substrates

Jaydutt Joshi, Seth Greiner, Conexant Systems, Inc.

## Design and Reliability Study of High-Density Memory Modules

Ilyas Mohammed, Young-Gon Kim, Tessera Technologies, Inc.

## The Reliability of the 1<sup>st</sup> Level and the 2<sup>nd</sup> Level Joint on Flip Chip Package

Eun-Chul Ahn, Ju-Hyun Lyu, Young-Min Lee, Tae-Gyeong Chung, Se-Yong Oh, Samsung Electronics Co., Ltd.

## Reliability Challenges of Flip Chip on Organic Substrate

Tae-je Cho, Eun-Chul Ahn, Jong-Bo Shim, Ho-Joong Moon, Se-Yong Oh, Samsung Electronics Co.

### FA2

## Thick Film II

Chair: Paul Galletta, Teledyne Electronic Technologies

**8 am - 11 am**

*Thick film and thin technology are the base line building blocks for most of the microelectronic devices in existence today. This session will highlight the newer aspects of these technologies and how it can support your needs from D/C to light. These technologies have reinvented itself to support a whole new series of product lines that meet both the cost and performance needs of those products. Please join us in a lively session that will explore new approaches for this 25 plus years old technology.*

## Simulation, Characterization and Design of Embedded Resistors in LTCC for High Frequency Applications

Fred D. Barlow, Gangqiang Wang, Aicha Elshabini, University of Arkansas

## Experiences in Obtaining Cross Belt Uniformity of $\pm 1$ °C in a 24-inch Wide Thick Film Conveyor Furnace

Fred C. Dimock, BTU International

## Copper Electroplating for Thick-Film Power Applications: A Successful Laboratory Method for Prototyping

Khalil Arshak, David Egan, University of Limerick

## Insertion Loss of A6 LTCC System up to 40 GHz

Liang Chai, Aziz Shaikh, Vern Stygar, Reinhard Kulke, Ferro Corporation

## A Study of Microwave Behavior of a Thin-Print Gold Ink

David J. Nabatian, Chuck Rosenwald, KOARTAN Microelectronic Interconnect Materials

## An Imprinting Process for Ceramic HDI Packages

Paul M. Anderson, George Gregoire, Dimensional Circuits Corporation

**FA3**

**Thermal Mechanical and Electrical Modeling**

Chair: Li Zhang, National Semiconductor Corp.

**8 am - 11 am**

*Electrical and thermo-mechanical modeling has increasingly become an integral part of robust package design and cost reduction. This session covers papers on CFD simulation of electronic equipment with radiation and convection effects, thermo-mechanical modeling of RF power sensor systems, thermal compact models for IC packages, and electrical simulation for wideband applications, modeling of structures with embedded passives for RFIC applications, and 3D electromagnetic modeling of optoelectronic transceivers.*

**Linearised Superposition using CFD for Thermal and Power Characterization of Electronic Equipment with Significant Thermal Radiation and Natural Convection**

Paul Gauché, Flomerics Inc.; Wen Wei, Intel Corp.

**Thermo-Mechanical Simulation and Modeling of RF Power Sensor Microsystem**

Jiri Jakovenko, M.Husak, T. Lalinsky, Czech Technical University in Prague

**Modeling of Return Loss on Multilayer Package for Wideband Applications**

Nansen Chen, Kevin Chiang, Y. P. Wang, SPIL

**New Configurations for High Frequency Capacitors and Composite Structures for Embedded Passive and RFIC Applications**

Kala Gururajan, Harish Peddibhotla, Raghu K. Settaluri, Oregon State University

**3D Electromagnetic Simulation of Optoelectronic Transceiver Structures**

John Schultz, Marek Turowski, Robert Trammel, Gordon Henson, 3M Company

**The Extraction of a Two-Resistor/Two-Capacitor Model for Common IC Packages and their Implementation in CFD**

Sarang Shidore, David Stiver, Flomerics Inc.

**FA4**

**Optoelectronics**

Chairs: Phil Zulueta, JPL; Ephraim Suhir, Ionon, Inc.

**8 am - 11 am**

*As the Photonics/Optoelectronics industry continues to experience growth fluctuations, the attempt to find reliable, low cost methods of assembling optoelectronics remains a primary focus among researchers, technologists and package-developers. This session in Photonics/Optoelectronics Packaging reflects this theme as it addresses work, ranging from novel adhesive and process technologies for fiber alignment and VCSEL assemblies to the development of new glasses for planar, optical waveguides.*

**Curing Low Yields and Reliability Issues in Photonics Assembly**

Mike Martuscello, Lambda Technologies

**An O/E Measurement Probe Based on an Optics-Extended MCM-D Motherboard Technology**

Herbert DePauw, J. De Baets, J. Vanfleteren, A. Van Calster, Ghent University (ELIS-TFCG)/IMEC

**Characterization of Adhesives for Low Temperature Microelectronics and Photonics Packaging**

Curtis Taylor, Hameed Naseem, William Brown, University of Arkansas

**Adhesive Assembly for Optoelectronic Transceivers**

John Schultz, Ron Davis, Glen Connell, Gordon Henson, 3M Company

**An Optimized System Solution for an Optoelectronic Transceiver Module**

Abdolreza Langari, Hassan Hashemi, Mindspeed Technologies Inc.; Winfred Morris, Rockwell Scientific Company

**Planar Optical Waveguides Fabricated by Ion-Exchange of Transition Metal Ions in Commercial and Special Optical Glasses**

Jarmila Spirikova, P. Nebolova, P. Nektivindova, M. Mika, A. Mackova, G. Kuncova, A. Langrova, K. Mach, J. Schrofel, Institute of Chemical Technology

**Special Session\***

**8 am - 10:35 am**

Authors are NSF/SJS 2001-2002 Award Recipients

*\*Presentations will be 20 minutes each.*

**FA5**

**National Science Foundation & Sidney J. Stein Educational Foundation**

Chairs: Rao Tummala, Leyla Conrad, Georgia Institute of Technology

**DC Resistivity Profile of Multilayer Dielectric Devices for Production Process Improvement**

Aaron E. Hydrick, Alfred University

**Surface Preparation of AlN Substrates for Metallization**

Robert Campman, The New York State College of Ceramics at Alfred University

**Fabrication of a Pressure Utilizing Low Temperature Co-fired Ceramics**

Yasmin Morales, Boise State University

**Finite Difference Time Domain Simulation of Multiport Networks using S-Parameter Macromodels for Packaging Applications**

Chris Lasek, University of Colorado @ Boulder

**Chip-Package Co-design of RF Microsystems**

Leroy Griffith, Rochester Institute of Technology

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**MEMS ATW**

Adam's Mark Hotel  
September 6 - 8, 2002

For more information visit:  
[www.imaps.org](http://www.imaps.org) or see page 26

You can also register on page 30.

# additonal events

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Register for the MEMS ATW on page 30

## **IMAPS 4th Advanced Technology Workshop on Packaging of MEMS and Related Micro Integrated Nano Systems**

**Adam's Mark Hotel  
Denver, CO  
September 6-8, 2002**

Sponsored by:  
**International Microelectronics And Packaging Society (IMAPS),  
in conjunction with the IMAPS 2002 Symposium - Denver**

**General Chair: Ajay P. Malshe**  
*University of Arkansas/HiDEC*  
Fayetteville, AR USA  
Email: [apm2@engr.uark.edu](mailto:apm2@engr.uark.edu)

For more information, visit [www.imaps.org](http://www.imaps.org)

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*Special Event at IMAPS '02*

## **Microelectronics Marketing Research Council (MMRC)**

*Presents a*

### **MARKETING FORUM WP5**

**Free of Charge for all IMAPS 2002 ATTENDEES!**

The MMRC (Microelectronics Marketing Research Council) will offer a free-of-charge Marketing Forum to all IMAPS 2002 attendees who wish to participate. The Marketing Forum will be held on Wednesday afternoon, September 4, 2002, at the Colorado Convention Center (Room number TBA).

Various segments of the microelectronics industry are re-establishing their growth models as the economy emerges from recession. This session will help clarify the direction of key markets/technologies which were previously perceived as "hot," but in 2001 were "not." Are we still placing the right bets with development efforts? Is growth expected this year, next year, or in 5 years? What is now driving demand after the rollercoaster ride of Y2K, a red hot economy in 2000, and the recession of 2001? These questions and more will be addressed.

Speakers will discuss their analysis and insights into various current and emerging markets of interest to both current and prospective IMAPS members. Some of these markets are Integrated Passive Devices, LTCC, and Optoelectronic market analysis, etc. The Forum will feature four presentations with a panel discussion at the end that will allow for audience participation in this **not to be missed event!**

**SAVE \$50 OFF FULL-SYMPOSIUM REGISTRATION BY REGISTERING ON-LINE: [WWW.IMAPS2002.ORG](http://WWW.IMAPS2002.ORG)**

# upcoming events

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## **IMAPS Topical Workshop on Optoelectronics Packaging and Micro- Optoelectromechanical Systems (MOEMS)**

**Radisson Hotel Bethlehem  
Bethlehem, PA  
October 8-11, 2002**

Sponsored by:  
**International Microelectronics And Packaging Society (IMAPS)  
and the Local IMAPS Keystone Chapter**

General Chair: **Thomas Green**, National Training Center for Microelectronics  
tgreen@northampton.edu

Technical Chair: **Rajeshuni Ramesham**, Jet Propulsion Laboratory  
Rajeshuni.Ramesham@jpl.nasa.gov

Building on the success of last year's Advanced Technology Workshop (ATW) on "Optoelectronics Packaging," an expanded venue is planned for this year including an afternoon of vendor exhibits and Professional Development Courses (PDCs). This IMAPS topical workshop will focus on recent advances in optoelectronics, packaging of optoelectronic devices and associated technologies including a special session on MOEMS. An outstanding program is planned with internationally recognized speakers from industry, academia and government.

**Visit [www.imaps.org](http://www.imaps.org) for more information**

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## **Advanced Technology Workshop on Thermal Management for High Performance Computing and Telecom/Wireless Applications**

**Sheraton Palo Alto Hotel  
Palo Alto, California USA  
October 24-26, 2002**

Sponsored by:  
**International Microelectronics And Packaging Society (IMAPS)**

**General Chair:**  
Dave Saums  
Ceramics Processing Systems Corporation  
Newburyport, MA USA  
dsaums@msn.com

**Information will be posted on the IMAPS site as it becomes available:  
[www.imaps.org](http://www.imaps.org)**

# hotel & registration

## Three Convenient Ways to Register

On-line: [www.imaps2002.org](http://www.imaps2002.org)

Fax: 202-548-6115

or

Mail this form to:

IMAPS 2002 Registration, 611 2nd Street, NE  
Washington, DC 20002 USA

For more information, please call IMAPS: 202-548-4001

### Advance Registration

To register in advance for IMAPS 2002, your registration and payment information must be received no later than **July 12, 2002**. Register early and save \$100. Register on-line at [www.imaps2002.org](http://www.imaps2002.org) and save an additional \$50! **All registrations received after July 12, 2002, will be considered "on-site registration."** Confirmations will be sent upon processing of registration form and payment. Those who register in advance may proceed on-site to Advance Registration to retrieve their badge and *Proceedings* at the Symposium. Cancellations will be refunded (less a \$50 processing fee) only if written notice is postmarked on or before **Friday, August 9, 2002**. No refunds will be issued after that date.

### International Wire Transfers can be directed to IMAPS

The following instructions must be followed exactly to ensure quick and accurate execution of your transfer.

- First Union National Bank
- 1970 Chain Bridge Road, 3<sup>rd</sup> Floor, McLean, VA 22102
- Account Name: IMAPS
- ABA Number: 051400549
- Account No. 2000004355830
- Swift Code: PNPB US 33

### Tax Deductions

Treasury regulation 1.162.5 currently permits an income tax deduction for educational expenses (fees and cost of travel, meals and lodging) undertaken to (1) maintain or improve skills required in one's employment; or (2) meet express requirements of an employer. Check with your accountant or tax attorney.

### Loss Due to Theft

Symposium management is **not** responsible for loss or theft of personal belongings. Security for personal belongings is the responsibility of the individual.



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Offers Special Discounts for  
IMAPS 2002  
Call 800-521-4041  
Refer to ID Number **583IW**

Take 5% off any United, United Express or Shuttle by United published fares, including First Class, subject to all applicable restrictions, or take 10% off applicable BUA, or like fares, in effect when tickets are purchased 7 days in advance. Reservations and schedule information may be obtained by calling the United Meetings desk at 800-521-4041 and reference Meeting ID # 583IW.

## Hotel Information

### ADAM'S MARK HOTEL\*\*

*Headquarters Hotel. Site of the IMAPS Welcome Reception*

1550 Court Place

Denver, CO 80202

Phone: 303-893-3333

Fax: 303-626-2542

Rates: Single \$167; Double \$182

Concierge: Single \$202; Double \$217

[www.adamsmark.com/denver/index.asp](http://www.adamsmark.com/denver/index.asp)

### COMFORT INN DOWNTOWN

401 17<sup>th</sup> Street

Denver, CO 80202

Phone: 303-296-0400

Fax: 303-312-5941

Rates: Single/Double \$119

### Housing Deadline: July 12, 2002

Housing Accommodations **MUST** be made directly to the hotel of your choice. Please make your reservation before **July 12, 2002**.

A one night's deposit is required to guarantee your accommodations.

**All IMAPS room blocks will be released on 7/12/02, after which IMAPS can not guarantee rates listed above.**

\*\**Headquarters Hotel*

## Tell Us About Yourself (please print)

Mr.  Ms.  Dr.      IMAPS ID# \_\_\_\_\_  
First \_\_\_\_\_ Last \_\_\_\_\_  
Position/Title \_\_\_\_\_  
Company/University \_\_\_\_\_  
Address \_\_\_\_\_  
City \_\_\_\_\_ State \_\_\_\_\_ Zip/Postal Code \_\_\_\_\_ Country \_\_\_\_\_  
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Register On-line  
Visit [www.imaps2002.org](http://www.imaps2002.org) for Special Offers

## Family/Guest Information (if attending)

Mr.  Ms.  Dr.  
First \_\_\_\_\_ Last \_\_\_\_\_  
City \_\_\_\_\_ State \_\_\_\_\_ Country \_\_\_\_\_

## How did you hear about this Event? (please check all that apply)

Direct Mail     Advancing Microelectronics     Web     Email  
 Industry/Trade Magazine     Colleague     Other \_\_\_\_\_

## Attendee Profile

### What is your primary job function? (please check only one)

- 1. Circuit, package, module, board, or system design (including management)
- 2. Research and development (including management)
- 3. Process, manufacturing or production engineering (including management)
- 4. Test and measurement engineering (including management)
- 5. Quality Control, product assurance, or reliability assessment (including management)
- 6. Purchasing (including management)
- 7. Sales and marketing (including management)
- 8. Corporate management
- 9. Consultant
- 10. Instructor or student
- 11. Technician or operator
- 12. Other (please describe) \_\_\_\_\_

### Your employer's Industry (include manufacturing and sales) (please check only one)

- 1. Optical telecommunications components (photonics, electro-optics, fiber)
- 2. Optical telecommunications systems (photonics, electro-optics, fiber)
- 3. Aerospace, Avionics
- 4. Commercial/Industrial
- 5. Consumer
- 6. Semiconductor
- 7. Computing (hardware or software)
- 8. Communications (equipment or devices)
- 9. Automotive
- 10. Medical
- 11. Government or military
- 12. Materials/Equipment/Service provider to any of the above
- 13. University/Education

## Total Fees and Deposits

#1 Symposium Registration Subtotal (from page 30) \$ \_\_\_\_\_  
#2 Foundation Contribution Subtotal (from page 30) \$ \_\_\_\_\_  
#3 PDC Registration Subtotal (from page 30) \$ \_\_\_\_\_  
#4 Additional Purchases Subtotal (from page 30) \$ \_\_\_\_\_

**TOTAL AMOUNT DUE \$ \_\_\_\_\_**

Enclosed check payable to IMAPS \$ \_\_\_\_\_  
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Cancellations will be refunded (less a \$50 processing fee) only if written notice is postmarked on or before **August 9, 2002**.

**No refunds will be issued after that date.**

## Full Symposium Registration

✓ Type (check one)	Includes	Advance on/before 7/12	On-site After 7/12
IMAPS Member*	WR, EL, TS, EX, PR	\$595	\$695
Non-member*	WR, EL, TS, EX, PR	\$670	\$770
Presenters/Speakers*	WR, EL, TS, EX, PR	\$495	\$595
Session Chair/Co-chair*	WR, EL, TS, EX, PR	\$495	\$595
Student Member*	WR, EL, TS, EX, PR	\$10	\$20
Student Non-member*	WR, EL, TS, EX, PR	\$15	\$25
Exhibits Admission	WR, EX	\$10	\$20
<i>*Includes one-year membership or membership renewal at no additional charge</i>			
<b>Additional Events</b>			
Spouse/Guest Tours ○ 2-Day Package only Wednesday & Thursday...see page 6	WR, EX	\$190	\$220
Golf Tournament...see page 4		\$125	\$150
<b>Packaging of MEMS Workshop** - September 6-8, 2002</b>			
IMAPS Member		\$500	\$550
Non-member*		\$575	\$625
Session Chair/Speaker		\$300	\$350
<i>*Includes one-year membership in IMAPS</i>			
Spouse/Guest Meals		\$150	\$150
Add'l CD of Presentations (member)		\$100	\$100
Add'l CD of Presentations (non-member)		\$160	\$160
○ Shipping in the US		\$7	\$7
○ Shipping Overseas		\$25	\$25
<b>**Workshop Fees include an Abstract Book and a CD of Presentations. CD of Presentations will be mailed 10 business days after the event.</b>			

Your Full Symposium registration includes the following:

- WR Welcome Reception
- EL Exhibit Hall Buffet Lunch (Wednesday & Thursday)
- TS Technical Sessions
- EX Exhibits
- PR Proceedings (includes Book and CD-ROM)

**#1 Subtotal Symposium Registration \$ \_\_\_\_\_**

## Foundation Contribution

- Sidney J. Stein Educational Foundation Contribution \$ \_\_\_\_\_

**#2 Foundation Contribution \$ \_\_\_\_\_**

## Professional Development Courses

✓	Course Title	Advance On/before 7/12	On-site After 7/12
T1	Wire Bonding in Microelectronics	\$575	\$625
T2	Metal Plating for Electronics	\$550	\$600
T3	Technology of Screen Printing	\$500	\$550
T4	Implementing Microvias and Embedded...	\$500	\$550
T5	Advanced Organic Substrate Package....	\$500	\$550
T6	Fundamentals of Fabrication....	\$500	\$550
T7	Flip Chip and CSP Technologies....	\$500	\$550
T8	Lead Free Soldering - Status Review....	\$500	\$550
T9	Design Failure Mode and Effects.....	\$500	\$550
F1	Process Engineering Fundamentals	\$500	\$550
F2	Advanced Materials for Microelectronics...	\$550	\$600
F3	RF/Microwave Hybrids; Basics.....	\$500	\$550
F4	Integrated Circuit Packaging Trends.....	\$575	\$625
F5	Low Temperature Cofired Ceramics....	\$500	\$550
F6	Microelectronic Thermal Management	\$550	\$600
F7	Lead-Free Solders – Tech/Apps (1/2 Day)	\$600	\$650
F8	Solder Joint Reliability (1/2 Day)	\$575	\$625
F9	Microelectronic Systems Pkg. (1/2 Day)	<b>Students Only - Free</b>	

*PDCs on Tuesday will be held at the Colorado Convention Center; they run from 9 am - 5 pm (T1-T9)*

*PDCs on Friday will be held at the Adam's Mark Hotel; they run from: 11 am - 6 pm (F1-F6); 11 am - 3 pm (F7 & F9); 3 pm - 6 pm (F8). Lunch will be at 11 am.*

**#3 Subtotal PDC Registration \$ \_\_\_\_\_**

## Additional Purchases

- 10'x10' Exhibit Space  
\$1800 members, \$2300 non-members

- 10'x20' Exhibit Space  
\$3600 members, \$4100 non-members

No. of Booths \_\_\_\_\_ @ \$ \_\_\_\_\_ Total \$ \_\_\_\_\_  
Company Name \_\_\_\_\_  
Contact Name \_\_\_\_\_

- Extra IMAPS 2002 Proceedings (Book or CD-ROM)  
Book: \$125 members, \$200 non-members\*  
CD: \$75 members, \$150 non-members\*

(\*Nonmember price includes 1 year IMAPS membership)

- Book Version Qty. \_\_\_\_\_ \$ \_\_\_\_\_  
 CD-ROM Version Qty. \_\_\_\_\_ \$ \_\_\_\_\_

(All publications add \$7 to ship U.S.; overseas add \$25)

**#4 Subtotal Additional Purchases \$ \_\_\_\_\_**

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# exhibitors

See the IMAPS on-line tradeshow at [www.imaps2002.org](http://www.imaps2002.org)

(as of April 12, 2002)

- |   |   |   |                                   |
|---|---|---|-----------------------------------|
| 3M Electronic Adhesives & Specialties Dept. | Flomerics, Inc.                           | Morgan Advanced Ceramics                  | Schiller Automation Systems, LLC  |
| Accuprobe                                   | Flow Autoclave/Ceratek                    | Mozaik Technology Ventures, Ltd.          | Schott Electronic Packaging       |
| AccuTech Laser Processing, Inc.             | Fraunhofer - IZM                          | MRSI                                      | SEFAR America/MEC Division        |
| AcousTech, Inc.                             | Gaiser Tool Co.                           | Nabertherm LLC                            | Semi Dice, Inc.                   |
| AI Technology, Inc.                         | Gannon & Scott                            | Nanopierce Technologies, Inc.             | Semiconductor Equipment Corp.     |
| AMI/PRESCO                                  | Geib Refining Corp.                       | National Semiconductor Die Products Group | SierraTherm Vacuum Products Group |
| Amitron/Anaren Microwave                    | Gel Pak/Quik Pak                          | NETZSCH Instruments, Inc.                 | Sikama International, Inc.        |
| Applied Laser Technology                    | GIL Technologies                          | NorCom Systems, Inc.                      | Solid State Equipment Corp.       |
| Asymtek/March Plasma/Nordson                | Graftech, Inc.                            | NTK Technologies                          | Sonix, Inc.                       |
| ATV Technology                              | Graphite Concepts, Inc.                   | OhmCraft, Inc.                            | Sonoscan, Inc.                    |
| Azimuth Electronics                         | GSI Lumonics                              | Olin Aegis                                | SST International                 |
| Bar-Lo Carbon Products                      | Haiku Tech International                  | Optical Systems                           | Suss MicroTec                     |
| BTU International                           | Harrop Industries/A.J. Carsten Co.        | Pac Tech                                  | Sypris Solutions                  |
| C & R Technologies                          | HCC Industries, Inc.                      | Packaging Research Center at Georgia Tech | TecNu                             |
| CCT Laser Services                          | Heraeus, Inc.-Circuits Materials Division | Palomar Technologies, Inc.                | Teledyne Interconnect             |
| Central Semiconductor                       | Hybrid Screen Technologies, Inc.          | Parelec, Inc.                             | Teledyne Microelectronics         |
| CeramTec NAE                                | Instron Corp.                             | PCC/Advanced Forming Technology           | Telephus                          |
| Ceratek                                     | Interconnect Systems, Inc.                | Perfection Products, Inc.                 | Thin Film Technology              |
| Chip Supply                                 | ITT Industries - MicroElectronics Center  | Plasma Etch, Inc.                         | Trebor Instruments                |
| Chipbond Technology Corp.                   | Ixion Technologies                        | Polaris Electronics, Inc.                 | Ultron Systems, Inc.              |
| CirQon Technologies Corp.                   | Kaneka High-Tech Materials                | Potomac Photonics, Inc.                   | Unichem Industries, Inc.          |
| Cobehn Systems                              | Kluwer Academic Publishers                | Probotech, Inc.                           | Unitek Benchmark                  |
| Cool Shield, Inc.                           | Kulicke & Soffa                           | Reinhardt Microtech AG                    | West-Bond                         |
| CoorsTek                                    | Kyocera America                           | Reldan Metals                             | Zymet, Inc.                       |
| Creative Automation                         | Kyzen Corp.                               | Rigsby Screen & Stencil, Inc.             |                                   |
| Curamik Electronics, Inc.                   | Lambda Technologies, Inc.                 | Riv, Inc.                                 |                                   |
| Daejoo Fine Chemical Co.                    | Laser Processing Technology               | RJR Polymers                              |                                   |
| Dage Precision Inds., Inc.                  | Laser Services, Inc.                      | Royce Instruments, Inc.                   |                                   |
| Dage Consulting                             | Laser Tech, Inc.                          | ScanCAD International                     |                                   |
| Dakota Consulting                           | Laserage Technology Corp.                 |   |                                   |
| Diamond Wire Technology                     | Lasereliance Technologies                 |   |                                   |
| Dow Chemical Company                        | Litron                                    |   |                                   |
| DuPont Microcircuit Materials               | Loctite Corp.                             |   |                                   |
| Dyconex Ltd.                                | March Plasma Systems/Asymtek/Nordson      |   |                                   |
| Dymatix                                     | Marpet Enterprises (MEI)                  |   |                                   |
| Eberts Electronic Sales                     | Metallix, Inc.                            |   |                                   |
| Egide USA                                   | Metech, Inc.                              |   |                                   |
| Electro Scientific Inds. (ESI)              | Micro Printing Systems                    |   |                                   |
| Electronic Packaging & Production           | MicroScreen                               |   |                                   |
| Electro-Science Labs.                       | Micross Components Corp.                  |   |                                   |
| Emerson & Cuming                            | Midas Vision Systems                      |   |                                   |
| Epoxy Technology, Inc.                      | Minco Technology Labs.                    |   |                                   |
| EXAKT Technologies, Inc.                    | Mini-Systems, Inc.                        |   |                                   |
| F&K Delvotec, Inc.                          |   |   |                                   |
| Fancort Industries                          |   |   |                                   |
| Film Microelectronics                       |   |   |                                   |

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# LOOKING FOR STUFF TO DO AROUND DENVER? HERE'S THE SHORT LIST!

## DENVER'S MUSEUMS AND ATTRACTIONS

DENVER HAS SOME OF THE FINEST MUSEUMS IN THE WEST; WITH A WIDE VARIETY OF HISTORICAL, WESTERN, ARTISTIC AND HORTICULTURAL EMPHASIS.

**THE BLACK AMERICAN WEST MUSEUM** tells the forgotten story of African American cowboys, who made up as many as one third of all the cowboys on the great cattle drives. Housed in the home of Dr. Justina Ford, Denver's first African American doctor, the museum has exhibits, historic photos and artifacts that tell the story of the many contributions made by Blacks in settling the West. (303) 292-2566.

**BUFFALO BILL'S GRAVE & MUSEUM** is filled with memorabilia honoring the famous frontier scout, showman and Pony Express rider, William F. Cody. A beautiful view of the mountains and the plains is visible from his grave site. (303) 526-0747.

**BUTTERFLY PAVILION & INSECT CENTER** features a lush tropical forest filled with up to 1,600 free-flying butterflies. There is also an insect center and gift shop, as well as outdoor gardens and many fun, educational exhibits. (303) 469-5441.

**THE CHILDREN'S MUSEUM OF DENVER** is a unique participatory museum for children and families to experience hands-on, interactive exhibits and activities. (303) 433-7444.

**THE COLORADO HISTORY MUSEUM** offers a series of dioramas and exhibits that trace the colorful history of the Indians, explorers, gold miners, cowboys and pioneers who have called Colorado home. Exhibits include an outstanding collection of William Henry Jackson photos and a large diorama of Denver as it appeared in 1860. Call for information on special exhibits. (303) 866-3670.

**COLORADO OCEAN JOURNEY**, which opened in June, 1999, is a world-class aquarium that immerses visitors on two journeys, from the Continental Divide in Colorado to Mexico's Sea of Cortez, and the other from an Indonesian rain forest to the Pacific Ocean. The Rocky Mountain West's only aquarium will also show visitors how all water and water life are inter-related. (303) 561-4450.

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**THE COLORADO STATE CAPITOL** stands a mile above sea level with a plaque on the 15th step to mark the spot that is 5,280 feet (1,609 m) high. The dome is covered with 200 ounces of pure gold and offers a beautiful view from the rotunda of the entire Front Range, from Pikes Peak, all the way north to the Wyoming border, a distance of over 150 miles (241 km). Free tours on weekdays of the beautiful rooms and appointments. (303) 866-2604.

**COORS BREWERY** offers free tours of the largest single brewery in the world. Free tours of the entire complex, from brewing to bottling, with free beer samples for those over the age of 21. (303) 277-2337.

**DENVER ART MUSEUM** has what is considered to be the finest collection of American Indian art works in the world covering all tribes, as well as 30,000 other art objects in seven curatorial departments. It is the largest art museum between Kansas City and the West Coast. (303) 640-2793.

**DENVER BOTANIC GARDENS** has a large conservatory, an alpine garden with rare tiny flowers, a Japanese tea garden, as well as a water garden with hundreds of water lilies that bloom in late summer. It is just one of 506 public gardens in Denver where over 240,000 flowers are planted each year. (303) 331-4000.

**DENVER MUSEUM OF NATURE & SCIENCE** is the fourth largest museum of its kind in the nation, with over 80 dioramas depicting animals from around the world. It also features an outstanding dinosaur collection, a Hall of Life devoted to studying the human body, a planetarium, an outstanding geological collection and an IMAX theater. (303) 370-6310.

**DENVER ZOO** is consistently rated as one of the top 10 in America with 3,500 animals in lovely spreading grounds in City Park. "Tropical Discovery," is a 1.5-acre rainforest under glass in which visitors feel the sensation of walking through a jungle teeming with wildlife. (303) 376-4800.

**SIX FLAGS ELITCH GARDENS THEME PARK** is a hundred-year-old theme park known for its European atmosphere, elaborate floral gardens, and thrill rides. In 1995, Elitch Gardens moved to an expanded location in downtown Denver along the South Platte River with all new rides, gardens, lagoons, restaurants and amusements. (303) 455-4771.

**THE MOLLY BROWN HOUSE** honors "Unsinkable Molly Brown," the heroine of the Titanic disaster with mementos from her life preserved in her beautiful home on Capitol Hill. Molly was one of the most colorful characters to come from Denver's gold rush period. While sailing on the Titanic, she took command of a lifeboat and was credited with putting down a panic. Her life story was the inspiration for the hit musical and film, "Unsinkable Molly Brown." (303) 832-4092.

**TINY TOWN** is a kid-sized village with dozens of "Old West" buildings, all built at 1/6 scale in a scenic mountain location. An authentic toy steam locomotive circles the park giving children and adults a ride past the miniature town. (303) 790-9393.

**THE U.S. MINT** is where over five billion coins are made each year and there are free 20 minute tours on weekdays. It is also the second largest storehouse of gold bullion in the U.S. after Fort Knox. The gift shop has many unique coins not available anywhere else, and there is a small museum on the history of money. (303) 844-3582.