SMTAnews
A publication of the Surface Mount Technology Association

&

Journal of Surface Mount Technology

April-June 2013 Volume 26, Issue 2

Free Tutorial for Members at SMTA International

October 17, 2013
Fort Worth, Texas

On Thursday, October 17, Cheryl Tulkoff, DfR Solutions, will present "Design for Reliability for PCBs" at no charge to SMTA members during SMTA International in Fort Worth, Texas.

Designing printed boards today is more difficult than ever before because of the increased lead free process temperature requirements and associated changes required in manufacturing. Not only has the density of the electronic assembly increased, but many changes are taking place throughout the entire supply chain regarding the use of hazardous materials and the requirements for recycling. Much of the change is due to the European Union (EU) Directives regarding these issues. The RoHS and REACH directives have caused many suppliers to the industry to rethink their materials and processes. Thus, everyone designing or producing electronics has been or will be affected.

This tutorial will first provide an introduction to Design for Reliability and the Physics of Failure (PoF), then Cheryl will dive into Printed Circuit Board applications such as Laminated Selection, Plated Through Vias (PTVs), Cracking and Delamination, PTH Barrell Cracking, CAF, Strain/Flexure Issues & Pad Cratering, Cleanliness, Electrochemical Migration, and Surface Finishes.

You are required to register to receive a handout and a Certificate of Completion, but there is no charge for the course.

Be Part of the Solution...
SMTA International

Questions? Please contact:
JoAnn Stromberg, SMTA Executive Administrator
Phone: 952-920-7682
Email: joann@smta.org

SMTAnews
A publication of the Surface Mount Technology Association

& Journal of Surface Mount Technology

April - June 2013 Volume 26, Issue 2

Information updated daily... check smta.org for the most current association news.

SMTAnews

A publication of the Surface Mount Technology Association

Volume 26, Issue 2, **April-June 2013**

SMTA International 2013 Technical Committee Plans Another Impressive Conference

Conference: October 13-17, 2013
Fort Worth, Texas

The distinguished SMTA International Technical Advisory Committee includes electronics manufacturing and packaging experts representing all facets of the industry. The Committee designed the 2013 conference program to ensure that today's latest trends and developments are fully addressed.

The final program is posted at www.smta.org/smtai.

SMTAI 2013 Technical Advisory Committee:
Rob Rowland, Axiom Electronics, Chair
Raiyomand Aspandiar, Ph.D., Intel Corporation
Donald Banks, St. Jude Medical
Lars Boettcher, Fraunhofer IZM Berlin
Mike Buetow, CIRCUITS ASSEMBLY Magazine
Bill Cardoso, Ph.D., Creative Electron, Inc.
Srinivas Chada, Ph.D., Schlumberger
Marie Cole, IBM Corporation
John Evans, Ph.D., Auburn University
Trevor Galbraith, Trafalgar Publications Ltd.
Reza Ghaffarian, Ph.D., Jet Propulsion Labs
Steve Greathouse, Plexus Corp.
Denis Jean, Plexus Corp.
Matthew Kelly, P. Eng., IBM Corporation
Jeff Kennedy, Celestica Inc.
Terry Kocour, Schlumberger
Pradeep Lall, Ph.D., Auburn University
Andrew Mawer, Freescale Semiconductor
Randy Schueller, Ph.D., DfR Solutions
Chrys Shea, Shea Engineering Services
Paul Vianco, Ph.D., Sandia National Labs
Bob Willis, ASKbobwillis.com
Charles Woychik, Ph.D., Invensas

SMTA International 2013 Registration Open

Conference: October 13 - 17, 2013
Exhibition: October 15 - 16, 2013
Fort Worth, Texas

Registration is open and the program for SMTA International is finalized and available on-line. The conference will be held at the Fort Worth Convention Center in Fort Worth, Texas on October 13-17, 2013. This year's program allows the attendee to choose from 18 courses, 130 technical papers, 4 focused symposia, and numerous free offerings throughout the conference and exhibition.

The SMTA International conference includes focused technical tracks covering Manufacturing and Assembly, Advanced Packaging, Substrates, Soldering, and Quality and Reliability. Technical sessions will be held on Monday through Thursday. Tutorials are half-day educational courses offered on Sunday, Monday, and Thursday. Thursday's tutorial on "Design for Reliability for PCBs" is free for SMTA members who register in advance.

Informative and focused symposia make up part of the technical conference and include the Evolving Technologies Summit, Harsh Environments Symposium, Counterfeit Electronics Symposium, and Lead-Free Soldering Technology Symposium.

New this year, IPC will co-locate its Fall Standards Development Committee Meetings from Oct. 12-17.

Over 150 supplier companies will display equipment, tools, and materials at the Electronics Exhibition, which will be held Tuesday and Wednesday, October 15-16. Attendees are invited to consult with high-level technical experts to solve specific problems at no cost during Doctor's Hours. Free lunch will also be provided both days on the show floor.

Many additional events at SMTA International are free to all attendees including spotlight sessions and the Sharing and Networking Experience on the show floor.

First time attendees can take an extra 10% off conference registration. The Early Bird registration deadline is September 13, 2013.

For full details and to register for SMTA International, visit www.smta.org/smtai.

SMTA / iNEMI Medical Electronics Symposium

November 12-13, 2013
Embassy Suites, Milpitas, CA

We invite you to join us for our 10th Medical Electronics Symposium co-sponsored this year by SMTA and iNEMI. From 2004 – 2008 this event was held in Minneapolis. From 2009 to 2012 SMTA was a co-sponsor of the MEPTEC medical electronics event help in Tempe, AZ. This is the first year SMTA will partner with iNEMI on this particular topic and we look forward to the collaboration.

Medical electronics technology offers complete solutions that give people the hope and reality to extend and improve their quality of life. These solutions are supported by a growing high-tech manufacturing industry that continues to have a strong North American presence. Medical electronics is a vibrant, interactive technical community. Improvements in miniaturization, medical device quality and system efficiency often result from close working relationships between industry, universities, government and private institutions. This conference will focus on medical electronic devices, carriers and components, advanced assembly techniques, reliability and the complex global regulatory requirements (including ROHS) required for medical applications.

The technical committee members are:
Donald Banks, St. Jude Medical, Co-Chair
Charles Richardson, iNEMI, Co-Chair
Bill Burdick, GE Medical
Erik Larkowski, Boston Scientific
Dale Lee, Plexus Corp.
John McNulty, Exponent Failure Analysis Associates
Anthony Primavera, Micro Systems Engineering
Peter Tortorici, Medtronic
Cheryl Tulkoff, DfR Solutions

Exhibit space is available and entitles you to a 6 ft. draped table, two chairs, a copy of the attendee list, company sign, breakfast, lunch & breaks, and one copy of the conference proceedings. Sponsorships and advertising opportunities are also available.

For more information contact Patti Hvidhyld at 952-920-7682 or patti@smta.org.

www.smta.org/medical/

F-35 Lightning Program Is Focus of SMTA International Keynote

US Air Force Major General (Ret) DuLaney, Lockheed Martin Aeronautics

The Opening Keynote Session and Annual Meeting at SMTA International, October 15, 2013, will feature Bob D. DuLaney, Lockheed Martin and US Air Force Major General (Ret), as the keynote speaker. He will present "F-35 Lightning II: The Centerpiece for 21st Century Global Security." This is a free event at SMTA International and includes breakfast treats and coffee for all attendees.

The F-35 Lightning II is a 5th Generation fighter, combining advanced stealth with fighter speed and agility, fully fused sensor information, network-enabled operations and advanced sustainment. Three distinct variants of the F-35 will replace the A-10 and F-16 for the U.S. Air Force, the F/A-18 for the U.S. Navy, the F/A-18 and AV-8B Harrier for the U.S. Marine Corps, and a variety of fighters for at least ten other countries. Bob DuLaney will provide an overview of the F-35 program detailing the importance of this particular aircraft, current progress on the program, and its economic impact.

Bob DuLaney is Senior Manager F-35 Customer Engagement for Lockheed Martin Aeronautics Company in Fort Worth, Texas. Bob joined Lockheed Martin in August 2007 after a thirty-three year career in the United States Air Force culminating as the USAFE Director of Operations at Ramstein AB, Germany. During his thirty plus years in the USAF he served in various locations throughout the world, including Europe and Asia. Bob is a combat veteran fighter pilot with 4500+ fighter hours in the F-16 and F-4. He has held command at flight, squadron, group, wing and joint task force levels; and served on the Joint Staff in the Pentagon and at North American Aerospace Defense Command (NORAD).

For more information on SMTAI as well as the opening keynote session, contact SMTA Executive Administrator JoAnn Stromberg at 952-920-7682 or joann@smta.org.

Welcome Back Joel!

SMTA is proud to welcome back Joel Eaton to the staff. Joel completed an internship with SMTA from 2011-2012. He earned his Bachelors in Communication Studies and Business Administration from Hamline University in 2012. He joined SMTA as a full-time employee in April 2013 in the role of Event Assistant.

Joel previously held administrative assistant positions for several different college offices throughout his time at Hamline. He was excited to get the internship position at SMTA during his senior year. Joel enjoys the friendly office environment and the opportunity to apply what he learned in his Marketing courses.

Originally from Oregon, Joel moved to Minnesota for college and has been here ever since. Some of his favorite hobbies are reading, playing Ultimate Frisbee, and watching college football (Go Oregon Ducks!)

"It was really an easy decision to accept the full-time position after the year of interning here at SMTA. My co-workers are great, and I enjoy working with the various members of the organization. I've already been able to connect some of the names with faces, and am hoping to be able to meet even more people soon!"

Joel can be reached at joel@smta.org and you will probably talk to him first if you call the office at 952-920-7682.

SMTA International Sponsorship Opportunities

Increase your exposure this year at SMTA International, the industry's best technical conference on electronics assembly and advanced packaging.

Why should your company be an SMTA International Sponsor?

- To reach focused decision makers
- To spotlight your company
- To increase your booth traffic
- To insure contact with focused electronic assembly attendees to SMTA

Sponsorship Opportunities:

- Beer Cart Sponsorship - New!
- Coffee Breaks
- Exhibit Hall signage
- Show Directory Advertising
- Golf Tournament sponsorships
- Proceedings Sponsorship

Sign up on-line: smta.org/smtai/sponsorinfo.cfm and contact Emmy Garner, emmy@smta.org or 952-920-7682, with questions.

International Wafer-Level Packaging Conference Turns 10!

November 5-7, 2013
San Jose, California

The SMTA and *Chip Scale Review* magazine are pleased to announce plans for the 10th Annual International Wafer-Level Packaging Conference and Tabletop Exhibition. This premier industry event explores leading-edge design, material, and process technologies being applied to Wafer-Level Packaging applications.

Paul Wesling, a CPMT Society Distinguished Lecturer, will give an exciting and colorful keynote on "The Origins of Silicon Valley."

The exhibition is a two-day opportunity (November 6 and 7) to answer all of your toughest packaging technical questions and network with industry leaders. Sponsorship and advertising opportunities are also available.

For more information please visit the website at www.iwlpc.com or contact Patti Hvidhyld at 952-920-7682, patti@smta.org. We look forward to seeing you this November in San Jose.

Summer 2013 Expos and Tech Forums

Find an Expo & Tech Forum near you!

Attendee and exhibitor registration is open for the following Expos and Tech Forums:

- July 11, 2013 - Ohio Valley Expo
- August 15, 2013 - Philadelphia Expo
- September 10, 2013 - Capital Expo
- September 18, 2013 - WI/Great Lakes Expo

Tabletop Expos are a great source for networking, education and company exposure. Attendee registration is free and includes a free lunch and access to the technical sessions.

Contact Emmy Garner at emmy@smta.org or call 952-920-7682, for more information or questions regarding these opportunities. Find more details and a listing of all exhibitor opportunities at the Upcoming Expos page: www.smta.org/expos

Upcoming Certification Dates and Locations Announced

Get the recognition you deserve with the industry's most respected sign of approval

Technologies change at the speed of light, and competition and expectations are forever increasing. This comprehensive program will provide the refresher course, study materials and examination allowing you to be recognized as an SMTA Certified Process or Six Sigma Green Belt Engineer. The SMTA Certification program is unique, as it recognizes and certifies the entire SMT assembly process at an engineering level.

- Enhance your stature in our industry
- Increase marketing value for your company
- Obtain proof of your knowledge and experience

August 27-29, 2013 (Processes) - Shenzhen, China
contact peggy@smta.org to register

October 15-17, 2013 (Processes and 6 Sigma)
Fort Worth, TX (In conjunction with SMTAI)

November 5 - 7, 2013 (Processes) - San Jose, CA
(In conjunction with IWLPC)

For more information contact Patti Hvidhyld at 952-920-7682 or patti@smta.org.

Upcoming SMTA Webinars and Webtorials

Learn from outstanding speakers without leaving your desk. SMTA online presentations are a great solution for getting the latest knowledge at the best price. Webtorials are delivered in two 90 minute sessions on in depth topics and are comparable to normal half-day tutorials. Webinars are formatted to one session lasting 60 to 90 minutes and are free for members! The benefit of attending, especially when your travel budget is limited, is the cost and time savings compared to a live event. The best part, if your facilities allow, is that you can fit all of your engineers into a conference room and broadcast the webinar, effectively training your whole team for the price of one registration.

PoP Applications, Requirements, Infrastructure and Technologies
Jul 16 & 23, 2013

Free Webinar: Cleaning a No-Clean Flux and Related Reliability Issues
Aug 13, 2013

Conformal Coating In The Factor
Aug 29 & Sep 5, 2013

Radiography Inspection as a tool for Quality Control and Assurance
Sep 19 & 26, 2013

Reliability and Failure Analysis of Electronics
Oct 24 & 31, 2013

For more info and to register for these online offerings, please visit:
smta.org/education/presentations/presentations.cfm


INLINE DEFLUXING
BATCH DEFLUXING
STENCIL CLEANING
MANUAL CLEANING

For further information about these ads or to place an ad, contact SMTA director of communications Ryan Flaherty at 952-920-7682 or ryan@smta.org.

All listings are made by SMTA members.

The Job Listings page of the SMTAnews section on smta.org contains updated listings as well as additional contact information. Job lsitings are FREE for members of the SMTA.

POSITIONS AVAILABLE

Field Service Technician/Engineer - San Jose, CA
Date Posted: 6/28/2013
This position is responsible for complete field installation, startup, inspection, maintenance, troubleshooting and repair of company supplied equipment of several products. Depending upon the terms of the contract or project, this may include planning, scheduling, coordinating, cost control and monitoring the work in an advisory capacity to others, as well as supervising company employees in the performance of the work. This also includes documenting all job activity. In this position the technician/engineer is expected to become proficient in basic systems technologies. Extensive travel required (75 - 80%), both domestic and international. This position reports to the Regional Field Service Supervisor.

EDUCATION: Technical Certification or Associates Degree and a minimum of 3 - 8 years experience within the SMT industry preferred. Experience with SIPLACE equipment and SIPLACE software preferred.

Contact: christina.oswalt@asmpt.com

Technical Outside Sales Rep - Atlanta / Huntsville Area
Date Posted: 6/25/2013
Hammond is looking for a Technical Outside Sales Representative. The territory to be covered is the Atlanta – Huntsville area with travel every other week for 2-3 nights. The ideal candidate would be a person who is mechanically inclined and eager to learn more about our industry. Further, the candidate should be outgoing, people-oriented with a customer service attitude. Someone who has experience in an industrial or electronics manufacturing environment would be a good fit such as an engineer, technician, line leader or buyer looking for more direct customer interaction. We will teach you the industry and products and offer continued coaching and mentoring. A four year degree is not necessary but some college or a two year degree would be preferred.
You would sell production supplies and equipment as well as electro-mechanical parts and assemblies. Hammond has been in business since 1947 and sells over 100 world class lines. Please view our line card at Hammond-usa.com.

Hammond offers a competitive pay plan, car allowance, paid expenses, insurance, 401K and the opportunity to earn quarterly / yearly bonuses.

If you are a dedicated worker, who wants to build their future within a caring & supportive team environment send your resume to resume@hammondelec.com or fax 407-481-8352.

Valid Driver's license & insurance are required. Hammond is a Drug-Free Workplace and Equal Opportunity Employer.

Contact: resume@hammondelec.com

Surface Mount Quality Engineer III - Cincinnati, OH
Date Posted: 6/25/2013
Immediate need for a Quality Engineer due to continued company growth. three to five (3-5) years minimum experience in Quality Engineering with electronic assemblies. Specific Experience in Surface Mount Technologies (SMT), Circuit Card (CCA) Manufacturing or assemblies, Printed Circuit Boards (PCB or PWB) and corresponding IPC and J-STD Specifications. Experience with Development Programs, demonstrated ability to perform problem solving (structured Root Cause and CAPA) on the manufacturing floor and experience with inspection methods and test plan creation is needed. Experience in leading continuous improvement projects in a manufacturing environment. Working knowledge of Industry Specifications, such as AS9100/ISO 9001 and Milspecs, is desired. ASQ Certified Quality Engineer, Green Belt certification (DMAIC process) and Lean Manufacturing experience desired. BS in Engineering or related technical field or equivalent experience.

L-3 Fuzing and Ordnance Systems (FOS) is a full service fuzing company specializing in the design, development, test, and manufacture of safe and arm and fuzing mechanisms for the ordnance market and system integration for tube launched and infantry employed weapons.

We offer a competitive salary and benefits package including health, life, and disability insurance, 401k match, bonus plan, 11 paid holidays, tuition reimbursement, career advancement, challenging work, and the opportunity to be part of a dynamic and profitable company.

HOW TO APPLY
If you meet the qualifications and have the motivation to succeed in this challenging role, please submit your resume to:
https://l3com.taleo.net/careersection/l3_ext_us/jobapply.ftl?job=049466

Sales Manager - Northern Massachusetts
Date Posted: 6/19/2013
Small Incubator High Tech Supplier with 25 years experience selling to the World-Wide SMT market seeks energetic, skilled communicator to support and expand company branding and sales, in all markets. Candidate should have at least 4 years experience in a similar role, and have thorough understanding of the SMT process. Knowledge or product experience with Stencils, Solder Paste, Squeegees, and SMT Printers is a plus. Position includes paid vacation, 35 hour work-week (Fridays off), and medical expense reimbursement.

Contact: mfghiring@yahoo.com

New Smartphone Factory Has 2000 Jobs Open in Fort Worth, TX
Date Posted: 6/03/2013
StepBeyond has been contracted to Outsource Recruiting for the new Flextronics factory at Alliance Airport. This factory will be doing high volume production of the new Moto X smartphone.

We are extremely excited, not only by the opportunity to fill many jobs at Flextronics, but what this represents. As company representatives explained to us this is just the beginning of high volume manufacturing in the United States!!!

As of May 30 the factory floor was empty, but within 90 days they will be in full production. We look forward to seeing the major transformation in the factory, and helping many people find a great job here.

Please apply to this posting be on the list for ANY job that opens up at this facility (even if a specific job is not listed for you today)

Apply at www.stepbeyond.com

NEW TITLES

Copyright Year : 2013
Non-Member Price : $60.00
Member Price : $50.00

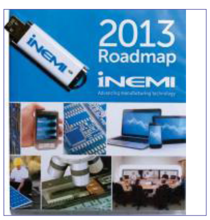
SMTA International Conference on Soldering & Reliability Proceedings on CD, 2013

SMTA

This CD-ROM features the proceedings from the technical program at the International Conference on Soldering & Reliability, held May 14-17, 2013, at the Sheraton Toronto Airport Hotel, Toronto, ON, Canada. There are 30 presentations on topics ranging from Vapor Phase technology and Stencil Design to Bottom Termination Components and Package on Package assembly issues. Research was compiled from a variety of companies including 3M Canada, Alcatel-Lucent, Alpha, BAE Systems, BlackBerry, Celestica Inc., Creation Technologies Inc., Honeywell International Inc., IBM Corporation, Indium Corporation, Kyzen Corporation, Nihon Superior Company, Ltd, Rockwell Collins, Universal Instruments Corporation, several reknowned universities, and more.

For more details on these and other titles, and to order directly, visit the Bookstore on smta.org.

Shopping on smta.org is secure.



Copyright Year : 2013
Full Price : $3000.00
Per-Chapter Price : $500.00

iNEMI 2013 Roadmap on USB

iNEMI

The complete 2013 Roadmap is available on a USB drive for $3000 (plus $100 when shipped outside of North America). This tenth edition of the iNEMI Roadmap features a 73-page executive summary, six chapters that cover product sectors, 20 chapters that cover technology and infrastructure areas, plus related appendices. All together, the document totals more than 1900 pages. If you don't need the whole Roadmap, chapters can be purchased individually.

MEMBER NEWS

Libra Industries' Rod Howell has taken on the title of CEO and has named a new President, Jennifer Altstadt. Howell, the owner and co-founder (and former SMTA President), said he wanted to hire someone who could take care of the day-to-day operations of the business while he focused on long-term strategic planning. Howell said he had been trying to do both as president and realized he would need to split those duties if the company was to continue to grow. Libra Industries currently brings in $30 million to $35 million in annual revenue, Howell said, and he'd like to see that double in the next few years.

Vicor Corporation promoted Ray Whittier Jr. to Principal SMT Engineer, VI Chip Manufacturing Engineering.

productronica 2013

innovation all along the line

International, innovative, unrivaled – productronica is THE leading trade show for electronics production and will open its gates from November 12 – 15, 2013, at the Munich Fair Ground. In 2011, 1,189 exhibitors from 39 countries presented their innovative products and solutions on an exhibition area of 829,000 square feet. 38,500 visitors from more than 80 countries represent an increase of around 34 percent compared to the previous show.

productronica is the only trade show in the world that features the entire value chain for electronics manufacturing - from software to process control, from technology to applications, and from products to system solutions – under one roof. All of the industry's key players will present their products and give an insight into the latest developments and innovations as well as a look at the future of electronics manufacturing.

Visitor registration will open in mid-July at http://productronica.com/en/home.

Contact the U.S. Office:
Francesca Novak
P: 646.437.1016
Email: fnovak@munich-tradefairs.com

Twenty-five-year Members

Corporate

Jon Jay J. Wimer, Valtronic Technologies Inc.

Individual

David Evans, Teradyne, Inc.
Martin J. Henson, Oracle
Richard Jaffe, Group J Design
Gary Krieg, Omni-Tec Inc.
Steve Ratner

Twenty-year Members

Corporate

Dudi Amir, Intel Corporation
Mike Buetow, CIRCUITS ASSEMBLY Magazine
Bruce Kadell, Garmin AT, Inc.
Robert Tarka, Department of Defense
Bill Winther, Vanguard EMS, Inc.

Individual

Howard A. Cyker, SynQor, Inc.
Archie Damman III, Adco Circuits, Inc.
William A. LaPois, L-3 Fuzing & Ordnance Sys
David Manero, Lutron Electronics Company Inc.
Jon Nyland, Digi International
Jonathan Strauch-Nelson, GE Healthcare

Fifteen-year Members

Corporate

Chris Arnold, E-Tool
Jason Edgar, Honeywell International Inc.
Susan Englander, EEI Manufacturing Services
Klaus M. Heimann, FKN Systek, Inc.
Frank Kurisu, SolderMask, Inc.
Richard Otte, Promex Industries Inc.
Vijay Tharmarajah, Surtek Industries Inc.

Individual

Jim Baker, Spectra Sales Corporation (Retired)
Steve Bowen, Benchmark Electronics
Alex Bratnikov, Jabil Circuit, Inc.
Bob Breu, OTC/SPX Corporation
Jeff Burlingame, Benchmark Electronics
James F. Callahan III, O'Callaghan Technology
Mark Carlson, Rockwell Collins
Larry Eshleman
Dean Gregory, WinTronics, Inc.
Paul N. Houston, Engent, Inc.
Timothy Jensen, Indium Corporation
Mark Keene, OT Systems
Delia Lara, Indium Corporation
Jack Maccarone, Argo/Zeta Company
Kathryn Mason, Stanley Supply & Services
Patricia Profator, WinTronics, Inc.
Alan B Siebenthall, Kirby & Demarest
Ronald S. Snyder, GE Aviation Systems
Chance Turner, TMG Electronics Inc.
Tom White

Ten-year Members

Corporate

Sherilyn Hill, PVA
Cyril Meagher, Allendale Electronics Ltd.
Ian Ruef, Ascentec Engineering

Individual

Mumtaz Y. Bora, Peregrine Semiconductor
Diane M. Gietzen-Jett, Visteon Corporation
Joel Herz, Controltek Inc.
Sam T. Lau, Altera Corporation
James William McDonald Jr., EIT, LLC
Dick Molin, Specialty Coating Systems
Wayne Montoya, TE Connectivity Ltd.
Edelando Nicolas, Creation Technologies Inc.
Andrew Pillsbury, Hypertherm Inc.
Jan Daniel Philippus Pretorius, Tabularium
John M. Radman, Trace Laboratories
Richard P. Savard, Raytheon
Daniel Schmidt, McGregor & Associates
Karl Schuepstuhl, IP Systems LLC
Chris Strand, Unisys Corporation

Five-year Members

Corporate

Russ Adams, Prototron Circuits
Sharon Breault, Precision Placement Machines
Steve Hakes, IBE SMT Equipment
Scott Johnson, Micron Technology, Inc.
Denver L. Jones, BSU Inc.
Lance Larrabee, Cobar/Balver Zinn
Kelly Nostrame, Zymet, Inc.
Claude Bubba Powers Jr., Apex Tool Group, LLC

Individual

Diana Baird, ITT Defense Systems
Bill Bansavage, Cambridge America LLC
Devon Beaver, GSA Optimum
Glynn Bernard, Cornet Technoloy
Dwight Broach, BBM, Inc.
John J. Campanella, Circor Aerospace, Inc.
Glen Chin, CEM Ltd
Jimmy Chow P.Eng., Celestica Inc.
Paul Ciorgovean, Autoliv Electronics Canada Inc.
Chris Cleveland, Medco
Danut Coada, Rockwell Automation
Brett Crane, Bird Technologies Group
Kenneth W. Cupples, Plexus Corp.
Silvio Dalla Piazza, Micro Crystal Ltd
David deBorde, Quality Manufacturing Services
Jeanette deChantal
Rangaraj Dhanasekaran, Pactron HJPC Corp
John Edward Dzarnoski Jr. Ph.D., Starkey Hearing Technologies
Yoshinori Ejiri, Hitachi Chemical Co., Ltd.
Brandie S. Fernandez, BBM, Inc.
Waldemar Galka, Telephonics Corporation
Jamie G. Hale, Onyx EMS
Harry Hansen, Air Techniques
Robert Harmer, Ultravolt, Inc.
Jim Hermann, Parker Hannifin - Aerospace
Mark W. Hnatov, Resonance Technologies
Prakash Kapadia, Celestica Inc.
John Kenavan, L-3 Communications NARDA
Mei-Ming Khaw, Agilent Technologies (M)
Daniel Kirschbaum, Watlow Controls
Richard E. Kocheff, Airtron Electronics
Jason Kuhlken, Q Source Inc
Leif Erik Laerum, IBM
Nina Li, Kapsch TrafficCom IVHS
William Martin, Concorde Electronics
Roger Maurizio, North Atlantic Industries
Robert P. McGarry Jr., Circuits, LLC
John McMahon P.E., Celestica Inc.
Michael John Mrazik, Imperial Electronic Assembly
Fred Musa, KB Electronics Inc.
Lian-Huat Ng, Apple Procurement & Operation Management Co., Ltd.
Lei Nie Ph.D., Lab126
Chee Wei Ooi, Plexus Manufacturing Sdn. Bhd.
Reuven Rokah, Rokah Technologies
Diane Semple, Q Source Inc.
John Scott Shaffer MBA, AMS Materials, LLC
Julie Silk, Agilent Technologies
Thomas Solosky, Circuit Sales
Bill Vierra, DiversiTech Representatives, Inc.
Rosanna Wellman, Apex Tool Group, LLC
Ian Williams, Intel Corporation
Ho Bun Wong, Acuma, Inc.

Upcoming Events

July 11, 2013
Ohio Valley Expo & Tech Forum
Independence, OH

July 16-23, 2013
SMTA Webtorial PoP Applications, Requirements, Infrastructure and Technologies

Aug. 13, 2013
Free Webinar: Cleaning a No-Clean Flux and Related Reliability Issues

Aug. 15, 2013
Philadelphia Expo & Tech Forum
Cherry Hill, NJ

Aug. 29-Sep 5, 2013
SMTA Webtorial Conformal Coating In The Factor

Sept. 10, 2013
Capital Expo & Tech Forum
Laurel, MD

Sept. 12, 2013
Intermountain Vendor Expo
University of Utah

Sept. 13, 2013
West Penn "Intro to DfM" Chapter Tutorial
Seneca, PA

Sept. 18, 2013
Wisconsin/Great Lakes Expo & Tech Forum
Milwaukee, WI

Sept. 19-26, 2013
SMTA Webtorial Radiography Inspection as a tool for Quality Control and Assurance

Oct 9, 2013
Long Island Expo & Tech Forum

Oct 13-17, 2013
SMTA International 2013
w/ Co-located IPC Fall Standards Development Committee Meetings
Fort Worth, TX

If you are interested in serving as a chapter officer in your local area, contact SMTA director of chapter relations Karen Frericks: karenchapters@smta.org or 952-920-7682.

HOT TOPICS

Arizona-Sonora Chapter
Chapter Lunch
September 11, 2013 11:30 am
Fiesta Resort

West Penn Chapter
Intro to DfM - Chapter Tutorial
September 13, 2013
Matric, Seneca, PA

Huntsville Chapter
Counterfeit Component Panel Discussion
September 17, 2013 3:00 pm
ADTRAN

Oregon Chapter
Sept. Meeting - Printing & Dispensing Challenges
September 18, 2013 4:30 PM

Wisconsin Chapter
Chapter Training Program
September 19, 2013 09:30am
Milwaukee, WI

LA-Orange County Chapter
LA/OC SMTA Chapter Dinner Meeting
September 19, 2013 6:00 pm
JT Schmid's, Anaheim, CA

FUN AND GAMES

Upper Midwest (Minnesota, Iowa & Dakotas)
SMTA Golf Tournament
July 18, 2013 11:15 am
Stonebrooke Golf Course

Atlanta Chapter
Member Social Cookout!
July 20, 2013 2:30 PM
Rhodes Jordan Park

Connecticut
Rock Cats Baseball Outing
July 23, 2013 5:30pm
Rock Cats Stadium

Wisconsin
Milwaukee Brewer Game
August 16, 2013 7:10
Miller Park

Oregon Chapter
Charity Golf Tournament
August 4, 2013 9:00
Chehalem Glenn in Newberg

Intermountain (ID, UT) Chapter
Golf Scramble
August 8, 2013 8:00 AM
Banbury Eagle, ID

LA-Orange County Chapter
14th Annual Golf 'Get Together'
August 12, 2013 1:00PM
Old Ranch, Seal Beach, CA

SHOW TIME

Ohio Valley Chapter
Expo and Tech Forum
July 11, 2013 9:15am
Independence, OH

Philadelphia Chapter
Expo & Tech Forum
August 15, 2013
Cherry Hill, NJ

Capital (DC) Chapter
Expo & Tech Forum
September 10, 2013
Laurel, MD

Intermountain (ID, UT) Chapter
Vendor Conference and Technical Symposium
September 12, 2013 9:30 AM
University of Utah

Wisconsin Chapter
Vendor Expo / Tech Forum
September 18, 2013 09:30am
Milwaukee, WI

Connecticut Chapter
2013 Tech Expo
October 22, 2013 10:00am
Waterbury, CT

Attendee registration is FREE for Expos and Tech Forums! Plan to attend now and visit with representatives from the major suppliers to the industry, have a chance to win great door prizes, attend **free** technical sessions, and enjoy a **free** lunch! Pre-register to ensure your **free** lunch! For more information please contact Emmy at 952-920-7682, emmy@smta.org.

Surface Mount Technology Association

Journal of Surface Mount Technology
April - June 2013
Volume 26, Issue 2 (Quarterly)
ISSN: 1093-7358

5200 Willson Road, Suite 215
Edina, MN 55424-1316

Phone: 952-920-7682
Fax: 952-926-1819
smta@smta.org

www.smta.org

Good summer to all the members. Now that schools are out of session and many of you are ready for summer vacation or already on it, we bring you this second quarter issue at a leisurely pace; not that summer has anything to do with it, but it sounded like a good excuse. In this issue we present 3 interesting papers reviewed and revised from last year's SMTA International. Please enjoy reading at the beach, by a swimming pool or whichever vacation spot you are lounging at.

Do remember SMTA International 2013 is coming up fast. If you haven't registered yet, please do so. As usual we have a slate full of great presentations and presenters in one single location.

To submit your original papers to the Journal of SMT, please contact SMTA at 952-920-7682, or send me an e-mail at drschada@hotmail.com.

— Srini Chada, Ph.D.
The Journal of SMT Editor/Journal Committee Chair

SOLDER ALLOY CREEP CONSTANTS FOR USE IN THERMAL STRESS ANALYSIS

Robert Darveaux, Ph.D.
Skyworks Solutions, Inc.
Irvine, CA, USA

Corey Reichman
Amkor Technology, Inc.
Chandler, AZ, USA

ABSTRACT

Creep constants were determined by conducting mechanical tests on solder joint array specimens. Either double lap shear or tensile loading was employed. Thirty combinations of alloy, pad metallization, and joint size were characterized. The test temperature range was from -55C to 134C. The strain rate range was from 10^{-8}/sec to 10/sec. The stress range was from 0.1MPa to 100Mpa. All of the data sets were fit to the same basic constitutive relation.

INTRODUCTION

Mechanical testing of solder is used for a two primary purposes: 1) alloy development and selection, 2) determining properties for use in predictive simulation. There are several mechanical test methods which put the material under different types of loading, e.g., tension, shear, torsion, bending, etc. For any particular test, the specimen can be fabricated purely of the bulk alloy, or it can be an actual solder joint (or an array of joints). A particularly good comparison of steady state creep data from several different sources is given by Clech [1].

Solder joints have some features that are unique from bulk specimens. Joints have intermetallic compounds at the interface between the bulk material and the substrate. They can also have intermetallic compounds dispersed throughout the joint. Joints are mechanically constrained at the interface between the substrate and the solder because the substrate is deforming elastically as the solder deforms inelastically. In most cases, a joint size is much smaller than a bulk specimen. Hence, the alloy microstructure of a joint is often difficult to reproduce in bulk. The advantage of testing actual joints is that one can be confident the microstructural effects of actual product have been accounted for.

All of these factors can result in a different mechanical response when a solder joint is subjected to loading as compared to a bulk alloy specimen. Several previous studies on testing actual solder joints are given in Refs [2-12] A comparison of room temperature creep data on near eutectic tin-lead alloy revealed a 5 orders of magnitude range in creep rate at a given stress level [6]. At a given strain rate, there was a 10X range in strength data for joints versus bulk specimens [6]. Solder joint data typically shows higher strength than bulk alloy specimen data. This trend was also evident in data on lead-free alloys compared in Refs. [8,10].

It was shown in Refs [6,12] that joint size and pad metallization also affect the creep behavior of solder alloys. The general trends were that larger joints and NiAu pad metallizaitons produce more creep resistant solder. The influence of these factors was found to be greater at lower test temperatures.

The present paper is a compilation of all the author's work to date on testing solder joint specimens. For each sample type (alloy, joint size, pad metallizaiton), creep constants are given which will enable accurate mechanical simulation using finite element analysis or other analytical methods.

CONSTITUTIVE RELATIONS

Since solder is above half of its melting point at room temperature, creep processes are expected to dominate the deformation kinetics. Steady state creep of solder can be expressed by a relationship of the form [13-15]

$$\frac{d\varepsilon_s}{dt} = C[\sinh(\alpha\sigma)]^n \exp(\frac{-Q_a}{kT}) \qquad (1)$$

where $d\varepsilon_s/dt$ is the steady state strain rate, k is Boltzmann's constant, T is the absolute temperature, σ is the applied stress, Qa is the apparent activation energy, n is the stress exponent, α prescribes the stress level at which the power law dependence breaks down, and C is a constant.

Both shear and tensile loading modes were utilized in the present paper. It has been shown in previous work [6,10] that Von Mises yield criteria work well to convert between shear data and tensile data. The constants C and α are dependent on the loading mode (shear vs. tensile). However, the constants n and Q_a are independent of loading mode. The following relations were used to covert between shear and tension constitutive constants

$$\sigma = \tau\sqrt{3} \quad (2)$$

$$\varepsilon = \frac{1}{\sqrt{3}}\gamma \quad (3)$$

$$C_T = \frac{1}{\sqrt{3}} C_S \quad (4)$$

$$\alpha_T = \frac{1}{\sqrt{3}} \alpha_S \quad (5)$$

Where σ and ε are tensile stress and strain, and τ and γ are shear stress and strain, respectively. C_T and α_T are tensile constants, and C_S and α_S are shear constants in Eq. (1).

EXPERIMENTAL PROCEDURE

All mechanical tests were conducted on solder joint array samples. The most important aspect of this type of experiment is to maintain good alignment in the load train throughout the test. The sample characteristics are given in Table 1.

For the strain rate range between 10/sec and 10^{-3}/sec, constant crosshead displacement rate loading was applied. For strain rates between 10^{-3}/sec and 10^{-8}/sec, constant load creep tests were used. Both tensile loading and double lap shear loading modes were used, as depicted in Figure 1. The stress and strain were calculated as follows for samples loaded in shear:

$$\tau = P / A \quad (6)$$

$$\gamma_{in} = d_{in}/h = (d - P/K) / h \quad (7)$$

Where τ is the shear stress, P is the load, A is the sum total pad area for all joints, γ_{in} is the inelastic shear strain, d is the displacement, K is the spring constant of the grips + solder, and h is the height of the solder joints.

Tensile stress and strain were calculated in a similar manner for samples loaded in tension:

$$\sigma = P / A \quad (8)$$

$$\varepsilon_{in} = \ln((h+d_{in})/h) = \ln((h+d - P/K) / h) \quad (9)$$

Where σ is the tensile stress and ε_{in} is the inelastic tensile strain

Solder Alloy Creep Data

The results of the creep testing are shown in Figures 2 to 31. Most of the tests were conducted in double lap shear mode. Only Figures 3, 4, 5, 23, and 24 represent tests that were conducted in tensile mode. Note that Figures 6, 7, 9, 10, 11, and 15 were from earlier work, so the units on stress are in psi.

Experience has shown that tensile testing of solder joint arrays results in more scatter in the data compared to double lap shear testing. This is due to a higher sensitivity to misalignment in the load train.

Care was taken to remove any data where brittle interface failure of the joints was observed. Nevertheless, the -55C data sets generally have more scatter than the other test temperatures. There at least two possible explanations for this: 1) there is more actual variation in solder properties at low temperatures, or 2) the effect of inaccuracies in the experimental setup are amplified due to higher loads at low temperatures.

Table 1. Solder Joint Array Sample Characteristics

Joints per array	25 to 3840
Joint Pitch (mm)	0.180 to 1.500
Joint Height (mm)	0.061 to 0.478
Pad Diameter (mm)	0.090 to 0.760
Joint Alloy	63Sn37Pb
	60Sn40Pb
	62Sn36Pb2Ag
	95Pb5Sn
	97.5Pb2.5Sn
	100 In
	50Pb50In
	Sn4.0Ag0.5Cu
	Sn3.9Ag0.6Cu
	Sn3.5Ag
	Sn3.0Ag0.5Cu
	Sn2.3Ag + SAC305
	Sn2.3Ag
	Sn1.2Ag
	Sn1.2Ag0.5Cu0.05Ni
	Sn1.0Ag0.5Cu
	Sn0.3Ag0.7Cu0.09Bi
	Sn0.7Cu
Pad Metallization (Top pad -- Bottom Pad)	NiAu – NiAu
	NiVCu -- NiVCu
	NiSn – NiSn
	Cu -- Cu
	Ni -- Cu
	Ni -- NiAu
	NiVCu -- Cu
	NiAu -- Cu
Post Reflow Aging	24hrs @ 125C
Test Temperature	-55C to 134C

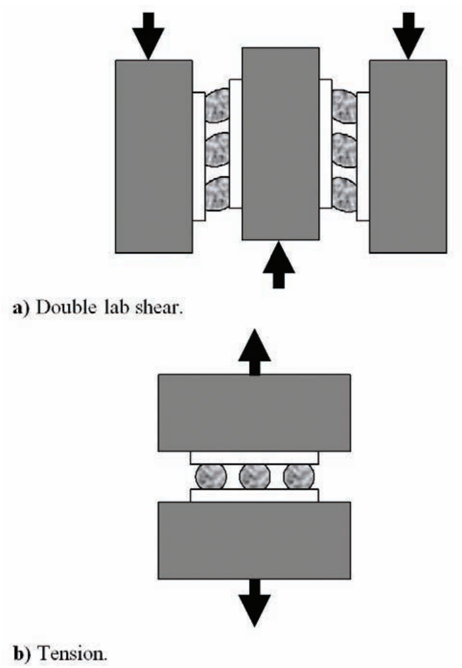


Figure 1. Solder joint array loading orientations.

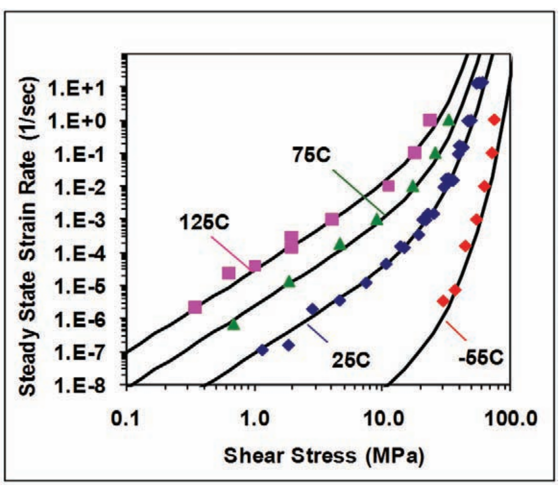


Figure 2. 63Sn37Pb, NiVCu -- NiVCu pad metallization, 0.5mm pitch, 0.208mm joint height, 0.290mm pad diameter.

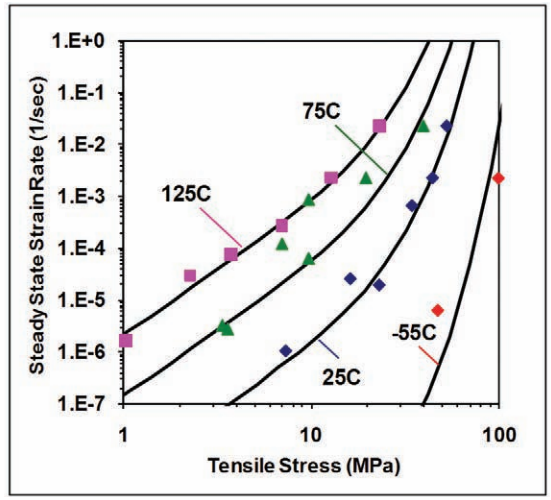


Figure 3. 63Sn37Pb, Ni -- Cu pad metallization, 0.180mm pitch, 0.090mm joint height, 0.090mm pad diameter.

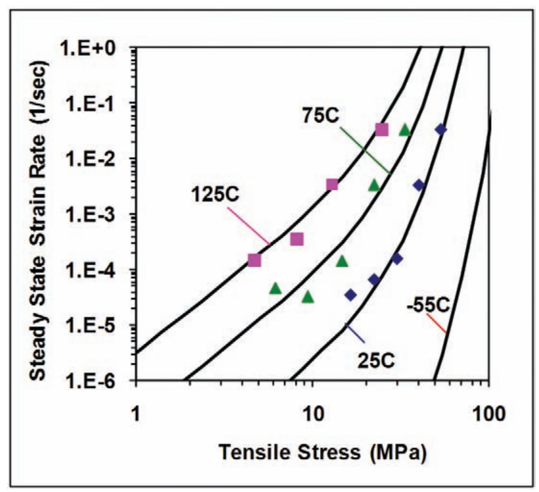


Figure 4. 63Sn37Pb, Ni -- Cu pad metallization, 0.200mm pitch, 0.061mm joint height, 0.106mm pad diameter.

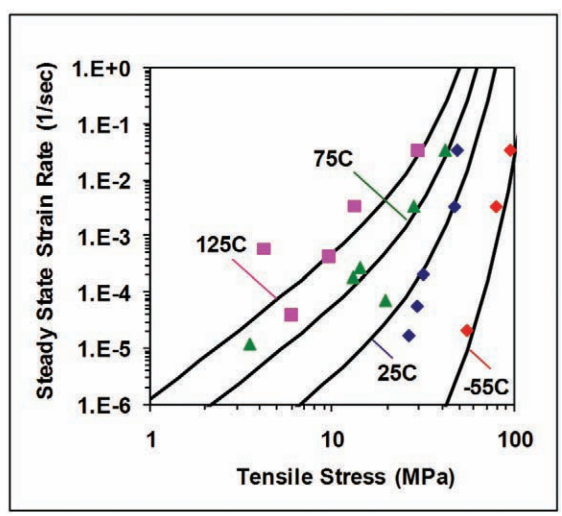


Figure 5. 63Sn37Pb, Ni -- NiAu pad metallization, 0.200mm pitch, 0.061mm joint height, 0.106mm pad diameter.

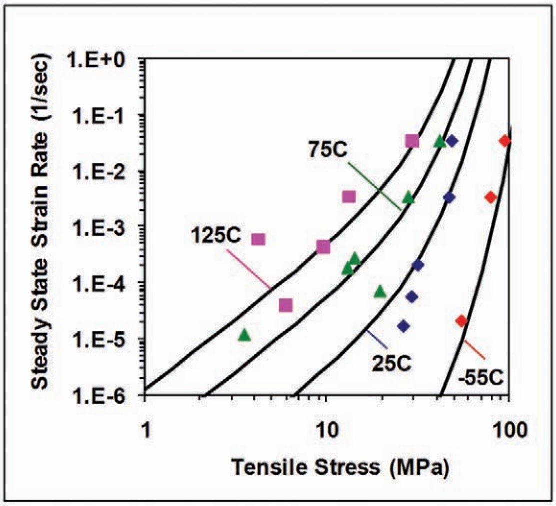


Figure 6. 60Sn40Pb, NiAu -- NiAu pad metallization, 1.5mm pitch, 0.450mm joint height, 0.760mm pad diameter.

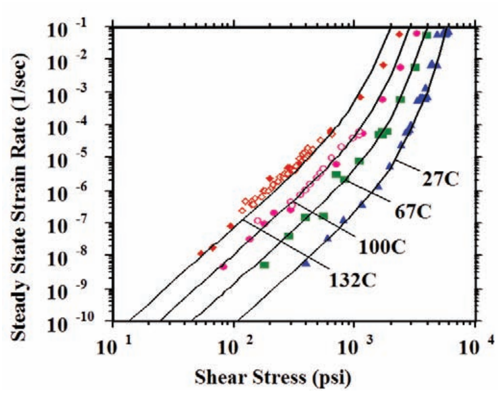


Figure 7. 62Sn36Pb2Ag, NiAu -- NiAu pad metallization, 1.5mm pitch, 0.450mm joint height, 0.760mm pad diameter.

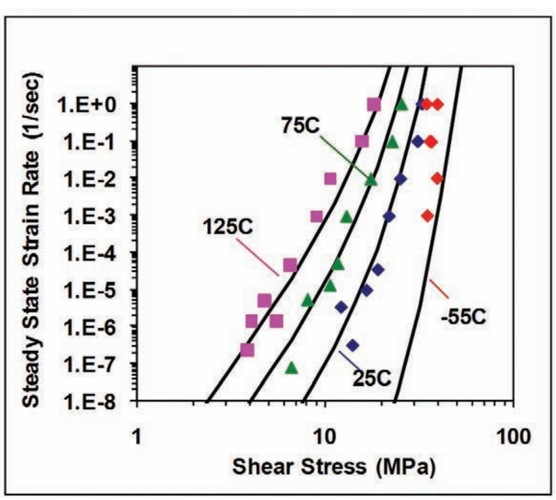


Figure 8. 95Pb5Sn, NiVCu -- NiVCu pad metallization, 0.5mm pitch, 0.213mm joint height, 0.290mm pad diameter.

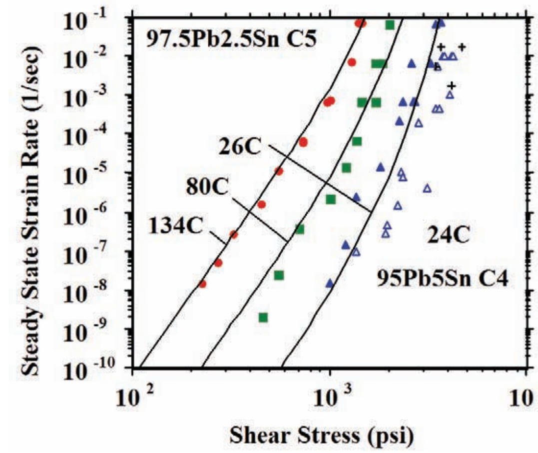


Figure 9. 97.5Pb2.5Sn, NiAu -- NiAu pad metallization, 1.5mm pitch, 0.410mm joint height, 0.735mm pad diameter.

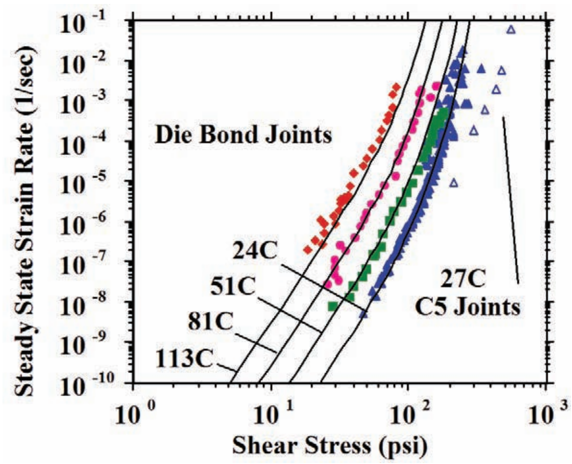


Figure 10. 100In, NiCu – NiCu pad metallization, 10mm square die bond joints, 0.49mm joint height.

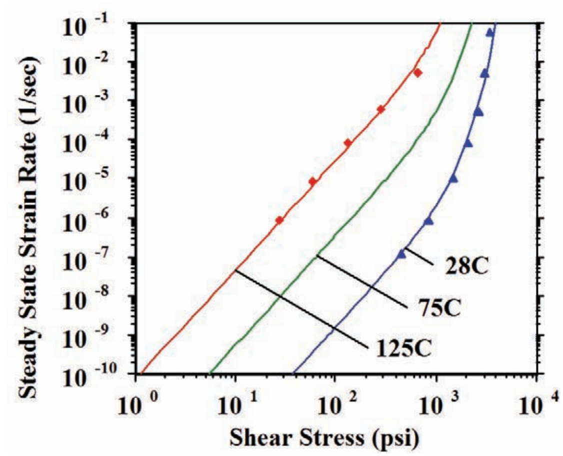


Figure 11. 50Pb50In, NiAu -- NiAu pad metallization, 1.5mm pitch, 0.450mm joint height, 0.760mm pad diameter.

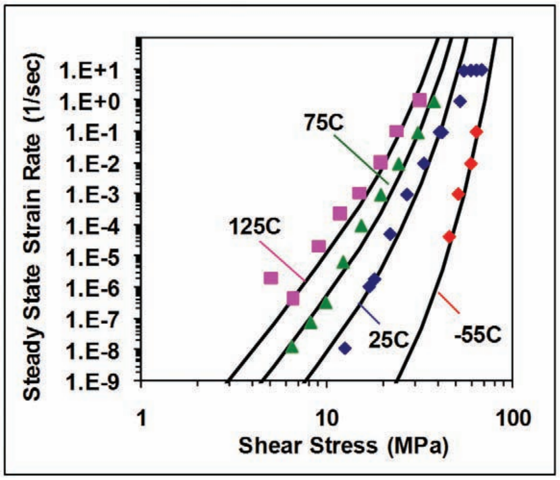


Figure 12. Sn4.0Ag05Cu, NiVCu -- NiVCu pad metallization, 0.5mm pitch, 0.209mm joint height, 0.290mm pad diameter.

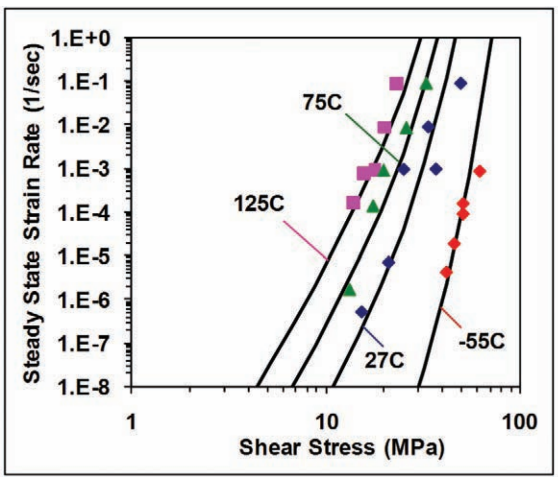


Figure 13. Sn3.9Ag0.6Cu, NiAu -- NiAu pad metallization, 0.4mm pitch, 0.235mm joint height, 0.176mm pad diameter.

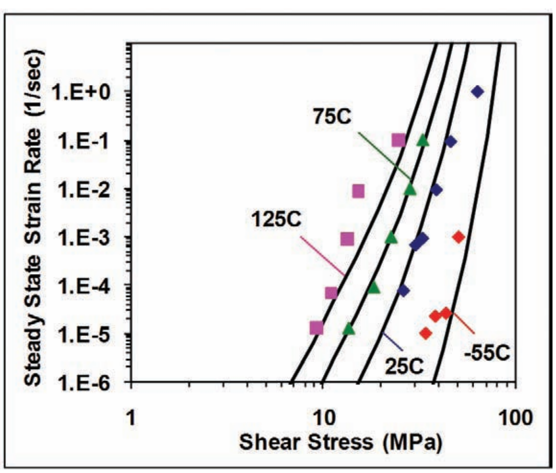


Figure 14. Sn3.9Ag0.6Cu, NiSn -- NiSn pad metallization, 0.4mm pitch, 0.213mm joint height, 0.176mm pad diameter.

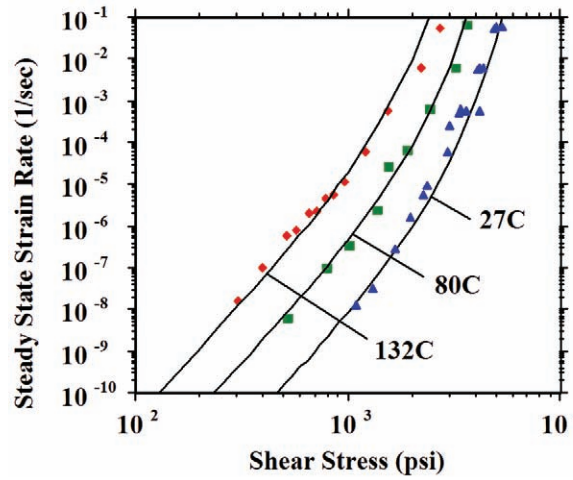


Figure 15. Sn3.5Ag, NiAu -- NiAu pad metallization, 1.5mm pitch, 0.450mm joint height, 0.760mm pad diameter.

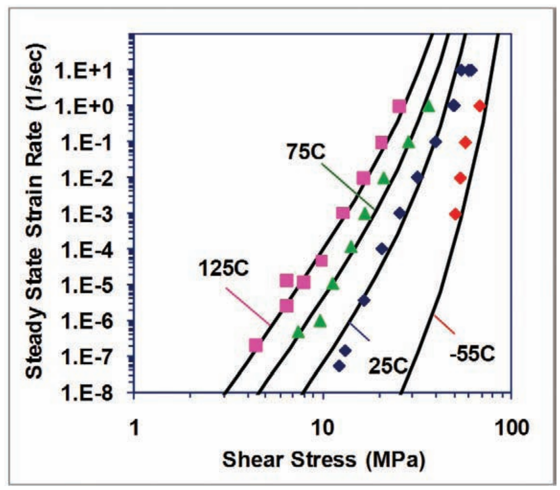


Figure 16. Sn3.5Ag, NiVCu -- NiVCu pad metallization, 0.5mm pitch, 0.213mm joint height, 0.290mm pad diameter.

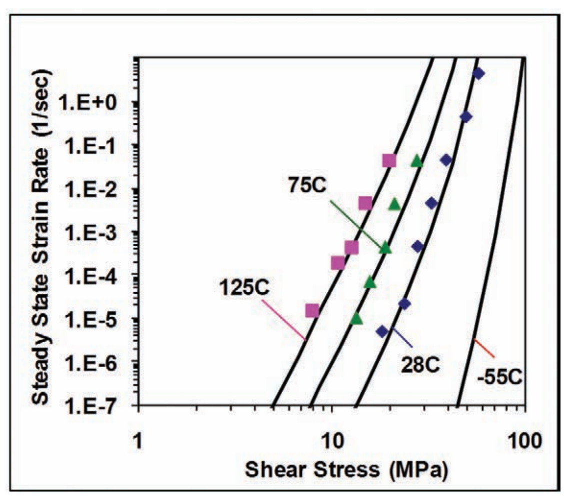


Figure 17. Sn3.0Ag0.5Cu, NiAu -- NiAu pad metallization, 1.0mm pitch, 0.452mm joint height, 0.458mm pad diameter.

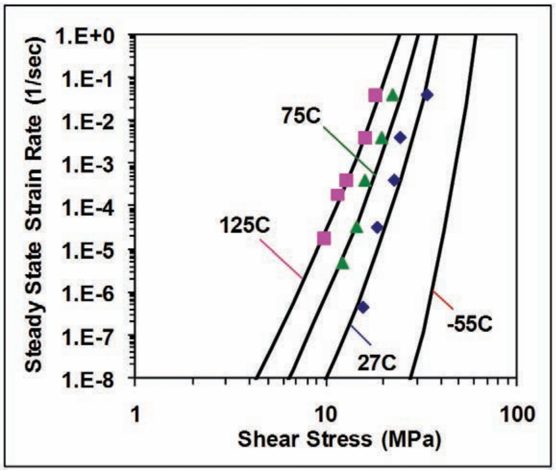


Figure 18. Sn3.0Ag0.5Cu, Cu -- Cu pad metallization, 1.0mm pitch, 0.478mm joint height, 0.454mm pad diameter.

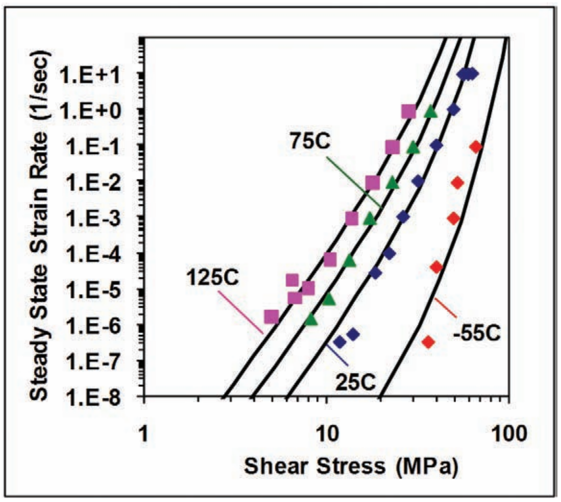


Figure 19. Sn3.0Ag0.5Cu, NiVCu -- NiVCu pad metallization, 0.5mm pitch, 0.211mm joint height, 0.290mm pad diameter.

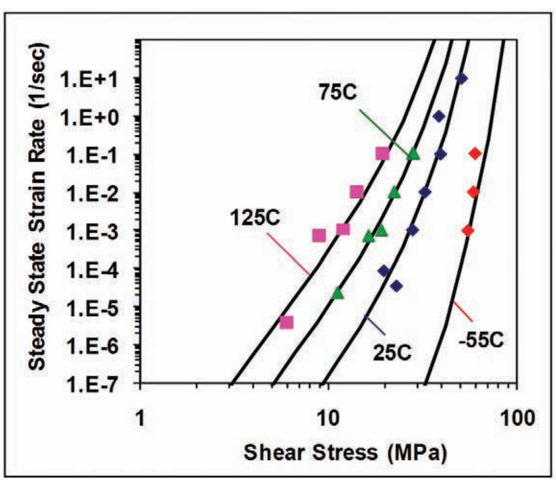


Figure 20. Sn3.0Ag0.5Cu, NiAu -- NiAu pad metallization, 0.400mm pitch, 0.195mm joint height, 0.215mm pad diameter.

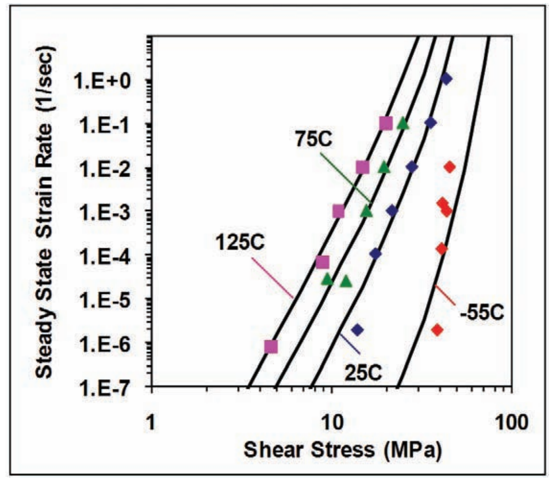


Figure 21. Sn3.0Ag0.5Cu, Cu -- Cu pad metallization, 0.400mm pitch, 0.195mm joint height, 0.215mm pad diameter.

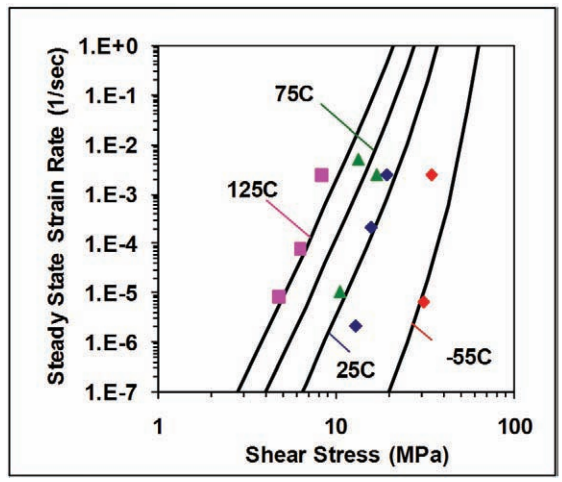


Figure 22. Sn2.3Ag bump + SAC305 SOP, Ni -- Cu pad metallization, 0.200mm pitch, 0.085mm joint height, 0.102mm pad diameter.

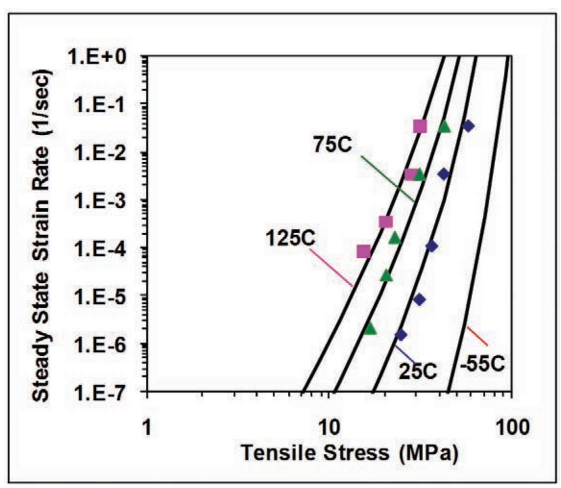


Figure 23. Sn2.3Ag, Ni -- NiAu pad metallization, 0.200mm pitch, 0.061mm joint height, 0.106mm pad diameter

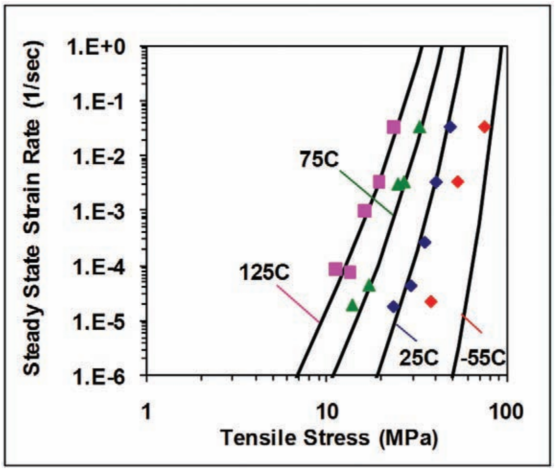


Figure 24. Sn1.2Ag, Ni -- NiAu pad metallization, 0.200mm pitch, 0.061mm joint height, 0.106mm pad diameter

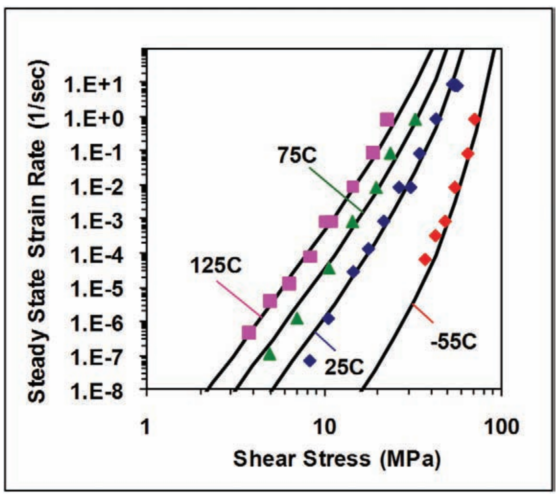


Figure 25. Sn1.2Ag0.5Cu0.05Ni (LF35), NiVCu -- NiVCu pad metallization, 0.5mm pitch, 0.225mm joint height, 0.290mm pad diameter.

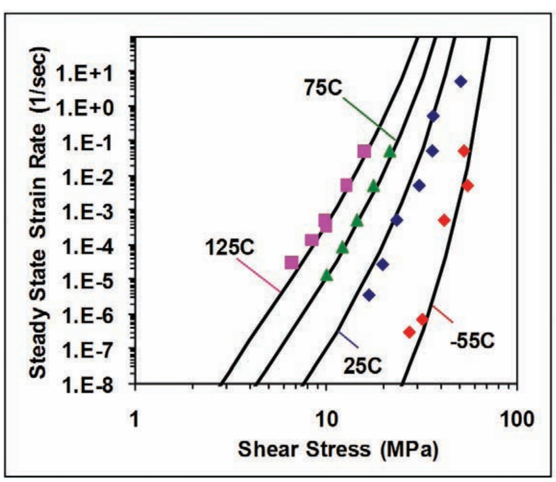


Figure 26. Sn1.0Ag0.5Cu, NiAu -- NiAu pad metallization, 0.8mm pitch, 0.360mm joint height, 0.352mm pad diameter.

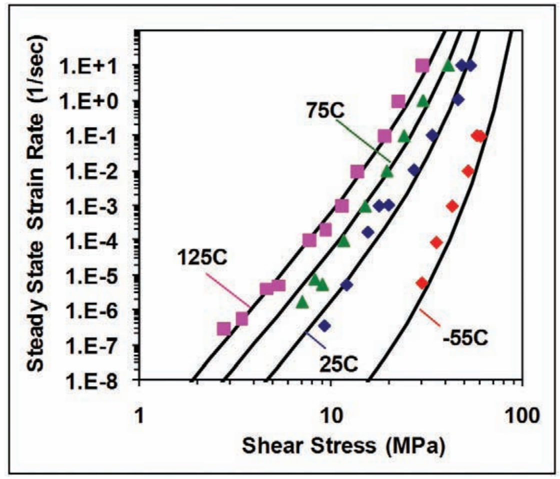


Figure 27. Sn1.0Ag0.5Cu, NiVCu -- NiVCu pad metallization, 0.5mm pitch, 0.214mm joint height, 0.290mm pad diameter.

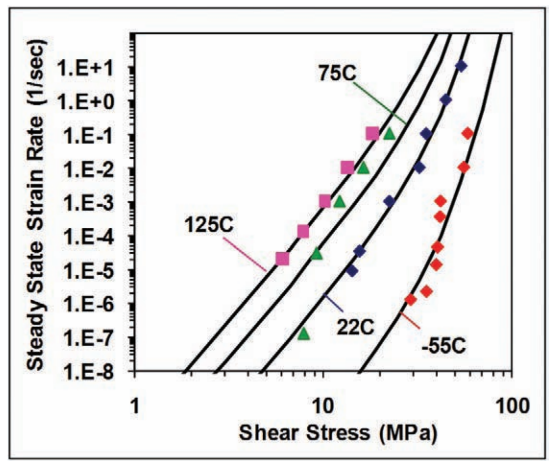


Figure 28. Sn1.0Ag0.5Cu, NiAu -- NiAu pad metallization, 0.4mm pitch, 0.195mm joint height, 0.215mm pad diameter.

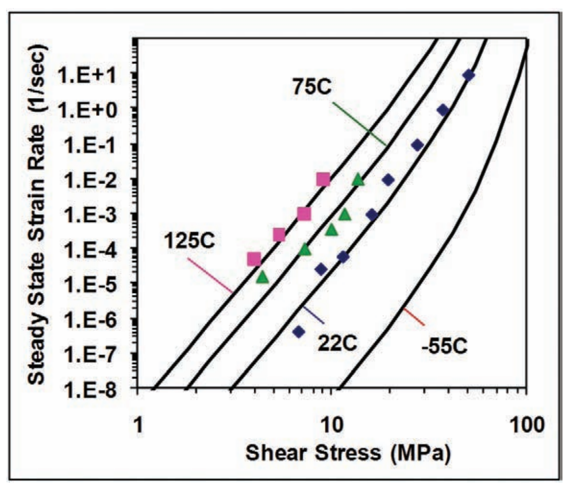


Figure 29. Sn0.3Ag0.7Cu0.09Bi (SAC X), NiVCu -- Cu pad metallization, 0.5mm pitch, 214.mm joint height, 0.281mm pad diameter.

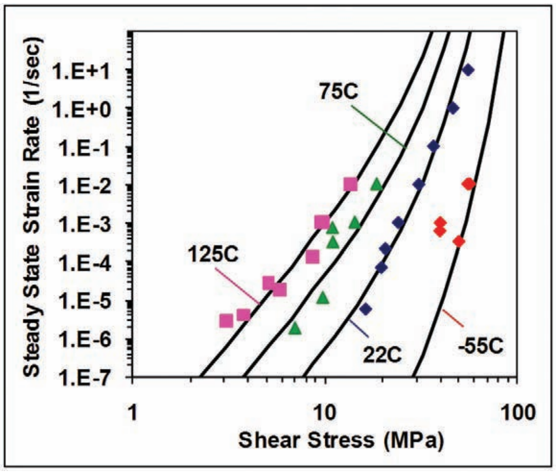


Figure 30. Sn0.3Ag0.7Cu0.09Bi (SAC X), NiAu -- Cu pad metallization, 0.4mm pitch, 0.195mm joint height, 0.215mm pad diameter.

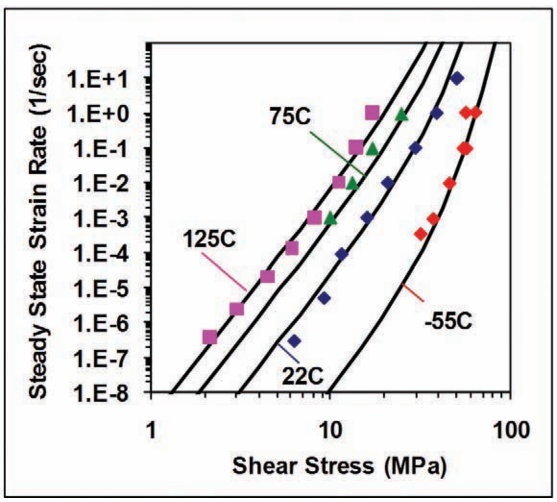


Figure 31. Sn0.7Cu, NiVCu -- NiVCu pad metallization, 0.5mm pitch, 0.210mm joint height, 0.290mm pad diameter.

Solder Alloy Creep Constants

The constitutive relation in Eq. (1) was fit to each individual data set by trial and error method. A plot of the model creep behavior is shown as the solid lines in Figures 2 to 31. It is remarkable that one equation with four constants does a good job of fitting such a wide range of experimental conditions and sample types over 24 years of testing. The largest deviation between model and data typically occurs at the highest strain rates and lowest test temperatures.

A summary of the creep constants for all data sets is given in Table 2. The constants C and α were converted between shear and tension as applicable using Eqs. (4) and (5). Most of the data sets were measured in shear and converted to tensile.

For finite element analysis, one would use the tensile constants for C and α listed in Table 2. One might choose the shear constants for various other closed form problems. It is recommended that an analyst choose a set of creep constants based on the following order of priority: 1) alloy 2) metallization 3) joint pitch (size). Since equation (1) is highly non-linear, it is not recommended to interpolate between values on the table (say between data sets for 0.5mm and 0.2mm pitch joint arrays). Rather, one should pick one set of constants from a specimen that is closest to the analyst's application.

DISCUSSION

In previous papers [2,5,6,7,8,10], both primary creep and time-independent plastic flow were discussed as additional refinements to the constitutive model. It is the author's current belief that these effects can be neglected for the majority of thermal stress analyses.

Experience with the double lap shear sample configuration has shown that misalignment between the two solder joint arrays can cause a higher deformation rate at the beginning of a test because only one array is carrying the majority of the load. As the test progresses, the two sides come into alignment, and both arrays carry the load equally. The net effect of this sample misalighment is that the initial creep rate is artificially high, and the "primary" creep behavior is exaggerated. This same argument applies to the time-independent plastic flow observed at the beginning of a constant displacement rate test.

Additionally, under cyclic loading conditions, testing has shown that most alloys work harden during the first few cycles. Hence, primary creep and time-independent plastic flow are likely negligible during the vast majority of the cycles in a fatigue test.

SUMMARY

1) Creep constants were determined by conducting mechanical tests on solder joint array specimens. Either double lap shear or tensile loading was employed.

2) Thirty combinations of alloy, pad metallization, and joint size were characterized. The test temperature range was from -55C to 134C. The strain rate range was from 10^{-8}/sec to 10/sec. The stress range was from 0.1MPa to 100Mpa.

3) All of the data sets were fit to the same basic constitutive relation. The creep constants for each data set with either shear loading or tensile loading were provided.

ACKNOWLEDGEMENTS

The authors wish to acknowledge K. Linga Murty, Kingshuk Banerji, and CJ Berry for insightful technical discussion, and Thanda Swe, Sabira Enayet, Ian Hsu, Priya Sundarraman, Lakshmi Kari, Scott McCann, and Nabeel Zafer for assistance in sample preparation.

REFERENCES

1] J.P. Clech, "An Obstacle-Controlled Creep Model for Sn-Pb and Sn-Based Lead-Free Solders," Proceedings 2004 SMTA International, pp. 776-802.

2] R. Darveaux and I. Turlik, "Shear Deformation of Indium Solder Joints," IEEE Transactions on Components, Hybrids, and Manufacturing Technology, Vol 13, No 4, December 1990, pp. 929-939.

3] R. Darveaux, E. Yung, I. Turlik, and K.L. Murty, "Mechanical Characteristics of In and Pb5Sn Solders in a Thin Film Multichip Package," Proc. MRS Fall Meeting, 1990.

4] K. Banerji and R. Darveaux, "Effect of Aging on the Strength and Ductility of Controlled Collapse Solder Joints," Proc. TMS-AIME Symposium, November, 1992, pp. 431-442.

5] R. Darveaux and K. Banerji, "Constitutive Relations for Tin Based Solder Joints," Proceedings IEEE 42nd ECTC, 1992, pp. 538-551, and IEEE Trans on CHMT, Vol. 15, No. 6, December 1992, pp. 1013-1024.

6] R. Darveaux, K. Banerji, A. Mawer, and G. Dody, "Reliability of Plastic Ball Grid Array Assembly," Ball Grid Array Technology, J. Lau Editor, McGraw-Hill, Inc., New York, 1995.

7] R. Darveaux, "Effect of Simulation Methodology on Solder Joint Crack Growth Correlation," Proc 2000 ECTC, pp. 1048-1058.

8] R. Darveaux, "Shear Deformation of Lead Free Solder Joints," Proc. 2005 ECTC, pp. 882-893.

9] R. Darveaux, C. Reichman, N. Islam, "Interface Failure in Lead Free Solder Joints," Proc. ECTC, May 2006.

10] R. Darveaux, "Mechanical Testing of Solder Joint Arrays versus Bulk Solder Specimens," Journal of Surface Mount Technology, vol 20, issue 1, pp 11-21, and Proc. SMTAI, 2006

11] R. Darveaux and C. Reichman, "Mechanical Properties of Lead-Free Solders," Proc. ECTC, 2007

12] R. Darveaux, et.al., "Effect of Joint Size and Pad Metallization on Solder Mechanical Properties," Proc. ECTC, 2008.

13] F. Garfalo, Fundamentals of Creep and Creep-Rupture in Metals, The Macmillan Company, New York, NY, 1965.

14] K.L. Murty and I. Turlik, "Deformation Mechanisms in Lead-Tin Alloys, Application to Solder Reliability in Electronic Packages," Proceedings 1st Joint Conference on Electronic Packaging, ASME/JSME, 1992, pp. 309-318.

15] H.J. Frost and M.F. Ashby, Deformation Mechanism Maps, Pergamon Press, 1982, Chapter 2.

APPENDIX

Table 2. Solder Alloy Creep Constants

					Tensile		Shear	
Alloy	Pad Metallization	Pitch	n	Qa	C_T	ϖ_T	C_s	ϖ_s
		(mm)		(eV)	(1/sec)	(1/MPa)	(1/sec)	(1/MPa)
63Sn37Pb	NiVCu – NiVCu	0.50	2.5	0.60	2.31E+05	0.0548	4.00E+05	0.0950
63Sn37Pb	Ni – NiAu	0.20	2.5	0.52	4.00E+03	0.0700	6.93E+03	0.1212
63Sn37Pb	Ni -- Cu	0.20	2.5	0.65	3.00E+05	0.0800	5.20E+05	0.1386
63Sn37Pb	Ni -- Cu	0.18	2.5	0.65	2.00E+05	0.0800	3.46E+05	0.1386
60Sn40Pb	NiAu – NiAu	1.50	3.3	0.55	1.61E+05	0.0670	2.78E+05	0.1160
62Sn36Pb2Ag	NiAu – NiAu	1.50	3.3	0.55	8.03E+04	0.0670	1.39E+05	0.1160
95Pb5Sn	NiVCu – NiVCu	0.50	7.0	0.90	2.89E+07	0.0577	5.00E+07	0.1000
97.5Pb2.5Sn	NiAu – NiAu	1.50	7.0	1.15	2.66E+11	0.0670	4.60E+11	0.1160
100 In	NiCu – NiCu	-	5.0	0.90	5.77E+07	1.0046	1.00E+08	1.7400
50Pb50In	NiAu – NiAu	1.50	2.8	1.08	3.00E+11	0.1046	5.19E+11	0.1813
Sn4.0Ag0.5Cu	NiVCu – NiVCu	0.50	7.5	0.75	1.15E+06	0.0335	2.00E+06	0.0580
Sn3.9Ag0.6Cu	NiAu – NiAu	0.40	7.5	0.75	3.46E+05	0.0346	6.00E+05	0.0600
Sn3.9Ag0.6Cu	NiSn – NiSn	0.40	7.0	0.65	1.73E+05	0.0289	3.00E+05	0.0500
Sn3.5Ag	NiAu – NiAu	1.50	5.5	0.75	1.42E+05	0.0527	2.46E+05	0.0914
Sn3.5Ag	NiVCu – NiVCu	0.50	7.5	0.75	2.31E+07	0.0289	4.00E+07	0.0500
Sn3.0Ag0.5Cu	NiAu – NiAu	1.00	8.5	0.95	5.77E+10	0.0231	1.00E+11	0.0400
Sn3.0Ag0.5Cu	Cu – Cu	1.00	9.0	0.85	5.77E+07	0.0346	1.00E+08	0.0600
Sn3.0Ag0.5Cu	NiVCu – NiVCu	0.50	7.0	0.60	1.15E+06	0.0231	2.00E+06	0.0400
Sn3.0Ag0.5Cu	NiAu – NiAu	0.40	6.5	0.80	4.62E+07	0.0346	8.00E+07	0.0600
Sn3.0Ag0.5Cu	Cu – Cu	0.40	7.5	0.65	1.15E+07	0.0260	2.00E+07	0.0450
Sn2.3Ag + SAC305	Ni -- Cu	0.20	7.5	0.65	5.77E+07	0.0260	1.00E+08	0.0450
Sn2.3Ag	Ni–NiAu	0.20	7.0	0.70	2.00E+05	0.0450	3.46E+05	0.0779
Sn1.2Ag	Ni–NiAu	0.20	7.0	0.80	5.00E+07	0.0450	8.66E+07	0.0779
Sn1.2Ag0.5Cu0.05Ni (LF35)	NiVCu – NiVCu	0.50	7.0	0.60	5.77E+06	0.0231	1.00E+07	0.0400
Sn1.0Ag0.5Cu	NiAu – NiAu	0.80	8.0	0.85	5.77E+08	0.0346	1.00E+09	0.0600
Sn1.0Ag0.5Cu	NiVCu – NiVCu	0.50	6.5	0.60	2.31E+06	0.0260	4.00E+06	0.0450
Sn1.0Ag0.5Cu	NiAu – NiAu	0.40	6.5	0.60	2.31E+06	0.0260	4.00E+06	0.0450
Sn0.3Ag0.7Cu0.09Bi (SACX)	NiVCu – Cu	0.50	6.5	0.60	5.77E+08	0.0173	1.00E+09	0.0300
Sn0.3Ag0.7Cu0.09Bi (SACX)	NiAu -- Cu	0.40	6.0	0.75	2.89E+07	0.0346	5.00E+07	0.0600
Sn0.7Cu	NiVCu – NiVCu	0.50	6.5	0.55	1.27E+07	0.0231	2.20E+07	0.0400

BIOGRAPHIES

Robert Darveaux, Ph.D. is Vice President at Skyworks Solutions, Inc. Robert has over 20 years of experience in the IC packaging field at the Microelectronics Center of North Carolina, Motorola, and Amkor. Robert has a B.S. in Nuclear Engineering from Iowa State University and a Ph.D. in Materials Science and Engineering from North Carolina State University. His areas of expertise in IC packaging include thermal and mechanical simulation, materials characterization, failure analysis, and fatigue life prediction for solder joints. Mr. Darveaux has won several major awards including best presentation at 1995 Surface Mount International Conference, best paper at 2003 SMTA Flip Chip and BGA Packaging Technologies Workshop, best paper at SMTAI 2006, and best paper at ECTC 2006. Robert has published 77 technical papers and has 24 patents.

Corey Reichman is an R&D product manager at Amkor Technology. He's been helping to bring advanced IC package technologies to production since 2005. He is currently working on Amkor's embedded die fan-out technology for fine pitch and ultra-thin IC package applications. He has several years' experience in material characterization and advanced testing methods. Corey has an M.S. Degree in Technology from Arizona State University.

A NANO SILVER REPLACEMENT FOR HIGH LEAD SOLDERS IN SEMICONDUCTOR JUNCTIONS

Keith Sweatman[1], Tetsuro Nishimura[1], and Teruo Komatsu[2]
[1]Nihon Superior Co., Ltd. and [2]Applied Nanoparticle Laboratory Co., Ltd.
Osaka, Japan

ABSTRACT

While it is now widely accepted that most electronic assembly can be reliably effected with lead-free solders, a practicable alternative to the high-lead high-melting-point solders has not been available. That reality has been acknowledged by the interim exemption from the requirements of the EU RoHS Directive granted for solders with 85% or more of lead. With no direct replacement yet found by conventional alloying of elements permitted by the RoHS Directive the search for a replacement for these high-lead solders has extended to alternative joining materials. One approach has been to take advantage of the reactivity of nano particles of silver to make a product that while ultimately having a melting point at or near the silver melting point of 961.8°C can combine to form reliable connections at temperatures much lower than that. The challenge in this approach is that the very reactivity that makes the formation of a joint possible at a relatively low temperature means that the nano silver tends to be unstable. In this paper the authors report the development of a unique nano silver material that is manufactured and stabilized in an alcohol environment to produce a material that can be used to make reliable joints between a wide range of the substrates commonly used in electronics in process conditions similar to those used with high-lead solders. This material can be used to make joints to ferrous materials (e.g. stainless steel) as well as non-ferrous materials such as copper and nickel. And most importantly for component manufacture this new material bonds strongly to semiconductor materials such as silicon. Where even longer life in thermal cycling is required the silver structure can be reinforced by the addition of other materials in the form of particles of the appropriate size. The paper will include details of mechanical and reliability testing of joints made with these materials under a range of temperature, pressure and atmosphere conditions.

Key words: Nano Silver, die attach

INTRODUCTION

The main application for high- Pb solders that resulted in the granting of an exemption from the requirement of the EU RoHS Directive has been in semiconductor packaging. The relatively high melting point of these solders (around 300°C) means that joints made with them in earlier stages of component assembly are not disturbed by subsequent stages of assembly with lower melting solders (step soldering) or by the high peak temperature sometimes required in final reflow soldering.

For power semiconductors the die-attach material has to be able to maintain a reliable joint at the relatively high operating temperature of these devices while at the same time providing a high thermal conductivity path for dissipation of the heat generated during their operation.

In this application the trend to wide bandgap semiconductor devices such as SiC power diodes and transistors means that there is an advantage if the die- attach material can sustain a higher operating temperature than can the high-Pb solders. With SiC devices a substantial increase in power density can be achieved because of its higher thermal conductivity, higher breakdown voltage and higher saturated carrier velocity. The larger bandgap of SiC can allow higher junction temperatures without compromising performance. [1]

The conventional metallurgical alternatives to the high-lead solders such as the gold-tin eutectic have a processing temperature that is higher than the semiconductor can tolerate without degradation, And another alternative, silver-filled epoxy cannot always provide the thermal conductivity that is required to keep the die at a temperature at which it can operate at maximum efficiency [1] [2].

The relatively high surface activity of nano particles means that, for example a 2.4nm Silver particle would be expected to have a melting point of 350°C [3], much less than the 961.8°C melting point of bulk silver (Figure 1). The outer layers of such a particle would have a mobility similar to that of the molten state at even lower temperatures so that they will bond to each other or to other compatible materials by wetting and interdiffusion at temperatures well below those required for conventional sintering of conventional Silver powder.

Although the application of external pressure during the sintering process does increase the area of contact of the particles it is not essential in sintering nano silver particles. Even at temperatures less than those used in reflowing the high-lead solders the capillary forces generated by the mobile atoms at the surface of the silver are sufficient to ensure the wetting of adjacent particles with which they are in contact.

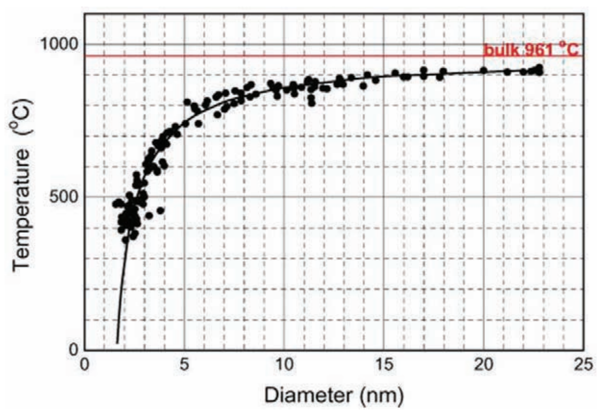


Figure 1. Silver melting point as a function of particle size [4]

Since silver is so much stronger than solder the full density of silver is not required to achieve the strength required in this application. In fact the lower modulus of the porous structure is an advantage in reducing the stress generated in the chip during thermal cycling because of the differences in the coefficient of thermal expansion

When properly formulated, pastes based on nano particles of silver can be processed to form reliable joints at temperatures that fall within a range similar to that required for the high-Pb solders and even lower.

NANO SILVER

There are significant challenges to be faced in delivering the highly reactive nano silver particles to the joint area and then facilitating their bonding to form a structurally strong joint that delivers the required levels of electrical and thermal conductivity.

Manufacturing the nano silver particles in itself is a major challenge but if they are to remain as nano particles with the properties required for them to sinter at the lowest possible temperature they have to be stabilized until they are in place in the joint gap ready for sintering. That is achieved by passivating or capping the particle during the manufacturing process with a coating that bonds to the nano silver surface while presenting a resistant external surface.

Chemicals such as thiols, amines and carboxylates have been identified as effective capping materials [2] but these are bound strongly to the silver and require a high temperature for their removal, to some extent negating the chief advantage of the nano particles they are protecting. Some capping materials require sintering to occur in air so that they can be removed by oxidation and that can compromise other parts of the component that need the protection of a nitrogen atmosphere at sintering temperatures.

Another disadvantage of some of these capping agents is residues of sulphur and nitrogen compounds that can interfere with the performance of the sintered silver and contribute to corrosion problems in service.

There is thus a strong motivation to identify a capping material that would not suffer from these disadvantages and make possible wider application of nano-silver bonding as a reliable die-attach material.

For practical application in commercial mass production the nano-silver bonding materials must also have the physical properties required by the application process, which might be screen printing, dispensing or dipping. This is achieved by dispersing the capped nano- silver particle in a suitable vehicle. The rheology can also be optimised by the inclusion in the mix of sub-micron particles of silver or other metals such as Cu and by adjustment of the particle size distribution

While offering the possibility of relatively low process temperatures and high temperature reliability, silver suffers from the disadvantage of a relatively high elastic modulus so that potentially damaging levels of stress can be developed in the die by the strains arising from CTE differences during the thermal cycling that can occur in service. Another objective in optimizing nano silver bonding materials is, therefore, the control of the microstructure to minimise the elastic modulus while retaining a high level of thermal conductivity.

ALCOXIDE-PASSIVATED NANO SILVER

In an attempt to address the problems encountered with established nano silver capping materials the possibility of using alcohols was explored. These can attach to the silver through the formation of alcoxides with silver atoms on the surface of the nano particle. The advantage of these chemicals in this application is that the oxygen-silver bond, while strong enough to stabilize the nano particle during manufacturing processes and subsequent storage and handling, is weak enough that it can be broken at a relatively low temperature to expose the active surface of the nano particle so that it can bond to adjacent particles. This opens the way to nano-silver materials that can effect bonding with thermal profiles comparable with those used for reflow soldering.

For example, alcoxide-capped nano silver particles were produced by reacting silver carbonate (Ag2CO3) with n-dodecanol (CH3(CH2)11OH) or n-decanol (CH3(CH2)9OH) under a nitrogen atmosphere. In this reaction the hydrogen atom (H) in the hydroxyl group at the end of n-dodecanol or n-decanol molecule (Figure 2 (a)) is replaced by a silver atom on the surface of the nano particle as it forms by reduction of the silver carbonate (Figure 2(b)) [5]

The result, a nano silver particle, protected by the n-dodecanoxide molecules, is illustrated schematically in Figure 3.

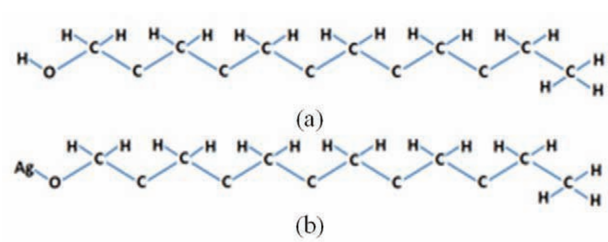


Figure 2. n-dodecanol (a) and Ag n-dodecanoxide (b)

The resulting mixture was cooled and the stabilized nano-silver particles filtered out washed in ethanol, dried and dispersed in hexane. The nature of the material so produced was confirmed by placing some of this dispersion on a carbon film substrate for examination in a transmission electron microscope (TEM).

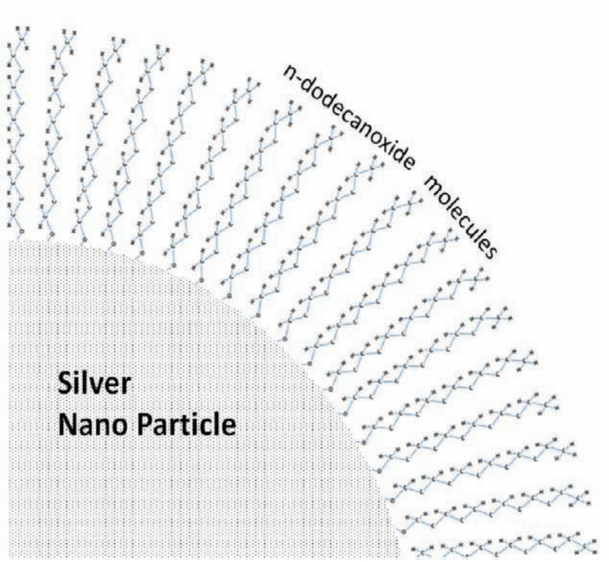


Figure 3. Schematic representation of alcoxide-passivated nano silver particle.

The particles were observed to be roughly spherical with a diameter of <5nm (Figure 4). The lattice planes of these crystalline particles is apparent in the TEM image and the estimated 0.23nm spacing between planes is consistent with the spacing of the [111] plane of silver's close packed cubic crystal structure.

The arrangement of the nano-silver particles on the carbon film in an approximately hexagonal pattern (Figure 5) suggests that in that area they are close packed so that their separation distance is determined by the thickness of the protective alcoxide coating. The estimated gap between the nano-silver cores of these particles of 2.5nm is close to the expected length of two n-dodecanoxide molecules aligned end to end, which is consistent with the passivation model illustrated schematically in Figure 3.

Similar reactions can be effected with shorter alcohols but as the number of carbon atoms in the alcohol falls the size of the nano particle produced increases (Figure 6).

SINTERING NANO SILVER

Nano-silver particles were mixed with 0.4μm silver powder in an isobonyl cyclohexanol (IBCH) vehicle to achieve a total metal content of 87% with the dodecanoxide-passivated nano-silver. This mixture was subjected to thermogravimetric and differential thermal analysis in air and nitrogen atmospheres with the temperature being raised at the rate of 10°C/minute.

The stages in the sintering process are apparent in Figure 7. The first stage is evaporation of the carrier and removal of the passivation layer. In air there is a highly exothermic reaction as the passivating alcohol is oxidized but in a nitrogen atmosphere the alcohol simple detaches with little heat evolution. With the passivation layer removed the active surface of the nano silver particles is exposed and the sintering proceeds.

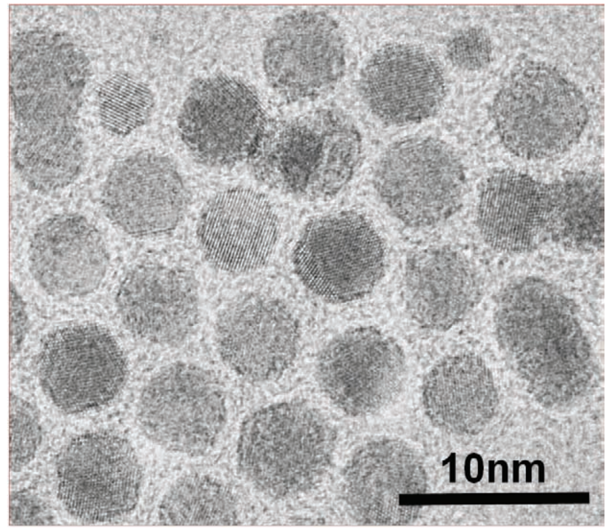


Figure 4. Dodecanoxide-passivated nano-silver particles recovered from reaction with Ag2CO3.

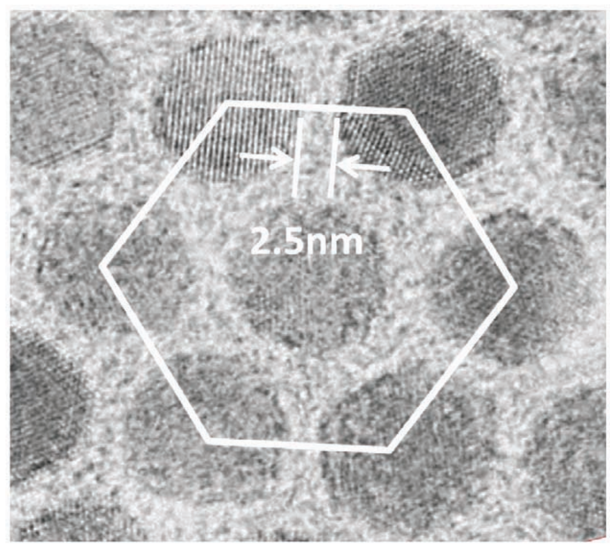


Figure 5. Close-packed arrangement of nano-silver particles with spacing approximately twice the length of the passivating n-dodecanol molecule

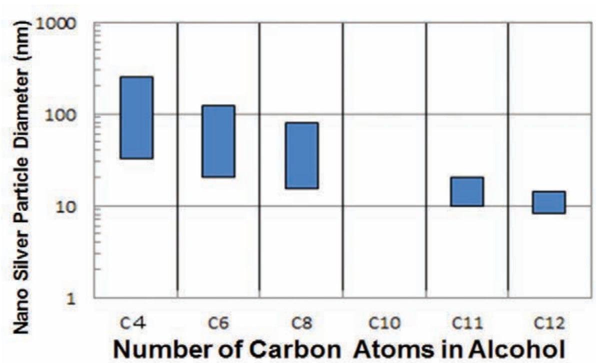


Figure 6. Relationship between the size of the silver nano particle and the alcohol used in its manufacture.

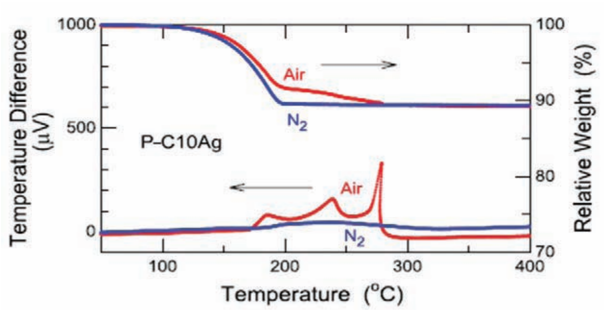


Figure 7. TGA-DTA plots for decanoxide-passivated nano-silver and 5µm silver mixtures dispersed in IBCH.

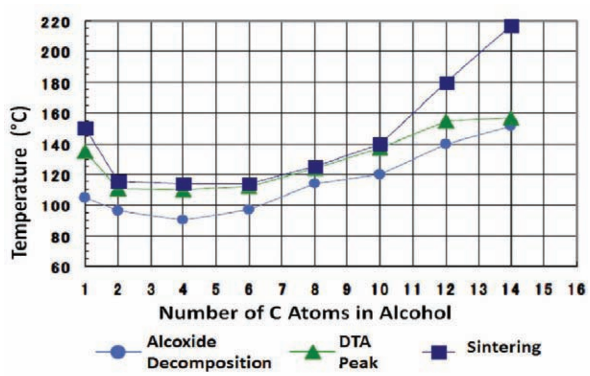


Figure 8. Sintering behaviour as a function of alcoxide passivator.

The temperature at which sintering occurs varies with the number of carbon atoms in the passivating alcoxide molecule and it can be seen in Figure 8 that sintering can be effected at temperatures under 120°C nano silver passivated with alcoxides with 2-6 carbon atoms. There is, however, a trade off in that the passivation by these shorter alcoxide molecules is not as stable as that of the longer molecules.

OPTIMIZING THE NANO SILVER PASTE

While it is possible to form a joint by sintering pure nano-particles there are cost and performance advantages to be achieved by mixing nano particles with conventional particles to which the nano particles can also bond at low temperatures. This arrangement is illustrated schematically in Figure 9.

The idea is to use a range of particle sizes that when bonded will fill the volume to the level required to achieve the required mechanical, electrical and thermal properties. The sub-micron voids in the sintered paste (Figure10) mean that the bond is more compliant than if it were solid silver so that the stress imposed on the die during thermal excursions due to CTE differences can be at least partly accommodated. However, the electrical and thermal conductivity of the sintered bond are still adequate.

PROPERTIES OF SINTERED NANO SILVER

The electrical conductivity of the sintered silver was assessed by printing a film of paste onto glass and measuring its resistance using the four terminal method. The data summarized in Figure 11 indicates that resistance varies in the range 2-15µΩcm, which is generally greater than the 1.6µΩ resistivity of bulk silver but at least as good as the resistivity of reflowed Pb-5Sn solder paste and better than the resistivity of silver/epoxy paste.

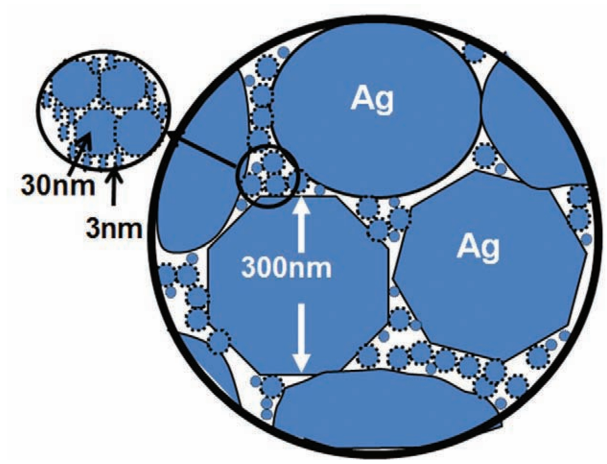


Figure 9. Schematic representation of a typical mix of nano silver particles with larger silver particles

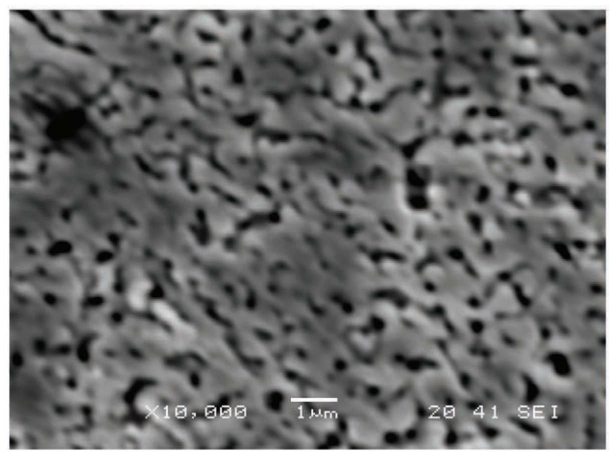


Figure 10. Submicron voids in sintered alcoxide-passivated nano silver

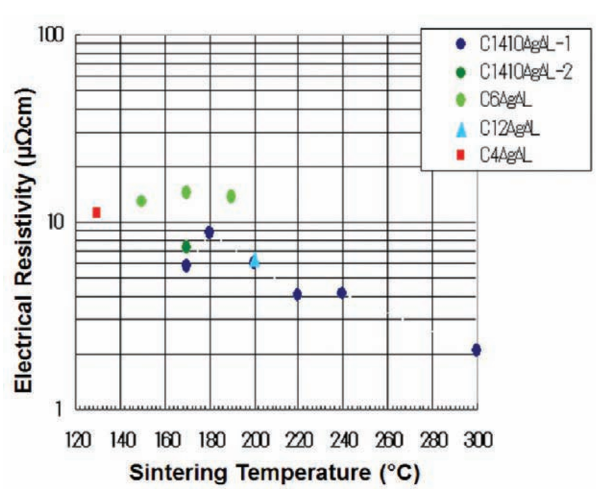


Figure 11. Electrical resistivity of nano silver paste as a function of sintering temperature. Sintering temperature varies with the number of carbon atoms in the passivating alcoxide.

EVALUATION

As a test of the practical applicability of pastes based on this nano silver technology a silicon diode package such as that represented in schematically in Figure 12 was assembled. The finish on the 2.3mm x 2.3mm x 0.25mm diode chip was gold and the substrate copper.

In the nitrogen atmosphere the assembly was heated to 300°C, a temperature similar to that which would be required to reflow the high-lead solder paste normally used in the manufacture of this product. In air the temperature was raised to 350°C to allow for burning off of the passivating material. The total time of the sintering process was 25 minutes in the nitrogen atmosphere and 30 minutes in air. No pressure was applied to the joint during the sintering process. After the joint was effected the components were packaging in resin according to normal production practice.

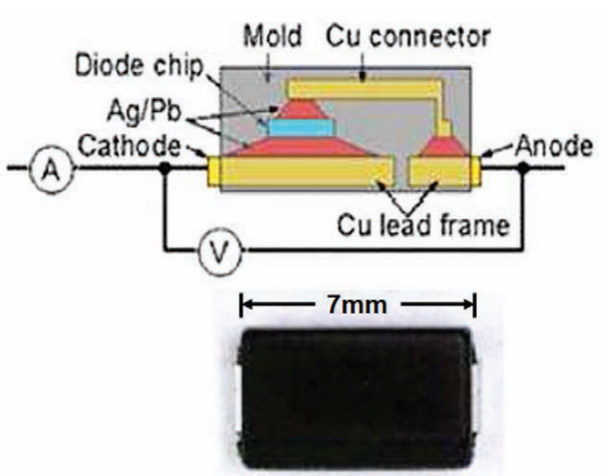


Figure 12. Nano-silver evaluation package

The stability of the electrical and thermal resistance of the joint was assessed by exposing the package to thermal cycling -55°C to 150°C. The results are plotted in Figure 13.

The electrical resistance was taken to be indicated by the forward voltage V_F at a constant current of 3A. Thermal resistance was estimated by measuring the difference in V_F before and after Joule heating with 100ms pulse of 10A.

In the as-manufactured condition diodes assembled with pastes based on nano silver passivated with both dodecanoxide and decanoxide had electrical and thermal resistances similar to those of that assembled with high-lead solder paste. The electrical resistance of those assembled with nano silver in air suffered rapid increase in electrical resistance. The increase in resistance of the diodes assembled with nano silver paste and sintered in nitrogen was similar to that of the diodes assembled with high-lead solder paste.

While the thermal resistance of the diode assembled with high-lead solder paste or nano silver pasted sintered in nitrogen remained stable, that of the diodes assembled with nano silver paste passivated with dodecanol and deconal pastes sintered in air suffered significant loss of conductivity. Further investigation is required but it is presumed that the lower stability of joints sintered in air is a consequence of oxidation of the silver. An advantage of the alcoxide passivation is that oxygen is not required in its removal during the sintering process so that the process can be carried out in a nitrogen atmosphere. Simple breakdown of the alcoxide bond is sufficient to allow the sintering process to proceed.

Metallographic examination of a cross-section through the joint to the copper substrate effected by the nano silver paste indicates that it differs from that formed by the high-lead solder paste in that there is no intermetallic layer at the interface. The silver is bonded directly the copper substrate (Figure 14).

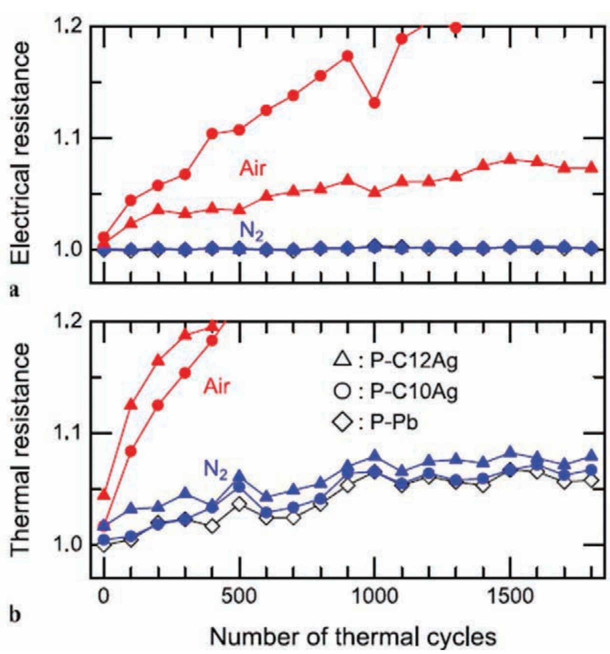


Figure 13. Electrical and thermal resistance of silicon diode package sintered in air and nitrogen as a function of the number of thermal cycles of -55°C-150°C. Results are normalized to that of the diode assembled with high-lead solder paste as manufactured. In the product code C12 and C10 indicate the number of carbon atoms in the passivating alcohol

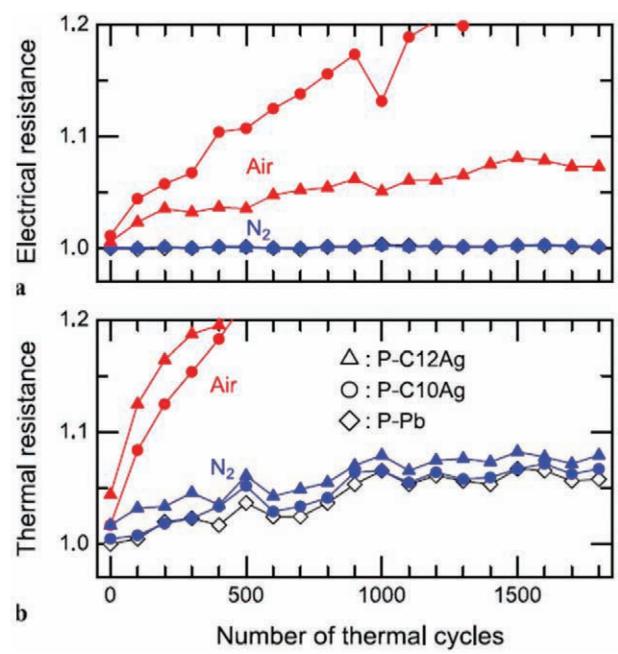


Figure 14. The bond line between the copper substrate and the sintered nano silver paste.

MECHANICAL PROPERTIES

Shear testing indicated the greater strength of joints made to copper with the the sintered alcoxide-passivated paste compared with those made with reflowed Pb-5Sn solder paste (Figure 15).

Although the shear strength of joints was greater when 1MPa of pressure was applied to the shear test piece during sintering the strength of joints made with the alcoxide-passivated nano silver paste exceeded that of a reflowed Pb-5Sn joint (Figure 17) even when the paste was sintered without applied pressure.

As explained earlier the sintering temperature can be adjusted by selecting the number of carbon atoms in the alcohol used. The results of shear testing joints made between copper surfaces with nano silver material fired at low, medium and high temperatures indicates that although those sintered at high temperature are stronger, even those sintered at lower temperatures are at least comparable in strength to joints made with reflowed Pb-5Sn solder.

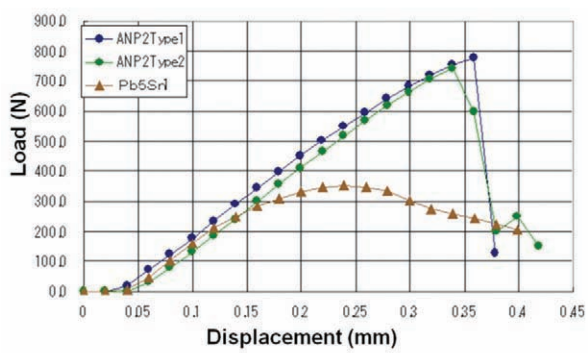


Figure 15. Shear testing load-displacement plots for sintered alcoxide-passivated nano silver joints to copper compared with reflowed Pb-5Sn joints.

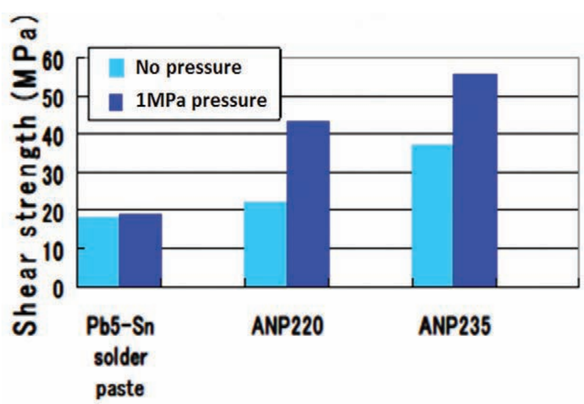


Figure 16. Shear strength of joint made to copper with nano silver solder paste with and without 1 MPa pressure compared with that of Pb-5Sn solder paste.

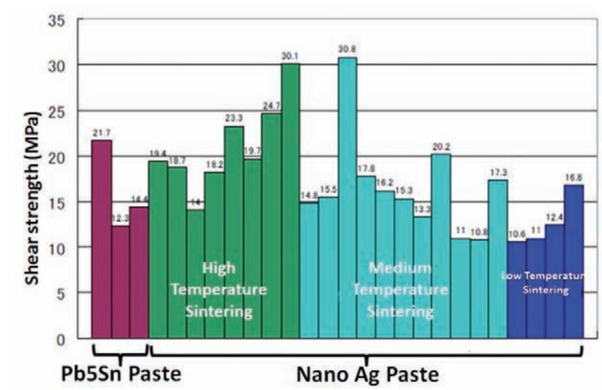


Figure 17. Shear strength of silver pastes sintered without pressure compared with reflowed Pb-5Sn solder paste.

APPLICATIONS OF NANO SILVER PASTE

In addition to die attach applications such as that described earlier in this paper alcoxide-passivated nano silver pastes can used to create printed wiring on substrates such as polyimide (Figure 18) and to be effective in wire bonding (Figure 19).

The alcoxide-passivated nano silver paste has been proven to have high bond strength to silver, gold, platinum, copper, iron and 304 stainless steel surfaces. The tenacious oxide films on nickel and aluminium interfere with the formation of the metal to metal bond by the highly active surface of the nano particles.

CONCLUSIONS

Sufficient evidence has been accumulated to prove that nano silver manufactured in an alcohol environment and passivated with alcoxides formed by reaction with the silver atoms on the surface of the particles can provide the basis for joining materials that can be sintered at temperature comparable with those used in the reflow of high-lead solder pastes and lower. The strength and electrical and thermal conductivity of the bond so formed is at least comparable with that formed by the reflow of high-lead solder.

While the nano silver so formed can be used alone it has also been shown to be possible to reduce the cost of the material and enhance mechanical properties by mixing the nano particles with sub-micron particles of silver and copper.

The temperature required for sintering the nano silver paste varies with the length of the carbon chain of the alcohol used for its passivation with sintering temperatures under 120°C possible with nano silver passivated with alcohols with 2 to 6 carbon atoms although there is trade off in regard to stability. Selecting a nano silver paste formulation it is therefore a matter of choosing the balance between sintering temperature and storage and handling stability that best fits the application.

ACKNOWLEDGEMENTS

This paper is based on work carried out and reported by Dr Teruo Komatsu and his colleagues at Osaka City University. Continuing work on alcoxide-passivated nano silver technologies is now being supported by Nihon Superior Co., Ltd

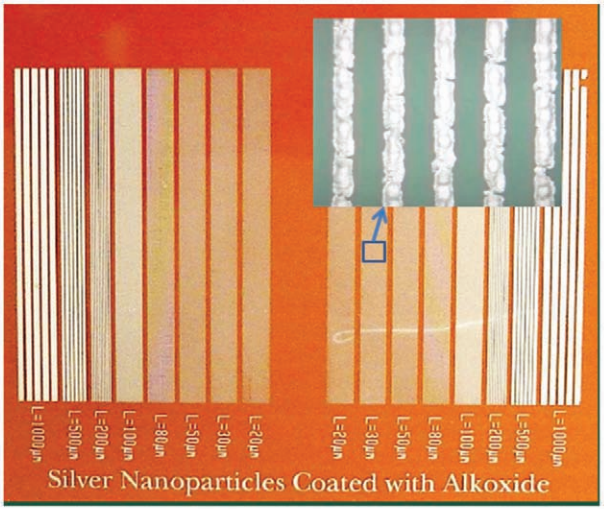


Figure 18. 20μm to 1000μm traces screen printed on polyamide with alcoxide-passivated nano silver paste sintered at 150C. Inset is 30μm traces

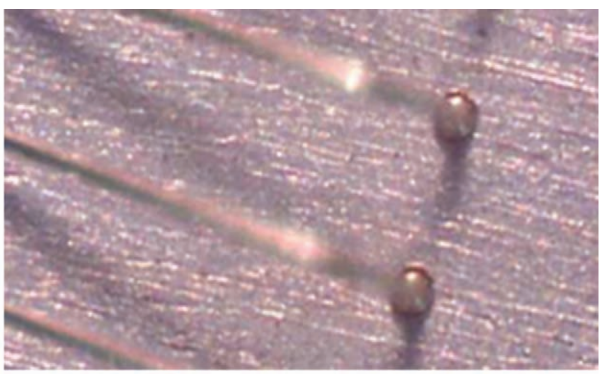


Figure 19. Wire bonding with alcoxide-passivated nano silver paste.

Figure 20. Examples of pastes based on alcoxide-stabilized nano-silver.

REFERENCES

1. J.N. Calata, T.G.Lei and G-Q Lu, Emphasis, November 2006
2. Kim S. Siow, Journal of Alloys and Compounds, 514(2012) 6-19.
3. W.D. Kingery, J. Appl. Phys. 30, 301 (1959)
4. Ph. Buffat and J-P Borel, Phys. Rev. A13 (1976) 2287
5. M. Maruyama, R. Matsubayashi, H. Iwakuro, S. Isoda, T. Komatsu, Appl Phys A (2008) 93: 467–470

BIOGRAPHIES

Keith Sweatman is a graduate in metallurgical engineering from University of Queensland. After being introduced to metal joining technology at the International Tin Research Institute he moved to Multicore Solders Ltd where he had a series of technical and management positions that culminated in his appointment at Asia Pacific Region managing director. Since 2001 he has been assisting Nihon Superior in the development of their global business, particularly in the lead-free technologies. With the establishment at University of Queensland of the Nihon Superior Centre for the Manufacture of Electronic Materials he has been appointed an adjunct senior fellow in the Department of Mechanical and Mining Engineering.

Tetsuro Nishimura, president of Nihon Superior Co., Ltd since 2004, graduated from Kansai University in 1980 with a degree in materials engineering. While developing commercial experience as manager of the company's Tokyo sales office and executive manager of Technical Service his continuing strong interest in research led to his development in 1999 of a unique lead-free solder that was marketed under the brand name "SN100C". The great success of this alloy around the world was responsible for lifting the profile of Nihon Superior from that of a small local solder maker to a company that is recognized as a significant player in the global market for electronic materials. His decision to invest in nano-silver technology reflects his commitment to the development of new joining materials that can meet the changing needs of the electronics industry.

Dr. Teruo Komatsu, is executive director of Applied Nanoparticle Research Laboratory Co. Ltd, which he co-founded in 2006 with colleagues at Osaka City University to pursue the commercial exploitation of the process they developed for the production of nano-silver particles passivated with a unique alcohol derivative. In this position Dr Komatsu is responsible for the development of materials that meet the electronics industry's need for cost-effective lead-free joining and electrical and thermal conduction. Dr Komatsu graduated from Osaka City University with a degree in physics in 1963 and began a career in research at that university that culminated in his appointment as professor in 1992. He continued to teach at that university until his retirement in 2002 and since then has enjoyed the position of emeritus professor.

RELIABILITY OF BIAGX SOLDER AS A DROP-IN SOLUTION FOR HIGH TEMPERATURE LEAD-FREE DIE-ATTACH APPLICATIONS

HongWen Zhang, Ph.D. and Ning-Cheng Lee, Ph.D.
Indium Corporation
Clinton, NY, USA

ABSTRACT

BiAgX paste, a mixed solder powder paste, has a melting temperature above 260°C after reflow, which satisfies the temperature requirement for semiconductor and power die attachment for consumer electronics. In this paste system, the metal powders are composed of a high melting alloy powder as majority and the additive powder as minority. The additive solder improves the wetting between Bi and various surface finish materials by its aggressive reaction with the surface finish materials during soldering. As a result, improved wetting, the associated low voiding, and the insensitive IMC layer thickness upon aging have been observed [1]. The bond shear strength of as-reflowed BiAgX joints between Ti/Ni/Au plated Si die and Cu substrate is up to 44% higher than the high lead-containing solder Pb5Sn2.5Ag. After aging at 200°C for 500 hrs, the bond strength of BiAgX shows only minor change, while the bond strength of the high lead-containing joint drops 26%. After 2000 cycles of TCT tests from -55°C to 125°C, BiAgX exhibits a bond shear strength up to 6.1 times that of Pb5Sn2.5Ag. Both well-dispersed micron-size Ag particles and Ag-rich phases along the boundaries of Bi colonies have been observed in BiAgX joint. Both Ag-rich phases constrain the dislocation movement in Bi matrix and contribute to the higher bond strength of the BiAgX joint. The stepwise fracture surface features surrounding the Ag particles and the AgSn phase along the step edges on the fracture surface evidenced the reinforcement from both types of Ag phases.

Key words: high temperature, lead-free, Pb-free, solder, solder paste, solder joint, mixed powder, wetting, voiding, BiAg, BiAgX

INTRODUCTION

The Pb-free replacement solders for the eutectic PbSn have been widely investigated and SnAg, SnCu, and SnAgCu solders have been becoming the mainstream for the electronics industry. However, the development of high temperature lead-free (HTLF) solders to replace the conventional high lead-containing alloys, i.e. Pb5Sn and Pb5Sn2.5Ag, is still in its infancy. Semiconductor or power die-attachment for consumer electronics products requires the use of high temperature solders in order to maintain the integrity of the joint between the die and the lead frame at board level assembly. The major requirements for the die-attachment are (i) a softening temperature no lower than 260°C , (ii) a drop-in alternative for the current process for high-lead solders, (iii) good thermal fatigue resistance, and (iv) low cost.

Currently, there are no drop-in Pb-free alternatives for the high lead-containing solders, although some possible alternatives including SnSb, BiAg, ZnSn, ZnAl, and AuSn etc [2-4] for the die attachment application have been studied and reported. However, due to the intrinsic defects associated with these alloys, they cannot be directly or widely used as the replacement for high lead-containing solders [1]. For example, SnSb based solders have the solidus temperature below 250°C. ZnSn shows the solidus temperature around 200°C. ZnAl solders are prone to oxidize and generate the massive IMC layer during soldering. AuSn solders are far too expensive.

BiAg alloys have a solidus temperature of 262°C, which satisfies the softening temperature requirement for the die-attach application [5]. However, the poor wetting and the low ductility of BiAg solders reduces the interest to use them as soldering materials. Alloying the reactive elements can modify the reaction chemistry between the alloy and the metallization surface finish and thus improve the wetting behavior. However, alloying is also associated with the loss of other properties. For example, Sn shows the better reaction chemistry to the common surface finish materials, including Cu, Ag, Ni, Au etc., comparing to Bi. However, directly alloying Sn into BiAg could lead to (1) the existence of a low melting phase (BiSn) if Sn is excessive, and/or (2) no improvement on wetting if Sn is less than enough, due to the complete conversion of Sn into Ag3Sn IMCs. Thus, it is hard to see the benefits of alloying Sn directly into BiAg alloys.

The mixed alloy powder solder paste technology was invented to efficiently improve the interfacial reaction chemistry. The mixed solder paste is composed of the primary solder powder and the additive solder powder in the minority. The additive solder powder contains the active elements, which will react aggressively with various surface finish materials, namely the commonly used Cu, Ag, Ni, Au etc, during reflow. When soldering, the additive solder powder will melt earlier than, or together with, the primary solder powder, spread and react with the surface finish materials. In this process, the additive solder will dominate the formation of the IMC layer at the interface and finally, the active elements in the additive solder will be completely converted into IMCs, including both the interfacial IMC layer and the IMC precipitates in the joint matrix. The non-active constituents of the additive solders are preferred to be the same elements as those in the primary solder powders. They will melt into the molten primary solder and solidified together to form a homogeneous solder joint. Fig. 2 depicts the design idea of this technology.

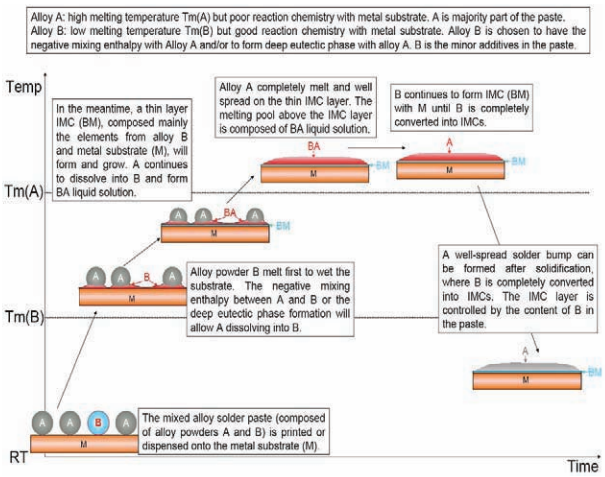


Figure 1. Design idea of the mixed solder paste system [5]

In the design, the selection of the additive is critical. First, the additive should contain the active element, which reacts with those commonly used surface finish materials such as Cu, Ag, Ni and Au. Second, the IMC layer formed by chemical reaction between the active element and the surface finish materials should be easily wetted by the molten primary solder powders. For instance, BiAg and BiSn can serve as the primary solder alloy and the additive alloy, respectively. During reflow, BiSn melt first and spread out. Sn from BiSn will react with surface finish materials of the bonding parts to form IMC layer and thus dominate the wetting behavior. When the temperature further increases beyond the melting point of the BiAg, the remaining constituents of BiSn will be thoroughly mixed with the molten BiAg to form the homogeneous alloy solution. After cooling down, a homogeneous joint will be formed. If there is extra Sn in the joint, it will react with Ag from the primary BiAg solder to form AgSn IMC precipitates and leave no low-melting phase in the system. An additional benefit from the design is that the interfacial IMC layer thickness is expected to be insensitive to aging. This is because the controllable active elements introduced from the additives are completely consumed to form either the interfacial IMC layer or the IMC precipitates during reflow and no more free active elements (Sn) are available for growing the interfacial IMC layer afterward. It has been reported [1] that BiAgX shows (1) a melting temperature above 260°C after reflow; (2) 5% or less voiding for the packages bonded with the selected pastes; (3) a good thermal stability upon aging at 200°C; and (4) a comparable or better thermal cycling behavior of BiAgX versus the high lead-containing solders for the package of the customized Cu die on Ag-Pt thick film pad Alumina substrate. Currently, we are more focusing on the reliability of BiAgX joints and the associated microstructure evolution.

EXPERIMENTAL

1. Solder Pastes

For the mixed solder pastes, BiAg+BiSn+flux, more than 10 different developmental fluxes were used for making the pastes. A commercialized Pb5Sn2.5Ag paste is also used for comparison purposes.

2. Test Vehicle

The customized 0.125 inch square Si die (0.72mm thick) is plated with Ti/Ni/Au surface finish. Bare Cu coupons (25mm diameter and 0.6mm thickness) are used to bond the Si die. Pastes are printed in the center of the Cu substrate with the designed stencil. Reflow is performed with IR oven under N2 condition with the peak temperature around 325°C. After reflow, the packages are inspected for voiding with X-ray.

3. Bond Shear Strength

To study the bond shear strength, the die shear tests were conducted through XYZTech Condor 250 bond tester. The bond shear strength is calculated from the peak load and the bonding area.

4. Thermal Aging and Thermal Cycling Reliability

The aging tests were done by keeping the bonded packages at 200°C for 500hrs. Then the bond shear strength of the aged packages was studied. For thermal cycling tests, the cycling temperature ranges from -55°C to 125°C with a dwell time of 5 minutes at peak temperature. The bond shear strength of the thermal cycled packages, including both BiAgX packages and high lead packages, was tested.

RESULTS

1. Bond Shear Strength

The bond shear strength of the joints made of seven different BiAgX solder pastes ranges from 23 to 40 MPa, depending on the flux in use. With Flux E, F, and G, the bond shear strength is even close to 40MPa. The average bond shear strength for all BiAgX joints is around 35.64 MPa. As a comparison, the average bond strength of the commercialized Pb5Sn2.5Ag is around 27.55 MPa. The average bond shear strength of all BiAgX joints is more than 30%, and some (BiAgX+Flux F) can be even up to 44% higher than Pb5Sn2.5Ag.

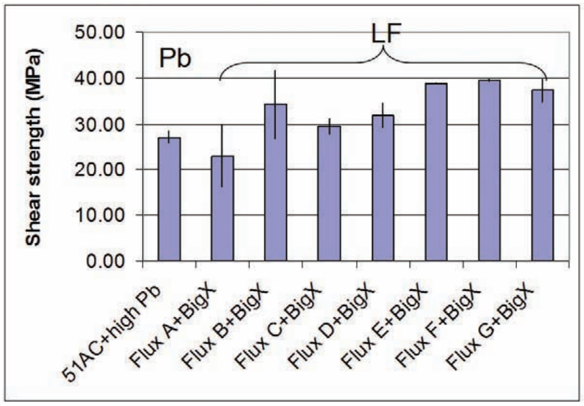


Figure 2. Bond shear strength of the joints made of seven BiAgX solder pastes and the high lead solder

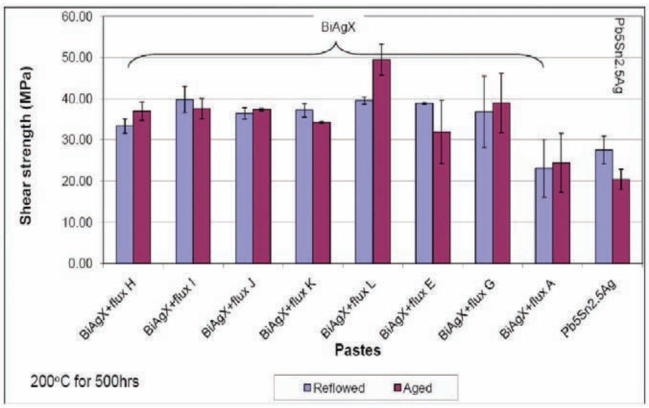


Figure 3. Bond shear strength of the joints aged at 200°C for 500hrs. Eight BiAgX solder pastes and one high lead solder paste are selected for the aging tests.

2. Aging

After aging, the bond shear strength of BiAgX ranges from 25MPa to 48MPa. Compared to the bond shear strength of the as-reflowed joints, most of the BiAgX pastes did not show the obvious softening after aging except the flux E sample. However, the high lead-containing solder (Pb5Sn2.5Ag) shows a decrease in the bond shear strength from 27.55MPa to 20.42MPa, which accounts for a 26% drop of the bond shear strength. By averaging the bond shear strength of all BiAgX pastes, the value before aging, 35.64MPa, and after aging, 36.38MPa, shows that aging does not lead to softening at all.

3. Thermal Cycling Test

After 2000cycles TCT tests from -55°C to 125°C, the highlead-containing solder Pb5Sn2.5Ag shows a 83% drop in the average bond shear strength, from the 27.55MPa to 4.57MPa. For the BiAgX solder, depending on the alloy composition, the drop in the bonding strength ranges from 4% to 56%, and the remaining strength ranges from 2.8 to 6.1 times of that of counter part of Pb5Sn2.5Ag. According to the IEC 60749-19 standard, the required joint shear strength for a 10mm^2 die (0.125 inch square) is 2.5MPa. The average bond shear strength of TCT conditioned BiAgX solder is around eight times the strength required in the IEC standard. The bond shear strength of the high lead-containing solder (Pb5Sn2.5Ag) is less than two times that of the required strength in the IEC standard.

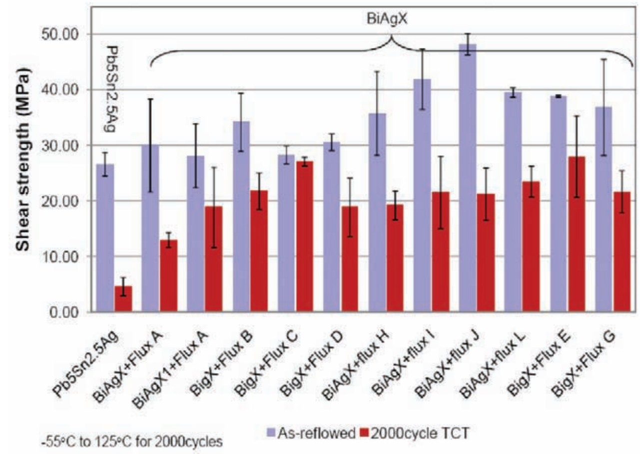


Figure 4. Bond shear strength of the joints after 2000cycles TCT conditioning. Eleven BiAgX pastes and the high lead-containing solder are selected for TCT conditioning.

DISCUSSION

The mixed powder solder pastes combine the merits from both the primary solder alloy and the additive solder, targeting as a drop-in HTLF solder solution for die-attach application. In our previous study, the BiAgX system showed a melting temperature above 260°C, a reasonable wetting and voiding, and an IMC thickness insensitive to aging [1]. In this study, BiAgX shows a higher reliability than Pb5Sn2.5Ag, as reflected by the consistent and higher bond shear strength upon aging at 200°C for 500hrs, as well as the stronger bond strength after 2000cycles thermal cycling.

As shown in Figure 5, the joint structure of BiAgX between the Au-plated Si die and the Cu substrate shows two types of Ag-rich phases reinforcing the Bi matrix: (1) many 5 to 10 microns Ag particles, and (2) AgSn phases along the boundaries between the Bi colonies. At first, the micron- sized Ag particles nucleated and grew when the molten solder was cooled down to a temperature between liquidus and solidus. The AgSn phases formed along the Bi colony's boundaries when the eutectic reaction starts in the remaining molten solder during solidification . Both Ag particle and AgSn phases are considered effective in constraining the dislocation movement within the brittle Bi phases. Indeed, the fracture surface of the joint in Fig. 6 does show evidence of reinforcement of both types of Ag phases.

The fracture surface of the BiAgX joints shows that the rupture occurs primarily within the solder, as shown in the top two images of Fig. 6. . Both the Si die and Cu substrate sides show a similar fracture morphology, although a small area of Si at the left edge of the die is exposed, as shown in the top left image. The regularly shaped Ag particles around 5 microns dispersed on the fracture surface are shown in the middle image of Fig. 6. Surrounding the Ag particles, the stepwise Bi matrix is seen. The AgSn phases are observed at the edge of these steps shown in the bottom image of Fig. 6. Normally, the cleavage is the dominant fracture feature in brittle bismuth. With reinforcement from the Ag-rich phases, including both the micron-sized Ag particles and the AgSn phases along the boundaries of Bi colonies, the stepwise pattern within Bi dominates the fracture surface. It indicates that when dislocations moving across the brittle Bi colonies, these reinforcements hamper the dislocation movement by acting as obstacles. Thus, the dislocations have to climb up to surpass these obstacles, hence the formation of the stepwise features. Recently, Shimoda et al. [5] also observed the stepwise feature in the Bi matrix surrounding Ag particles and they observed an impressive tensile ductility up to 20% and an improved strength in their bulk BiAg solder. BiAgX shows a similar phenomenon of the stepwise fracture structure in solder joint, and also similarly displays a higher bond shear strength than Pb5Sn2.5Ag joints, as shown in Figure 2. The high ductility reported for BiAg solder [5] is also expected in BiAgX system. In brief, the microstructure of BiAgX joint promises both improved ductility and enhanced strength. The better thermal aging tolerance, as shown in Fig. 3, and the better TCT reliability, as shown in Fig. 4, of BiAgX than Pb5Sn2.5Ag can be attributable to the reinforcement from both types of Ag phases and the associated mechanical properties.

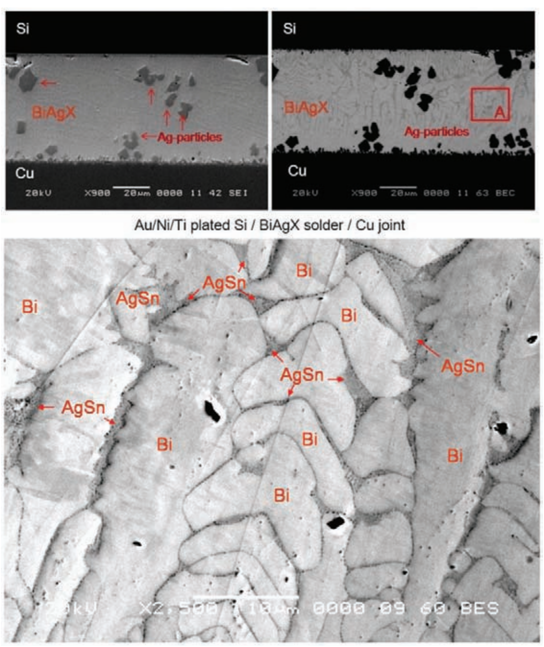


Figure 5. The microstructure of the BiAgX joint between Au/Ni/Ti Si die and bare Cu substrate. Top left: overview of the joint structure from SEI image. Top right: overview of the joint structure from BSE image. Bottom: the enlarged image of location A in top right, showing the Bi colonies separated by AgSn phases along the boundaries.

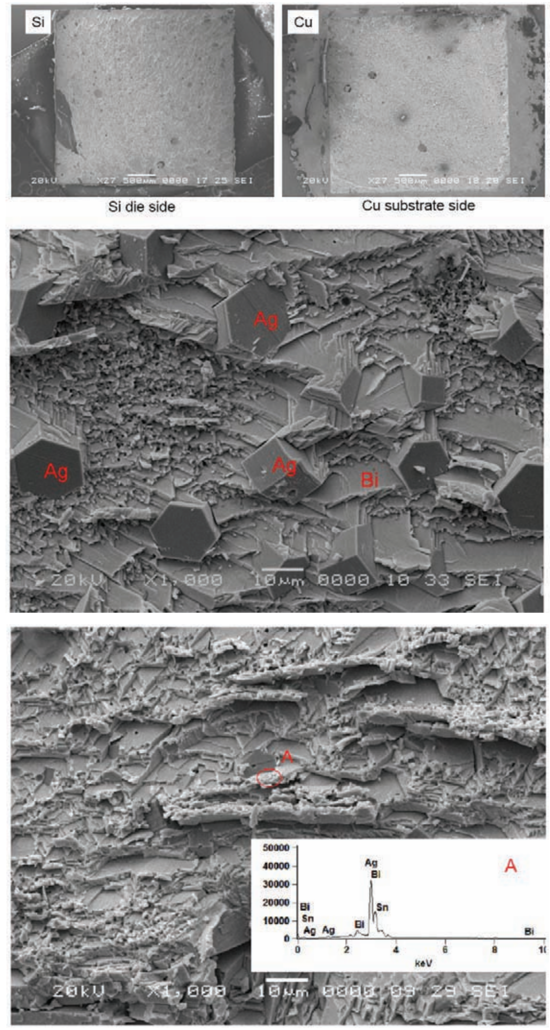


Figure 6. Fracture surface of BiAgX joint. Top left: Si die side; Top right: Cu substrate side; Middle: Micron sized particles and the stepwise fracture surface of Bi matrix; Bottom: AgSn phase at the edge of Bi steps.

CONCLUSIONS

A mixed powder solder paste technology has been invented as a drop-in high temperature lead-free solder pastes for die-attach applications in which the merits from both the primary alloy solder and the additive solder are utilized. BiAgX solder joints show a bond shear strength up to 44% higher than Pb5Sn2.5Ag. After aging at 200°C for 500hrs, Pb5Sn2.5Ag shows a drop in the bond shear strength by 26%, while BiAgX shows a negligible change. After thermal cycling from -55°C to 125°C for 2000 cycles, BiAgX joints exhibit a bond shear strength up to 6.1 times of Pb5Sn2.5Ag. The higher bond shear strength and stability of BiAgX joints is attributed to the dislocation movement within the Bi lattice being hampered by the micron-sized Ag particles together with AgSn phase along the Bi colony's boundaries.

REFERENCES

Zhang H.W. and Lee N.C., " A drop-in die-attach solution for the high temperature lead-free BiAgX solder paste system", Proceedings of IMAPS High Temperature Electronic Conference , 2012, pp000058-000064

Chen S.W. et al, "Phase equilibria of the Sn-Sb Binary System", Journal of Electronic Materials, Vol.37, No.7 (2008), pp.992-1002

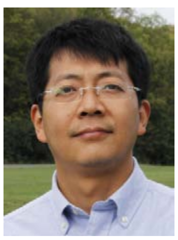
Takaku, Y. et al, " Interfacial Reaction between Cu substrate and Zn-Al base High-Temperature Pb-Free Solders", Journal of Electronic Materials, Vol.37, No.3(2008), pp.314-323.

Kim, S. et al, "Interfacial Reaction and Die Attach Properties of Zn-Sn High-Temperature Sodlers", Journal of Electronic Materials, Vol. 38, No.2 (2009), pp.266-272.

Lalena, J. et al, " Experimental Investigation of Ge-doped Bi11Ag as a New Pb-Free Solder alloys for Powder Die Attachment", Journal of Electronic Materials, Vol.31, No.11(2002), pp.1244-1249

Masayoshi Shimoda et al., "Improvement of Ductility of BiAg high temperature lead-free solders", Proceedings of 26th Spring conference of Japan Institute of Electronics Packaging, 2012, pp231-232

BIOGRAPHIES



Dr. HongWen Zhang is a Research Metallurgist in R&D of Indium Corporation. His focus is on the development of lead-free solder materials for high temperature die attach application. Dr. HongWen Zhang has a bachelor's degree in Metallurgical Physical Chemistry from Central South University of China, a master's degree in Materials Science and Engineering from the Institute of Metal Research, Chinese Academy of Science, a master's degree in Mechanical Engineering from Michigan Technological University, and a Ph.D. in Material Science and Engineering from Michigan Technological University. He has published more than 30 articles in the fields of metallurgy, materials science, physics, mechanics and electronic interconnections. Dr. HongWen Zhang had Six-Sigma Green Belt and been certified as IPC Specialist for IPC-A-600 and IPC-A-610D.

Ning-Cheng 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. He has more than 20 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 underfills and adhesives. He received his PhD in polymer science from University of Akron in 1981, and BS in chemistry from National Taiwan University in 1973.

Ning-Cheng is the author of "Reflow Soldering Processes and Troubleshooting: SMT, BGA, CSP, and Flip Chip Technologies" by Newnes, and co-author of "Electronics Manufacturing with Lead-Free, Halogen-Free, and Conductive-Adhesive Materials" by McGraw-Hill. He is also the author of book chapters for several lead-free soldering books. He received 1991 award from SMT Magazine and 1993 and 2001 awards from SMTA for best proceedings papers of SMI or SMTA international conferences, and 2008 award from IPC for Honorable Mention Paper – USA Award of APEX conference. He was honored as 2002 Member of Distinction from SMTA, 2003 Lead Free Co-Operation Award from Soldertec, 2006 Exceptional Technical Achievement Award from CPMT, 2007 Distinguished Lecturer from CPMT, 2009 Distinguished Author from SMTA, and 2010 Electronics Manufacturing Technology Award from CPMT. He served on the board of governors for CPMT, serves on the SMTA board of directors. Among other editorial responsibilities, he serves as editorial advisory board of Soldering and Surface Mount Technology, Global SMT & Packaging and as associate editor for IEEE Transactions on Electronics Packaging Manufacturing. He has numerous publications and frequently gives presentations, invited to seminars, keynote speeches and short courses worldwide on those subjects at international conferences and symposiums.

Welcome New SMTA Members!

Gerald Scott Adams
Honeywell Technology Solutions Inc.
Columbia, MD

Josh Akman
Rockville, MD

James Allred
Electric Fuel Battery
Auburn, AL

Dan Amiralian
New Age EMS, Inc.
Attleboro, MA

Richard L. Anderson
Bird Technologies Group
Solon, OH

Sonia Arrazolo
Invensys Controls
Brownsville, TX

Tony Arteaga
OnCore Manufacturing Services
San Marcos, CA

Zaeem Baig
University of Texas at Arlington
Arlington, TX

Steve Banas
Ellsworth Adhesives
Crystal Lake, IL

Pankaj L. Bansod
Diebold India Pvt. Ltd.
Mapusa, Goa, India

Yulo Braga Barbosa
Jabil Do Brasil
Manaus, Amazonas, Brazil

Marcelo Baru
Micro Systems
Lake Oswego, OR

Gary Beckstedt Jr.
Spectral Response
Lawrenceville, GA

Richard Bellemare
Procasys LLC
Dallas, TX

Joe Beri
Renal Solutions Inc
Warrendale, PA

Daniel L. Berry
Touchstone Systems, LLC
Melbourne, FL

Prasad BP
Schneider Electric ITB India Pvt Ltd
Bangalore, Karnataka, India

Jason Bragg
Celestica Inc.
Toronto, ON, Canada

Wayne Brdlik
Target Corporation
Pleasant Prairie, WI

Jason Bretz
Source 2000
Edina, MN

Douglas Earl Buchanan
Pine Electronics
Grove City, PA

Thomas Burkett
Intersil Corporation
Palm Bay, FL

Thomas Karl Buschor
Harris Corporation
Melbourne, FL

Eduardo Candanedo
Redwall
Porto Alegre, RS, Brazil

Shuo Cao
San Jose, CA

John Carlton
Newson USA LLC
Hillsboro, OR

Chuan Winn Chai
Agilent Technologies (M) Sdn. Bhd.
Bayan Lepas, Penang, Malaysia

Sathiyanarayanan Chandran
Cuddalore, Tamil Nadu, AA, India

Xin Chang
University of Washington
Seattle, WA

David O. Chavez DBA
Season Group
San Antonio, TX

Andrea Chen
PCB Piezotronics, Inc.
Seattle, WA

Ding Wang Chen Ph.D.
Celestica (Asia)
Singapore, Singapore

Wei-Hsun Chen
Purdue University
West Lafayette, IN

Brendan Chew
Singapore, Singapore

Leila Choobineh
University of Texas at Arlington
Arlington, TX

Dale E. Christman
C & W Global
Rio Vista, CA

An-Shyang Chu
PCB Piezotronics, Inc.
Seattle, WA

Yaw Sing Chuah
Kirsten Soldering AG
Bayan Lepas, Penang, Malaysia

Nico Coenen
MYDATA Automation, Inc.
Rowley, MA

Cathy Cross
STI Electronics, Inc.
Warner Robins, GA

Ed Reniedo Cruz
Kent, WA

Rudy M. Cruz
Foxconn NSG
San Jose, CA

Amer Basheer Dababneh
Iowa City, IA

Julie Davis
Lighthouse Technical Sales
Haverhill, MA

Dave DeCrosta
Intersil Corporation
Palm Bay, FL

Christine Sadullo Dela Cruz
Cypress Semiconductor
Santa Clara, CA

Douglas DellAccio
Bose Corporation
Framingham, MA

Gerjan Diepstraten
Vitronics Soltec BV
Oosterhout, NB, Netherlands

Dave DiFolco
REStronics
Castle Rock, CO

Nam Dinh
OnCore Manufacturing Services
San Jose, CA

Tony Du
Acutool LLC.
Fountain Valley, CA

Sora Earm
Digi Interntional
Oakdale, MN

Ed Edwards
Circuit Board Medics
Greer, SC

Joe Endres
Jendco Technologies
Fort Wayne, IN

Randy Ferrell
GHSP
Grand Haven, MI

Christopher Fitzgerald
Honeywell Technology Solutions Inc
Columbia, MD

Stefan Pisegna Flower
Amptech Inc
Sharon, PA

Jason Fullerton
Alpha
King of Prussia, PA

Shaojun Gao
Panasonic
Peachtree City, GA

Sally Garcia
Teledyne RDI
Poway, CA

John Good
OnCore Manufacturing Services
Longmont, CO

Sowmya Gotety
Arizona State University
Tempe, AZ

Daniel Gray
Solar Systems Pty Ltd.
Melbourne, Victoria, Australia

Jennifer Green
Minneapolis, MN

William Green
Seagate Technology
Shakopee, MN

Roger N. Hamilton
Avant Technology
Pflugerville, TX

Paul J. Handler
Schoeller-Electronics GmbH
Johns Creek, GA

Jennifer Lynn Harkless
Accuspec Electronics
Erie, PA

Derrick Herron
Indium Corporation
Clinton, NY

Michelle Van Hout
Wolcott-Park, Inc.
Rochester, NY

Ling Hung Huong
Osram Opto Semiconductor (M) Sdn. Bhd.
Bayan Lepas, Penang, Malaysia

Ivan Ionash
Avago Technologies
Fort Collins, CO

Eic Jiang
JinAn Electronics MFG Co.,LTD.
HeFei, Anhui, China

Yu Jie
Meiko Electronics (Guangzhou Nansha) Co., Ltd.
Guangzhou, Guangdong Province, China

Mike Joyner
Town Line Technologies
McGraw, NY

Ivers Keller
Lutron Electronics
Coopersburg, PA

Walter Keller
Nokomis
Charleroi, PA

Michael Khbeis Ph.D.
University of Washington
Seattle, WA

Walter Kim
Daesam USA Corporation
Northfield, IL

Kevin Ko
Adcotron EMS Inc
Boston, MA

Barbara Koczera
MatriX Technologies
San Diego, CA

Todd Kramer
Secure Components LLC
Norriston, PA

Lisa Kraniske
Delta Systems, Inc
Steetsboro, OH

Chandramouleeswaran Krishnaswamy
University of South Florida
Tampa, FL

Darrell LaMoure
DnS LaMoure Enterprises
Phoenix, AZ

Dave Laubscher
PACE Inc.
Colorado Springs, CO

Tri Le
NxGEN Electronics
San Diego, CA

Peter Lenkey
Culver City, CA

Steve Lewis
Circuitronics
Rockwall, TX

James Liow
OnCore Manufacturing Services
Suzhou, China

Liang Liu
Binghamton University
Binghamton, NY

Jack Alan Looman
Winona, MN

William MacDonald
Amphenol Borisch Technologies
Grand Rapids, MI

Scott Maclin
EWD Solutions
Carrollton, TX

John Marcil
OnCore Manufacturing Services
Springfield, MA

Thiago Soares Marques Ph.D.
Alent
Sao Bernardo Do Campo, SP, Brazil

Fred Lane Martin
Southwire
Carrollton, GA

Noah Martin
Tech-Etch Inc.
Plymouth, MA

Wanda Martin
Electric Fuel Battery
Auburn, AL

Christine Mason
AirBorn Electronics, Inc.
Akron, OH

Anthony Massini
OccamMD
Clearwater Beach, FL

Doug Mathews
ViaSat
Mesa, AZ

Charles McLeavy
Tech-Etch Inc.
Plymouth, MA

Sarah McQuaide
North Seattle Community Colleges
Seattle, WA

Steven D. Meredith
Steve Meredith & Associates
Dallas, TX

Shawn Moore
Celestica Inc.
Toronto, ON, Canada

Richard Moraca
Scottsdale, AZ

Reuben Morgensteren
Ultimate Linings
Houston, TX

Janet Morris
Aerotech, Inc.
Pittsburgh, PA

Jerry Murray
Cummins Power Generation
Fridley, MN

Francis Mutuku
Binghamton University
Binghamton, NY

Gaurang N. Naware
University of Texas at Arlington
Arlington, TX

Yan Ning
University of Maryland
College Park, MD

Richard Nix
Eclipse Electronic Systems
Dallas, TX

Riley Northam
Honeywell - NMTTC
Columbia, MD

Stephen Olan
STIM Canada Inc.
Toronto, ON, Canada

Boon Pin Ooi
STEC Technology Sdn. Bhd.
Bayan Lepas, Penang, Malaysia

Ed Oshaben
Lincoln Electric
Cleveland, OH

Hardik Maheshkumar Parekh
University of Texas at Arlington
Arlington, TX

Adam Timothy Pearl
Center for Advanced Life Cycle Engineering
College Park, MD

Kevin Pflaum
3M Company
Austin, TX

Brian Procek
Plexus Corp.
Buffalo Grove, IL

Dai Dee Pun Ph.D.
Altera Corporation
San Jose, CA

Larry Pymento
IBM Corporation
Cary, NC

Jose Arturo Quintero
Cryoinfra S.A. DE C.V.
Naucalpan, Estado De Mexico, Mexico

Sandya Radhakrishna
QuickLogic
Cupertino, CA

Jennifer Read
Charlie Barnhart & Associates
Spring Grove, IL

Norbert Rehm
Intersil Corporation
Palm Bay, FL

Ulf Reinhardt
Schoeller-Electronics GmbH
Wetter, Germany

Steven M. Reinstein
Waveroomplus
Londonderry, NH

Eddie Rezaei
STIM Canada Inc.
Toronto, ON, Canada

Todd Rice
Circuit Pak Inc.
Dayton, OH

Pedro Rincan
Invensys Triconex
Lake Forest, CA

Reynaldo Rio
Henkel Singapore Pte. Ltd.
Singapore, Singapore

Walt Rowe
Intersil Corporation
Palm Bay, FL

Luis Rustrian
OnCore Manufacturing Services
Tijuana, BC, Mexico

Pete Ruth
Conecsus LLC
Terrell, TX

David Rutledge
Lattice Semiconductor
Hillsboro, OR

Alexander Schreiner
Newson USA LLC
Hillsboro, OR

Brad Anthony Sciulli
Electronic Assembly Products, Ltd.
Cranberry Township, PA

Larry Shea
Midwest Micro-Tek
Brookings, SD

Angleat Shelikoff
DoD Air Force
Niceville, FL

Mathieu Silver
Disco Hi-Tec
Hillsboro, OR

Craig Simons
N.F. Smith & Associates, L.P.
Houston, TX

Shashwat Sinha
Dassault Systemes Simulia Corp
Fremont, CA

Jacob C. Smith
Quanta Computer Nashville
Lavergne, TN

Yeong Sohn
Natel Engineering
Chatsworth, CA

Jose Solis
Electric Fuel Battery
Auburn, AL

Marty Spilde
DJO Global
Clearlake, SD

Richard G. Stichter
Avidyne Corporation
Melbourne, FL

Ken Stoddart
Intersil Corporation
Palm Bay, FL

Cary Stubbles
Cypress Semiconductor
San Jose, CA

Gary Sulski
Anuva Manufacturing
Marietta, GA

Wen Wen Tan
Zestron Precision Cleaning Sdn. Bhd.
Kulim, Penang, Malaysia

David C. Tang
Adcotron EMS
Boston, MA

Peter Thoen
KLA-Tencor
Milpitas, CA

Jeff Thomas
Digi International
Montgomery, MN

Kathleen Thompson
Horizon Sales
Fowlerville, MI

Lam Tran
AbelConn, LLC
New Hope, MN

Phillip Tran
I-TECHeServices, LLC
Norcross, GA

Michael Tvedt
Minnetronix
St. Paul, MN

Mackenzie Valasek
Aerotech, Inc.
Pittsburgh, PA

Cagdas Varel
University of Washington
Seattle, WA

Christine D. Walter
Industrial Instruments
Southampton, PA

Heidi Williams
IBM Materials Engineering Lab
Research Triangle Park, NC

Charles Edward Williamson
Anuva Services Inc.
Morrisville, NC

Jeremy D. Williamson
Calient Networks
Ventura, CA

Ernie L. Woods
Audio Authority
Lexington, KY

Kris Young
Alpha
Altoona, PA

Jessica Zhang
Super PCB
Dallas, TX

Global Members

Celestica Inc.
Toronto, ON, Canada

Creation Technologies Inc.
Markham, ON, Canada

Ellsworth Adhesives
Germantown, WI

Henkel Corporation
Irvine, CA

HISCO Inc.
Houston, TX

Lockheed Martin
Ocala, FL

OnCore Manufacturing Services
Springfield, MA

Plexus Corp.
Appleton, WI

Quality Systems Integrated Corp.
San Diego, CA

Specialty Coating Systems
Indianapolis, IN

Vitronics Soltec Inc.
Stratham, NH

Corporate Members

3M Company
Andover, MA

3M Company
Austin, TX

AB Electronics Inc
Brookfield, CT

AbelConn, LLC
New Hope, MN

Able Electronics
Mesa, AZ

ACC Electronix, Inc.
Normal, IL

AccuAssembly
Whitby, ON, Canada

Accu-Automation Corporation
Waterloo, ON, Canada

Accurate Carriers U.S.A.
Glendale Heights, IL

Accuspec Electronics
Erie, PA

ACE Production Technologies
Spokane Valley, WA

ACI Technologies, Inc.
Philadelphia, PA

Advance Circuit Technology, Inc.
Rochester, NY

Aegis Industrial Software
Horsham, PA

AEIC
New Durham, NH

AGI Corporation
Huntsville, AL

Agilent Technologies
Cary, NC

AI Technology, Inc.
Princeton Junction, NJ

AIM
Cranston, RI

Air Products and Chemicals, Inc.
Allentown, PA

Akrometrix LLC
Atlanta, GA

Alcatel-Lucent
Westford, MA

All Flex Flexible Circuits LLC
Northfield, MN

Allendale Electronics Ltd.
Lockeport, NS, Canada

Alpha
South Plainfield, NJ

Alpha 1 Technologies
Binghamton, NY

Altek Electronics
Torrington, CT

Alternative Manufacturing Inc.
Winthop, ME

Altron, Inc.
Anoka, MN

Altronic, Inc.
Girard, OH

America II Electronics
St. Petersburg, FL

Amistar Automation, Inc.
Vista, CA

Amitron Corporation
Elk Grove Village, IL

AMTECH Solder Products
Deep River, CT

Analog Technologies Corporation
Burnsville, MN

Apex Factory Automation
Chantilly, VA

Apex Tool Group, LLC - Weller Professional Tools
Apex, NC

Apollo Seiko
Bridgman, MI

Applicad Inc.
Farmingdale, NJ

Applied Concepts, Inc.
Plano, TX

APSM Systems
Phoenix, AZ

Aqueous Technologies
Rancho Cucamonga, CA

Arc-Tronics, Inc.
Elk Grove Village, IL

Area51 ESG, Inc.
Irvine, CA

Argo Transdata Corporation
Clinton, CT

ASC International
Hamel, MN

Ascentec Engineering
Tualatin, OR

Ascentech, LLC
Chester, CT

Ascentron, Inc.
White City, OR

ASM Assembly Systems, LLC
Suwanee, GA

Assembleon America, Inc.
Ball Ground, GA

Assembleon Asia Limited
Harbour City, Kowloon, Hong Kong

Assembly Solutions LLC
Soddy Daisy, TN

Astronautics Corporation of America
Milwaukee, WI

Astute Electronics, Inc.
Suffolk, VA

ASYS Group Americas Inc.
Suwanee, GA

Austin Manufacturing Services
Austin, TX

Automated Circuit Design
Richardson, TX

Avid Associates Inc.
Flemington, NJ

Ayrshire Electronics
Harrodsburg, KY

Ayrshire Electronics Minnesota
Oakdale, MN

B&D Enterprises Inc.
Russell, PA

Bare Board Group
Largo, FL

Barry Sales, Inc.
Richardson, TX

BBM, Inc.
Mckinney, TX

36

Beckman Coulter
Porterville, CA

Benchmark Electronics, Inc.
Angleton, TX

Benchmark Electronics, MN Division
Winona, MN

Bergquist Company
Prescott, WI

BEST Inc.
Rolling Meadows, IL

BGA Test & Technology
Bohemia, NY

BIAMP Systems
Beaverton, OR

BlackBerry
Waterloo, ON, Canada

Blackfox Training Institute
Longmont, CO

Bow Electronic Solders
Greenwood, SC

BPM Microsystems
Houston, TX

Brady Corporation
Milwaukee, WI

Brock Electronics Ltd.
Newmarket, ON, Canada

BSU Inc.
Ithaca, NY

BTU International
North Billerica, MA

BTW Inc.
Coon Rapids, MN

CAMtek, Inc.
Bloomington, IL

Carlton Industries Corporation
Hamden, CT

Celestica Inc.
Toronto, ON, Canada

CEMSI
Weyers Cave, VA

CGI Americas
Santa Ana, CA

CheckSum
Arlington, WA

Circuit Check Inc.
Maple Grove, MN

Circuit Connect, Inc.
Nashua, NH

Circuit Pak Inc.
Dayton, OH

Circuitronics
Irving, TX

CIRCUITS ASSEMBLY Magazine
Amesbury, MA

Cisco Systems, Inc.
Cd. Juarez, Chihuahua, Mexico

Cisco Systems, Inc.
San Jose, CA

Cisco Systems, Inc.
Austin, TX

CMC Electronics Inc.
St. Laurent, QC, Canada

CMK America Corporation
Tyrone, GA

Co-Ax Technology, Inc.
Solon, OH

Cobar Solder Products/ Balver Zinn
Londonderry, NH

Cobar Solder Products/Balver Zinn
Balve, DE, Germany

Colonial Circuits Inc.
Fredericksburg, VA

Colonial Electronic Manufacturers Inc.
Nashua, NH

Component Trends
Foothill Ranch, CA

Compunetics, Inc.
Monroeville, PA

Computrol Meridian
Meridian, ID

Computrol Orem
Orem, UT

Comtree Inc.
Mississauga, ON, Canada

Concept 2 Market, Inc.
Pompano Beach, FL

Conductive Containers, Inc. (CCI)
New Hope, MN

Conecsus LLC
Terrell, TX

Conelec of Florida, LLC
Deland, FL

Contemporary Controls
Downers Grove, IL

Continental Automotive Guadalajara México
Tlajomulco de Zuniga, Jalisco, Mexico

Control Micro Systems, Inc.
Winter Park, FL

Control Products Inc.
Chanhassen, MN

Conveyor Technologies Inc.
Sanford, NC

Corfin Industries LLC
Salem, NH

Counterfeit Avoidance Mark Alliance
Monroe, OR

Count-On Tools, Inc.
Gainesville, GA

Creation Technologies Inc.
Markham, ON, Canada

Creative Electron
San Marcos, CA

Custom Analytical Services Inc.
Salem, NH

CyberOptics Corporation
Singapore, , Singapore

Data I/O Corporation
Plymouth, MA

Dataram Corporation
Montgomeryville, PA

Datest Corporation
Fremont, CA

DCA Manufacturing
Cumberland, WI

DCSI
Pismo Beach, CA

Debron Industrial Electronics Inc.
Troy, MI

DEK USA
Bloomfield, NJ

DEK USA
Rolling Meadows, IL

DELO Industrieklebstoffe GmbH & Co. KGaA
Windach, Lech, Germany

Department of Defense
Ft. Meade, MD

DG Marketing Corporation
Moody, TX

DiagnoSYS Systems, Inc.
Westford, MA

Diamond-MT, Inc.
Johnstown, PA

Diehl Controls
El Márquez, Querétaro, , Mexico

Digico Global Network Inc.
Laval, QC, Canada

Digitaltest, Inc.
Concord, CA

DigitTron Technologies, Inc.
Lenexa, KS

Distron Corporation
North Attleboro, MA

DIVSYS International, LLC
Indianapolis, IN

Dorigo Systems Ltd.
Burnaby, BC, Canada

Ducommun LaBarge Technologies, Inc.
E. Pittsburgh, PA

Dynalab, Inc.
Reynoldsburg, OH

E.T.S. Group, Inc.
Rowlett, TX

Echostar
Englewood, CO

EEI Manufacturing Services
Clearwater, FL

EI Microcircuits, Inc.
Mankato, MN

EIT LLC
Sterling, VA

ELANTAS PDG, Inc.
St. Louis, MO

Electro-Comp Tape & Reel Services, LLC
Clearwater, FL

Electrolab Inc.
San Antonio, TX

Electronic Assembly Products, Ltd.
Dayton, OH

Electronic Coating Technologies
Cohoes, NY

Electronic Controls Design, Inc.
Milwaukie, OR

Electronic Interconnect
Elk Grove Village, IL

Electronic Services Unlimited, Inc.
Houston, TX

Electronic Systems Inc.
Sioux Falls, SD

Electrotek Corporation
Oak Creek, WI

Ellsworth Adhesives
Germantown, WI

Eltek USA Inc.
Londonderry, NH

EMI Asia Limited
Kowloon, , Hong Kong

EMT
Irvine, CA

Endicott Interconnect Technologies
Endicott, NY

Engent, Inc.
Norcross, GA

Engineered Systems Inc.
Windsor, ON, Canada

Enthone Inc.
West Haven, CT

Epoxy Technology Inc.
Billerica, MA

EPTAC Corporation
Manchester, NH

Equipment Services LLC
Benicia, CA

ERSA North America
Plymouth, WI

ESP Safety Inc.
San Jose,

ESSEMTEC USA
Glassboro, NJ

E-Tool
Minnesota City, MN

Europlacer
Tampa, FL

EWD Solutions
Carrollton, TX

Express Manufacturing Inc.
Santa Ana, CA

FCT Assembly, Inc.
Greeley, CO

FCT Assembly, Inc.
Milpitas, CA

FedEx TechConnect
Collierville, TN

FHP Reps
Granbury, TX

FICOSA Electronics
Barcelona, , Spain

Finetech
Gilbert, AZ

Firstronic LLC
Grand Rapids, MI

FKN Systek, Inc.
Millis, MA

Flexible Circuits, Inc.
Warrington, PA

FlexLink Systems, Inc.
Allentown, PA

Florida MicroElectronics
West Palm Beach, FL

FocalSpot, Inc.
San Diego, CA

Foresite, Inc.
Kokomo, IN

Fuji America Corporation
Vernon Hills, IL

Fujitsu Network Communications
Richardson, TX

Garmin AT, Inc.
Salem, OR

Garmin International
Olathe, KS

GD4 Test Services
Austin, TX

GE Energy
Minden, NV

General Microcircuits Inc.
Mooresville, NC

General Monitors, Inc.
Lake Forest, CA

G-Force Reps, Ltd
Double Oak, TX

Glenbrook Technologies Inc.
Randolph, NJ

Global Cable & Electronics
Lawrenceville, GA

GPD Global
Grand Junction, CO

Great Lakes Engineering
Maple Grove, MN

GSC (Garland Service Company)
Garland, TX

H.B. Fuller Company
St. Paul, MN

Hammond Electronics
Orlando, FL

Hangzhou H3C Tech. Co., Ltd.
Hangzhou, Zhejiang Province,
China

Harris Corporation
Rochester, NY

Harris Corporation
Melbourne, FL

Henkel Electronic Materials LLC
Irvine, CA

HEPCO, Inc.
Sunnyvale, CA

HISCO Inc.
Houston, TX

Hitachi High Technologies America,
Inc.
Dallas, TX

Hi-Tek Electronics
Salem, OR

Hi-Tronics Designs, Inc.
Hackettstown, NJ

Honeywell - NMTTC
Columbia, MD

Honeywell International Inc.
Kansas City, MO

Houstech, Inc.
Houston, TX

Hughes Circuits, Inc.
San Marcos, CA

I Source Technical Services, Inc.
Lake Forest, CA

I. Technical Services, LLC
Alpharetta, GA

IBE SMT Equipment
Magnolia, TX

IBL Technologies
El Paso, TX

ICS
Decatur, IL

IDENTCO International
Ingleside, IL

IEC Electronics
Newark, NY

ILTAM
Tel Aviv, , Israel

IMI, Inc
Haverhill, MA

Indium Corporation
Utica, NY

Industrial Instruments
Southampton, PA

Infinite Graphics Inc.
Minneapolis, MN

Innovative Circuits, Inc.
Alpharetta, GA

Inovaxe Corporation
Deefield Beach, FL

InsulFab PCB Tooling
Spartanburg, SC

Intel Corporation
Hillsboro, OR

Interplex Technologies Corporation
North Haven, CT

Invensas Corporation
San Jose, CA

INVENTEC Electronic Business Unit
Vincennes, , France

IPC Systems
Westbrook, CT

IPTE, LLC
Alpharetta, GA

Ironwood Electronics
St. Paul, MN

Isola Group
Titusville, PA

IST-Integrated Service Technology
Inc.
Hsinchu, , Taiwan

ITL Circuits
Markham, ON, Canada

ITM Consulting
Durham, NH

Itron, Inc.
Waseca, MN

ITW Thermal Films
Romeo, MI

Jabil Circuit, Inc.
San Jose, CA

Jabil Circuit, Inc.
St. Petersburg, FL

Javad EMS
San Jose, CA

JBC Tools USA Inc.
St. Louis, MO

Jendco Technologies
Fort Wayne, IN

Jet Propulsion Laboratory
Pasadena, CA

JH Technologies, Inc.
Fremont, CA

JMW Enterprises, Inc.
Rushford, MN

Johnson Controls, Inc.
Milwaukee, WI

JRT Manufacturing, LLC
Sanford,

Juki Automation Systems
Morrisville, NC

K & F Electronics, Inc.
Fraser, MI

K&L Services Group Inc.
Allentown, PA

Kapsch TrafficCom IVHS
Mississauga, ON, Canada

Kasion Automation Ltd.
Kwun Tong, Kowloon, Hong Kong

Keihin Carolina System Technology
Tarboro, NC

Kester ITW
Itasca, IL

Key Electronics
Jeffersonville, IN

KIC
San Diego, CA

Kimball Electronics Group
Jasper, IN

Koh Young Technology Inc.
Seoul, , Republic of Korea

Kostal Ireland GMBH
Abbeyfeale, Co. Limerick, Ireland

Krayden, Inc.
Denver, CO

Krypton Solutions
Plano, TX

Kyzen Corporation
Nashville, TN

L-3 Communications
Camden, NJ

LaserJob GmbH
Fuerstenfeldbruck, DE, Germany

LaserJob Inc.
Cambridge, ON, Canada

Lewis & Clark, Inc.
Tampa, FL

Lexicon Technologies Inc
Conyers, GA

Libra Industries, Inc.
Mentor, OH

Lockheed Martin
Sumterville, FL

Logic PD
Eden Prairie, MN

Logical Products, Inc.
Waukegan, IL

Logican Technologies
Edmonton, AB, Canada

LORD Corporation
Cary, NC

LPKF Laser & Electronics
Tualatin, OR

M.I.S. Electronics Inc.
Richmond Hill, ON, Canada

MacDermid, Inc.
Waterbury, CT

Machine Vision Products, Inc.
Carlsbad, CA

Mack Technologies
West Melbourne, FL

Manncorp
Huntingdon Valley, PA

Manufacturing Services, Inc.
Kennewick, WA

Masterwork Electronics, Inc.
Rohnert Park, CA

Matric
Seneca, PA

MatriX Technologies
San Diego, CA

MC Assembly
Palm Bay, FL

McDonald Technologies
Carrollton, TX

Medallion Technology, LLC
Houston, TX

Meiko Electronics (Guangzhou
Nansha) Co., Ltd.
Guangzhou, Guangdong Province,
, China

Mercury Marine
St. Cloud, FL

Metal Etch Services, Inc.
San Marcos, CA

Metal Etching Technology
Associates Inc.
Lumberton, NJ

Micro Industries
Westerville, OH

Micro Systems Engineering
Lake Oswego, OR

MicroCare Corporation
New Britain, CT

Micron Technology, Inc.
Boise, ID

MicroScreen
South Bend, IN

Microsoft Corporation
Redmond, WA

Microtek Laboratories
Anaheim, CA

Mid-America Taping & Reeling, Inc.
Glendale Heights, IL

Mirtec Corporation
Oxford, CT

Moog, Inc.
East Aurora, NY

MPL Inc.
Ithaca, NY

Multicircuits
Oshkosh, WI

Murray A. Percival Company
Auburn Hills, MI

MYDATA Automation, Inc.
Rowley, MA

N.F. Smith & Associates, L.P.
Houston, TX

NAMICS Technologies, Inc.
San Jose, CA

National Circuit Assembly
Garland, TX

Navitas Systems, LLC
Woodrige, IL

NCAB Group USA, Inc.
Hampstead, NH

New Age EMS, Inc.
Attleboro, MA

New Wave Components
St. Louis Park, MN

Newtechnik Ind.Com.Prod.Eletr.
ltda
Ribeirao Pires, SP, Brazil

Nihon Superior Company, Ltd
Suita, Osaka, Japan

Nikon Metrology
Brighton, MI

Niltronix Circuits, Inc.
Houston, TX

Nisene Technology Group
Watsonville, CA

Nordson ASYMTEK
Carlsbad, CA

Nordson DAGE
Fremont, CA

Nordson EFD
East Providence, RI

Nordson YESTECH
Carlsbad, CA

Norway Labs
Beaverton, OR

NPI Technologies, Inc.
Richardson, TL

nScrypt, Inc.
Orlando, FL

NuSil Technology
Carpinteria, CA

Nu-Way Electronics, Inc.
Elk Grove Village, IL

OES, Inc.
London, ON, Canada

OK International
Garden Grove, CA

OnCore Manufacturing Services
Fremont, CA

OnCore Manufacturing Services
Springfield, MA

One Source Group
Plano, TX

Optimal Electronics Corporation
Austin, TX

Orpro Vision
Billerica, MA

Osram Sylvania
Danvers, MA

P. Kay Metal, Inc.
Los Angeles, CA

PAC Global, Inc.
Addison, TX

Pac Tech USA
Santa Clara, CA

Panasonic Factory Solutions of America
Rolling Meadows, IL

Paramit Corporation
Morgan Hill, CA

PDR Rework and Inspection
Shingle Springs, CA

Peerless Instrument
East Farmingdale, NY

Pennatronics Corporation
California, PA

Pentagon EMS Corporation
Hillsboro, OR

Petroferm
Gurnee, IL

PFC Flexible Circuits Ltd.
Scarborough, ON, Canada

Philips Entertainment
Dallas, TX

Phoenix International
Fargo, ND

Pinnacle Technology Group Inc.
Ottawa Lake, MI

Pitney Bowes
Danbury, CT

Plexus Corp.
Appleton, WI

Point Six Wireless
Lexington, KY

Polyonics, Inc.
Westmoreland, NH

Power-One
Phoenix, AZ

PPSI
Houston, TX

Practical Components Inc.
Los Alamitos, CA

Practical Technologies, Inc.
Baltimore, MD

Precise Connections, Inc.
Duncanville, TX

Precision Assembly Technologies, Inc.
Bohemia, NY

Precision Graphics, Inc.
Somerville, NJ

Precision Placement Machines
Fremont, NH

Precision Technology, Inc.
Plano, TX

Premier Semiconductor Services
Tempe, AZ

PRIDE Industries
Roseville, CA

Prime Technological Services, Inc.
Suwanee, GA

Pro Ex
West Jordan, UT

Procasys LLC
Dallas, TX

Process Sciences, Inc.
Leander, TX

Production Analysis & Learning Services LLC
Trabuco Canyon, CA

Production Automation Corporation
Eden Prairie, MN

Projects Unlimited
Dayton, OH

Promex Industries Inc.
Santa Clara, CA

Prototron Circuits
Redmond, WA

PVA
Cohoes, NY

PW Stoelting, L.L.C.
Kiel, WI

QRP Gloves & Finger Cots
Grafton, WV

QSC Audio Products, LLC
Costa Mesa, CA

Qualitek International
Addison, IL

Quality Circuits Inc.
Fergus Falls, MN

Quality Production Ltd.
Hillsboro, OR

Quality Systems Integrated Corporation
San Diego, CA

Qual-Pro Corporation
Gardena, CA

Rauland-Borg Corporation
Mount Prospect, IL

Raven Industries Inc.
Sioux Falls, SD

Raytheon Company
McKinney, TX

Raytheon Missile Systems
Tucson, AZ

RBB Systems, Inc.
Wooster, OH

Rehm Thermal Systems LLC
Roswell, GA

Reliable Controls Corporation
Victoria, BC, Canada

RelianceCM
Corvallis, OR

RF Micro Devices
Greensboro, NC

Riverside Electronics Ltd.
Lewiston, MN

Rochester Institute of Technology
Rochester, NY

Rockwell Automation
Mequon, WI

Rockwell Automation
Mayfield Heights, OH

Rockwell Collins
Melbourne, FL

Rommel GmbH
Ehingen, , Germany

Roper Resources, Inc.
Dallas, TX

RPS Automation LLC
Spokane Valley, WA

S and Y Industries
Winfield, KS

Safran Electronics Canada Inc.
Peterborough, ON, Canada

Saline Lectronics, Inc.
Saline, MI

Sauer-Danfoss Company
Plymouth, MN

Schoeller-Electronics GmbH
Wetter, , Germany

Schweitzer Engineering Labs
Pullman, WA

Scienscope International
Chino, CA

Scott Electrokrafts Inc.
Andover, CT

Seagate Technology
Shakopee, MN

SEAKR Engineering, Inc.
Centennial, CO

Season Group
San Antonio, TX

SEHO North America, Inc.
Erlanger, KY

Seica Inc.
Salem, NH

Seika Machinery, Inc.
Torrance, CA

SemiPack Services Inc.
Melbourne, FL

SenDEC Corporation
Fairport, NY

Senju Comtek Corporation
Campbell, CA

Sensible Micro Corporation
Tampa, FL

Shenmao Technology Inc.
San Jose, CA

Shenzhen Kun Qi Xin Hua
Technology Co., Ltd.
Ban-tian, Long-gang, Shenzhen,
Guangdong, China

SIPAD Systems Inc.
Alphahretta, GA

SMC Manufacturing Services
Nicholasville, KY

SMEC, Inc.
Cedar Park, TX

SMTC Corporation
Markham, ON, Canada

SmtXtra
Doncaster, , United Kingdom

Solder Indonesia, PT.
Cileungsi - Bogor, , Indonesia

SolderMask, Inc.
Huntington Beach, CA

Sonoscan Inc.
Elk Grove Village, IL

Southwest Systems Technology Inc.
Plano, TX

SPEA America
Tyler, TX

Specialty Coating Systems
Indianapolis, IN

Spectra-Tech Manufacturing Inc
Batavia, OH

Spectrum Assembly, Inc.
Carlsbad, CA

Spectrum Laser & Technologies
Colorado Springs, CO

Speedline Technologies
Franklin, MA

Speedprint
Tampa, FL

STACI LaGrange, OH
LaGrange, OH

Stanley Supply & Services
North Andover, MA

STARboard TECHnology
Melbourne, FL

Static Solutions
Hudson, MA

Stellar Technical Products
Gardena, CA

StenTech
Markham, ON, Canada

STI Electronics, Inc.
Madison, AL

Stone Mountain Tool, Inc.
Conyers, GA

Stratesys Group
Yorba Linda, CA

Sunburst Electronics
Erie, PA

Sunburst EMS
West Bridgewater, MA

Sunshine Circuits
Plano, TX

Super PCB
Dallas, TX

Surface Mount Technologies Inc.
Anaheim, CA

Surface Mount Technology
Corporation
Appleton, WI

Surtek Industries Inc.
Surrey, BC, Canada

SVTronics, Inc.
Plano, TX

Symetrics Industries, LLC
Melbourne, FL

Synerject LLC
Delavan, WI

Syntek, Inc.
Chicago, IL

Sypris Electronics, LLC
Tampa, FL

Syscom Tech
Moorestown, NJ

Systronix, Inc.
Sugar Land, TX

Takaya - TEXMAC
Lombard, IL

Target Corporation
Pleasant Prairie, WI

TDI International, Inc.
Tuscon, AZ

Technica, USA
San Jose, CA

Technical Devices Company
Torrance, CA

Technical Support Inc.
Omaha, NE

Techni-Tool, Inc
Worcester, PA

Techtron Systems Inc.
Sohon, OH

Tectrol Inc.
Toronto, ON, Canada

Teka Interconnection Systems
Warwick, RI

Tektronix, Inc.
Beaverton, OR

TeligentEMS
Havana, FL

Tellabs, Inc.
Naperville, IL

Tenere, Inc.
Dresser, WI

Teradyne, Inc.
N. Reading, MA

Test Medics, Inc.
Deerfield Beach, FL

Test Research, Inc.
Taipei, , Taiwan

Texmac, Inc.
Acton, MA

The IPS Group, LLC
Flower Mound, TX

The Jefferson Project
Orlando, FL

The Test Connection, Inc.
Owings Mills, MD

Tintronics
Huntsville, AL

TMG Electronics, Inc.
Cheswick, PA

TopLine
Milledgeville, GA

Total Parts Plus, Inc.
Fort Walton Beach, FL

Touchstone Systems, LLC
Melbourne, FL

Trace Laboratories, East
Hunt Valley, MD

Tramonto Circuits, LLC
Lake Elmo, MN

Transforming Technologies
Toledo, OH

Transition Automation, Inc.
Tyngsboro, MA

Trans-Tec America LLC.
Chandler, AZ

Trenton Technology Inc.
Utica, NY

Triad Electronic Technologies
Phoenix, AZ

Trilogy Circuits, Inc.
Richardson, TX

Trison Inc.
Hibbing, MN

Tropical Stencil, Inc.
Jupiter, FL

TS3 Technology, Inc.
Stafford, TX

TT Electronics
Perry, OH

Tyco Safety Products Canada Ltd
North York, ON, Canada

Unicote Finishes LLC
Amherst, NH

Universal Instruments Corporation
Conklin, NY

Valtronic Technologies (USA) Inc.
Solon, OH

Vanguard EMS, Inc.
Beaverton, OR

Variosystems, Inc.
Southlake, TX

VersaLogic Corporation
Tualatin, OR

VI Technology
Richardson, TX

Virtual Industries Inc.
Colorado Springs, CO

Viscom Inc.
Duluth, GA

Vision Engineering Inc.
New Milford, CT

Vitronics Soltec
Hampton, NH

VJ Electronix, Inc.
Littleton, MA

V-Tek, Inc.
Mankato, MN

Wellex Corporation
Palo Alto, CA

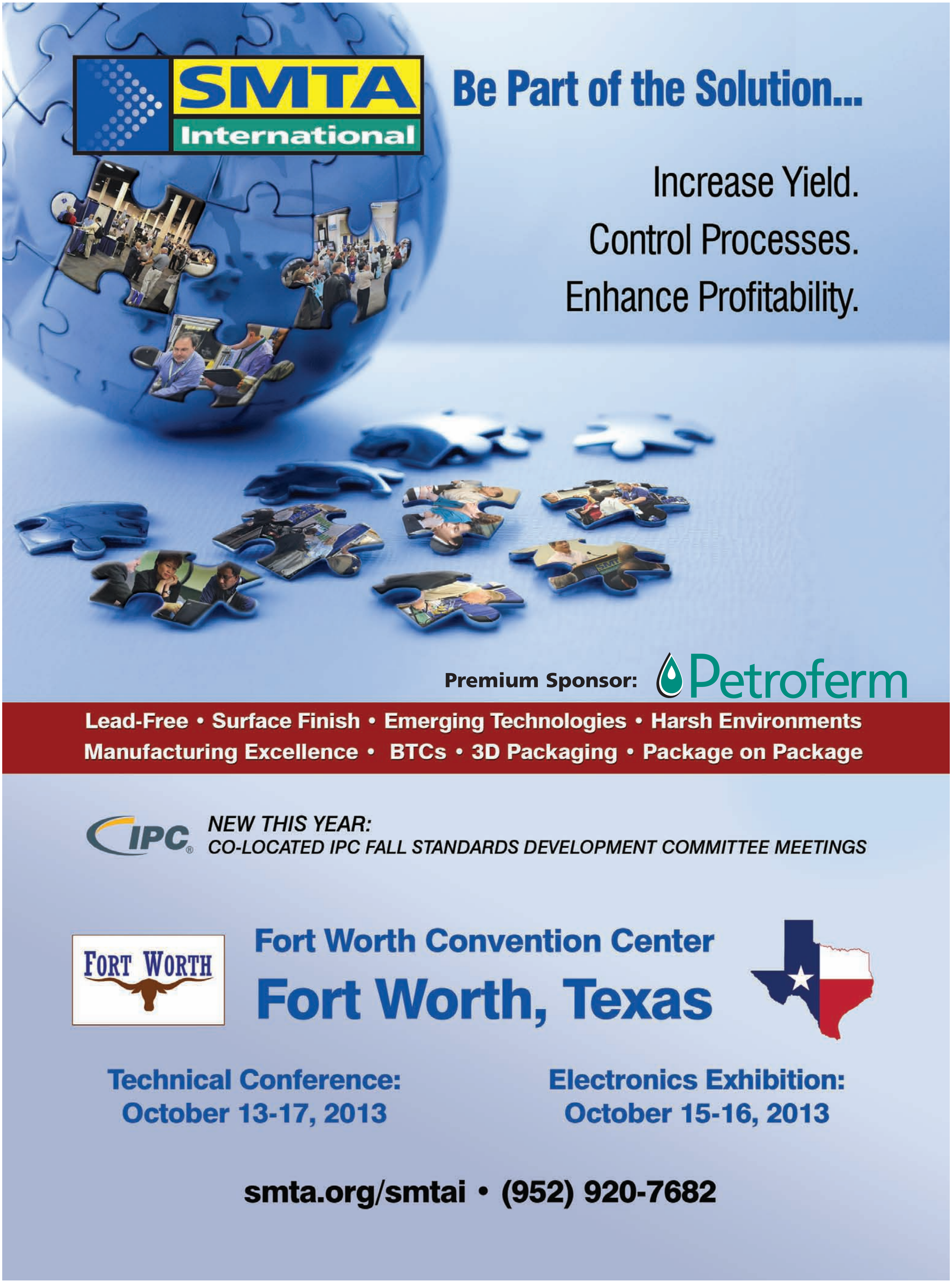
WinTronics, Inc.
Sharon, PA

Wolcott-Park, Inc.
Rochester, NY

ZESTRON America
Manassas, VA

Zollner Electronics Inc.
Milpitas, CA

Zymet, Inc.
East Hanover, NJ


SMTA International
Be Part of the Solution...
Increase Yield.
Control Processes.
Enhance Profitability.
Premium Sponsor: Petroferm
Lead-Free • Surface Finish • Emerging Technologies • Harsh Environments
Manufacturing Excellence • BTCs • 3D Packaging • Package on Package
IPC
NEW THIS YEAR:
CO-LOCATED IPC FALL STANDARDS DEVELOPMENT COMMITTEE MEETINGS
FORT WORTH
Fort Worth Convention Center
Fort Worth, Texas
Technical Conference:
October 13-17, 2013
Electronics Exhibition:
October 15-16, 2013
smta.org/smtai • (952) 920-7682