

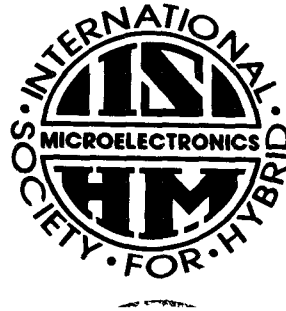


CHICAGO, ILLINOIS

1990
PROCEEDINGS
INTERNATIONAL
SYMPOSIUM ON
MICROELECTRONICS

ISHM '90 Proceedings

**PROCEEDINGS
of the 1990
INTERNATIONAL
SYMPOSIUM ON
MICROELECTRONICS**



江苏工业学院图书馆
藏书章

**October 15-17, 1990
McCormick Place North
Chicago, Illinois**

Sponsored by the INTERNATIONAL SOCIETY
FOR HYBRID MICROELECTRONICS

ISHM '90 Proceedings

**Edited and Assembled
by the
1990 Technical Program Committee
and the
Society Staff**

J. M. S.
**Copyright © 1990 by
The International Society for Hybrid Microelectronics
All rights reserved
Printed in U.S.A.**

ISBN 0-930815-27-0

**International Society for Hybrid Microelectronics
P.O. Box 2698
1861 Wiehle Avenue, Suite 260
Reston, VA 22090
(800)232-4746 / (703)471-0066**

ISHM '90 Proceedings
Introduction
to the
1990
International Symposium on Microelectronics

Welcome to Chicago, The Windy City and home to ISHM 1990. The theme chosen by the Symposium Committee is the "Winds of Change In Microelectronics." This year's symposium ushers in the 90's, a time that promises to bring tremendous change to our industry. These *Proceedings* represent the latest work from 118 of the finest research, development, and engineering groups in our field. The information presented here will be of value to newcomers to the industry as well as the "hardened" veterans. In keeping with industry trends, this volume presents the information found in twenty-five technical sessions concerned with surface mount technology, multichip modules, TAB, materials, analysis and reliability, processing, and applications of hybrid circuits.

The Technical Program Committee has spent countless hours trying to ensure the best possible symposium and written technical *Proceedings*. The Technical Session Chairs have reviewed each manuscript for appropriateness and technical content prior to publication. I would particularly like to thank Harry K. Charles, Jr., Ph.D., Richard Gehman, Thomas Luin, Mark Naretto, and Bernie S. Aronson for their willingness to review the abstracts and final manuscripts prior to publication. A special thanks must go to the people at ISHM headquarters, the people who work behind the scenes and whose efforts have made these *Proceedings* possible. I would also like to thank Loren Saar, Symposium General Chair, for allowing me to serve ISHM.

Alan P. Genis, Ph.D.
 Technical Program Chair

Important ISHM '91 Dates	
Date	Activity
January 18-20	Executive Council Meeting Hyatt Reston, Reston, VA
January 30-2/1	ATW—Advanced Placement Technology Sedona, AZ
February 15	ISHM '91—Abstracts Due
April 8-9	JTC '91—Materials and SMT Symposium
April 15	ISHM '91 Exhibit Space Deadline
April 18-21	Leadership Conference & Executive Council Mtg Hyatt Reston, Reston, VA
May 1-3	ATW—EC '92 Washington, DC area
May 29-31	IMC—Rotterdam, Netherlands
June 15	ISHM '91 Papers Due for Proceedings
June 19-21	ATW—Multichip Modules II Coastal Maine
July 20-22	Executive Council Meeting Hyatt Reston, Reston, VA
September 19	ISHM '91—Registration and Housing Cut-off
October 21-23	ISHM '91 Orlando Convention Center, Orlando, FL

1990 SYMPOSIUM COMMITTEE

Loren Saar, Motorola, General Chair
Lauren K. Andersen, Ph.D., DuPont, Continuing Education Chair
David Arata, Crest Ultrasonics Corporation, Exhibits Chair
Arthur O. Capp, Jr., Laserage Technology Corporation, Arrangements Chair
Thomas B. Della, Process Technology, General Vice-Chair
Christ J. Dumas, Methode Electronics, Inc., Arrangements Vice-Chair
Richard E. Gehman, Micro Switch, Technical Vice-Chair
Alan P. Genis, Ph.D., Northern Illinois University, Technical Chair
Janice M. Giesler, Motorola, Special Events
R. Wayne Johnson, Auburn University, President-Elect
W. Kinzy Jones, Ph.D., Florida International University, ISHM '91 Chair
Jon F. Krause, Zenith Microcircuits, Education Chair
Ruth Ann May, Honeywell, North Central Regional Director
Christine Missele, Special Events
Louise C. Pauly, Carborundum Company, Exhibits Vice-Chair
Nancy Saar, Registration Chair

INTERNATIONAL SOCIETY FOR HYBRID MICROELECTRONICS

The International Society for Hybrid Microelectronics (ISHM) is a not-for-profit professional society, dedicated to the advancement of hybrid microelectronics. The Society's prime objectives are to provide a forum for the dissemination of knowledge within the field of microelectronics and to serve as a common denominator for the diverse engineering disciplines upon which the microelectronics industry is based.

ISHM encourages the exchange of information among the complementary technologies of ceramics, thin and thick films, semiconductor devices, and monolithic circuits into a distinct field of activities embracing materials, design, processing techniques, equipment, fabrication, and application engineering.

The Society is composed of almost 7,000 individual members in over 60 regular and student chapters in the United States and Canada. Our nearly 600 organizational members worldwide supplement the Society's technical strength.

1990 ISHM EXECUTIVE COUNCIL

Janette R. Williams, The Carborundum Company, President

R. Wayne Johnson, Ph.D., Auburn University, President-Elect
Julian Blankinship, DuPont, Vice President
Charles E. Bauer, Ph.D., MicroLithics Corporation, Technical Vice President
Paul H. Beddo, Hybridyne, Secretary
Dennis Keyfauver, Magnavox, Treasurer
James C. Lawson, Raytheon, First Past President
Richard E. Bennett, Electromagnetic Sciences, Inc., Southeast Regional Director
Doug R. Bokil, Film Microelectronics, Inc., Northeast Regional Director
Byron W. Bumgarner, West Engineering Sales, Inc., Pacific Northwest Regional Director
Edward M. Gildein, Hybrid-Tek, Inc., Mid-Atlantic Regional Director
Ruth Ann May, Honeywell, North Central Regional Director
Hank Merino, Merino Sales Company, South Central Regional Director
Thomas L. Muir, Villa Precision, Inc., Southwest Regional Director
Kenneth R. Reynolds, Watkins-Johnson Company, Southern California Regional Director
*Russell Atkinson, Affiliated Manufacturers, Inc., I/SMT Division Chair
*Christopher R. Needes, Ph.D., DuPont, Materials Division Chair
*Eugene DeMichele, ISHM, Executive Director
*ex officio

1990 ISHM AWARDS

Daniel C. Hughes, Jr., Memorial Award

Presented to
John Wagnon, (Posthumous Award)

For his significant technical contributions to ISHM in the field of thick film materials technology and his untiring efforts as National Treasurer and Executive Council member to advance the technical and administrative programs of the Society.

Corporate Recognition Award

Presented to
Teledyne Microelectronics

In recognition of its achievements in the development and manufacture of hybrid microelectronic circuits and support of ISHM by its employee participation in technical symposia, local and national offices.

Technical Achievement Award

Presented to
Paul Van Loan

For his work in the field of thick film resistor wafers, liquid crystal displays, and the design and development of new hand held electronic calculators and hybrid packaging technologies, in addition, his many technical presentations and publications.

Fellows of the Society

Carl Missele
Gary W. Johnson
Charles Q. Scrantom
Donald J. Spigarelli
George S. Szekely

Best Paper of the 1989 Symposium (Baltimore)

Presented to
Akira Matsui, Kenichi Kawai, and Eiji Asada, Toyota Motor Corporation
for the paper
"Experimental Research on Fatigue and Fracture of Solder"

ISHM ORGANIZATIONAL MEMBERS

*as of July 15, 1990

A.I. Technology, Inc.
A.J. Electronics, Inc.
A. T. Wall Company
A-B Lasers, Inc.
AAI Corporation
Ablestik Laboratories
ACC Electronics Company
Accu-Tech Laser Processing Inc.
Accumet Engineering Corp.
Accuprobe, Inc.
Advance Reproductions Corp.
Advanced Interconnections
Advanced Packaging Systems
Advanced Technology Group, Inc.
Advantek, Inc.
Aegis Laser, Inc.
Aegis, Inc.
Aerofeed, Inc.
Aeroflex Labs
AG Communications Systems
Air Products and Chem., Inc.
Air-Vac Engineering Company
Airo Industrial Gases
Airo Clean Engineering, Inc.
Airpax/Cambridge Division
Airpax/Cheshire Division
Akzo Electronic Materials Co.
Alabama Micro Science/Tech Ctr.
Alcatel Comptech, Inc.
Alcatel Vacuum Products, Inc.
Alcoa Electronic Packaging Inc.
Alessi Industries, Inc.
Algorex Corporation
Allen Davis Associates
Allen-Bradley Company
Allied-Kelite Division
Allied-Signal Inc.
Alpha Industries, Inc.
Alpha Metals, Inc.
Alphasem AG
Alsimag Technical Ceramics Inc.
Amberwood Research
American Chemical & Refining
American Etching & Mfg.
American Fine Wire Corp.
American Precision Industries
American Tech. Ceramics
AMI (Affiliated Mfg., Inc.)
Amitron
Amplifonix
AMR Industries Inc.
Analog Devices, Inc.
Analysis Tech
Analytek, Ltd.
Anrich Microscreens, Inc.
AOT Corporation
Applied Image, Inc.
Applied Laser Technology
Applied Process Technology
Aptek Technologies, Inc.
Aremco Products, Inc.
Array Technology
ASPE, Inc.
Assembly Technologies
Associated Testing Labs Inc.
Aster Technology Inc.
Asymtek
AT&T Network Systems
Ausimont
Austin American Tech. Corp.
AVX Corporation
AWK & Associates
Axtech, Inc.
Aydin Vector Division
Azimuth Electronics, Inc.
B & G Enterprises
Balo Hermetics Company
Balzers
Banner Engineering, Inc.
Basic Glass Products
Baxter Healthcare Corp.
Beckman Industrial Corporation
Behr Precious Metals
BEI Defense Systems Company
Benchmark Industries, Inc.
Bergquist Co.
Betatron, Inc.
Boeing Aerospace & Electronics
Bourns Networks Inc.
Bourns, Inc.
Branson/IPC
Brewer Science Inc.
Brush Wellman/Ceramics Unit
BTU International, Inc.
Buehler Ltd.
Bullen Ultrasonics, Inc.
Burr-Brown Corporation
C. W. Price Company, Inc.
C.H.P.S., Inc.
Cabot Ceramics
Cabot Ceramics-Microwave Div.
CAC Microcircuits
Cadmet Inc.
California Fine Wire Company
California Micro Devices Corp.
Cambridge Instruments Inc.
Camelot Systems, Inc.
Canadian Marconi Company
Carborundum Company
Carl Zeiss, Inc.
Cascade Laser Corp.
Cascadia Technology Corp.
CBL Ceramics Ltd.
Centronic, Inc.
Cerac, Inc.
Ceradyne, Inc.

ISHM '90 Proceedings

Ceratronics
Cerprobe Corporation
Charles Ross & Son Co.
Chemet Corporation
Cherry Corporation
Chicago Laser Systems, Inc.
Chip Supply, Inc.
Ciba-Geigy Corporation
Cimflex Teknowledge Corp.
Cincinnati Electronic Corp.
Circuits Processing Technology
Clean Room Products, Inc.
Clestra Cleanroom Technology
Climax Specialty Metals
Cobehn Systems, Inc.
Cognex Corporation
Coherent Circuit Tuning
Coilcraft, Inc.
Comatel USA, Inc.
COMCO, Inc.
Comlinear Corporation
Compaq Computer Corporation
Composite Tech Alloys, Inc.
Control Laser Corporation
Controlled Atmosphere Tech.
Coors Ceramics Company
Coors Electronic Package Co.
Corpane Industries, Inc.
Crest Ultrasonics Corporation
Crystal Mark, Inc.
CTC Engineering Corporation
CTS Corporation
Custom Laser Inc.
CVC Products Inc.
Cyberoptics Corporation
de Haart, Inc.
Dae Woo Electronic Components
Dage Precision Industries Inc.
Danam Industrial., Ltd.
Data Composition, Inc.
David Sarnoff Research Center
DEK USA, Inc.
Delco Elec. Division/GMC
Devar Corporation
Dexter Electronic Materials
Diacon Inc.
Dicing Technology, Inc.
Die-Tech, Inc.
Directed Light, Inc.
Disco Hi-Tec America, Inc.
DIT-MCO International Corp.
Dong-A Hybrid & Ceramics, Inc.
Dow Corning Corporation
Dynapert, Inc.
E.I. Dupont de Nemours
Eagle Test Systems, Inc.
Eastern Smelt. & Refin. Corp.
Eastman Kodak/Apparatus Div.
Ed Fagan Inc.
Edison Welding Institute Inc.
EDO Corp/Barnes Engineering
Edwards High Vacuum Internatl.
Eldec Corp.
Electro Scientific Industries
Electro-Films, Inc.
Electro-Science Labs, Inc.
Electromagnetic Sciences, Inc.
Electronic Packaging
Electronic Prod., Inc.
Electrovert USA Corp.
Elmo Semiconductor Corp.
EMC Domestic Inc.
EMCA-Remex Products
EMCA/Rohm and Haas
EMD Associates, Inc.
Emerson & Cuming
Emerson & Cuming Inc.
Engelhard Corporation
Engineered Specialty Products
Engineered Technical Products
Enthone-OMI Inc.
Epotecny
Epoxy Technology, Inc.
ESEC SA
ESEC USA, Inc.
Etri
Everest Interscience, Inc.
Excellon Automation
Explosive Fabricators, Inc.
Fancort Industries
FDK America, Inc.
Ferro Corp/Elec Matls Div
Ferro-ECA Electronics Company
Film Microelectronics, Inc.
Florod Corporation
Fluoroware, Inc.
Fox Laboratories
Frenchtown Ceramics Co.
FSI International
FTS Systems, Inc.
Furane Products Company
Gaiser Tool Company
GBC Materials Corporation
Geib Refining Corporation
Gel-Pak Div./Vichem Corp.
Geller Microanalytical Lab
General Ceramics, Inc.
General Dynamics
General Laser, Inc.
General Metal Finishing Co.
Generon Systems
Gentron Corporation
Gerard Daniel & Company, Inc.
Gordos, A Flint Industries Co.
GTE Government Systems Corp.
Gulton Industries
H.E.S. International, Inc.
Handy & Harman
Hard Materials Cutting
Harper Electric Furnace Corp.
Harris Corporation
Harris Corporation, GCSD
HEI, Inc.
Henry Mann, Inc.

ISHM '90 Proceedings

Heraeus Inc./Cermalloy Div.
Hetherington
Hewlett Packard Company
Hi-Rel Laboratories
Hoechst Ceramtec N.A., Inc.
Honeywell Marine Division
Honeywell, Inc.
Hughes Aircraft Company
Hughes Aircraft/GSG
Hy-Meg Corporation
Hybond, Inc.
Hybrid Data
Hybrid-Tek, Inc.
Hybrids International, Ltd.
Hybridyne, Inc.
Hycomp, Inc.
Hydelco, Inc.
Hydrostatics, Inc.
HYTEK Microsystems, Inc.
I.C. Probotics, Inc.
I-Stat Corporation
IBM Corporation
ICI
ICI Americas
ICI Americas, Inc.
IFP Enterprises/Cemota
ILC Data Device Corporation
Indium Corp. of America
Infinite Graphics, Inc.
Integrated Ceramic Technology
Integrated Circuit Engineering
Integri-Test Corporation
Interconnect Devices, Inc.
Interfet Corp.
Intergraph Corporation
International Resistive Co.
Interpoint Corporation
Intl Mfg Services Inc. (IMS)
IRI, A Dover Technologies Co.
Irvine Sensors
Ismeca USA, Inc.
Isotronics, Inc.
Itere
ITW Chronomatic
J & J Materials, Inc.
Jeol U.S.A., Inc.
Jerry Bachur & Associates
Johanson Dielectrics, Inc.
Johanson Manufacturing Corp.
John Fluke Mfg. Company, Inc.
Johnson Matthey
Keller Technology Corporation
Kemet Electronics Corp.
Keramont Corporation
Kester Solder Company
Kilburn Glass Industries, Inc.
Kimball Electronics
Koch High Tech AG
Kraft Dynatronix, Inc.
Kulicke & Soffa Industries
Kyle Technology Corporation
Kyocera America, Inc.

L. Gordon Packaging
Lake Publishing Corporation
Lanxide Corporation
Laser Precise
Laser Services, Inc.
Laser Tech, Inc.
Lasera Technology Corp.
Lasereliance Technologies
Lasermation, Inc.
Lastec, Inc.
Latronics Corporation
Laurier, Inc.
Lawrence Associates, Inc.
Layout Concepts, Inc.
Lea Ronal, Inc.
Leach Corporation
Lentronics
LFE Plasma Systems
LFG Micro
Liberty Industries, Inc.
Lindberg Unit/General Signal
Liquid Air Corporation
Litton Guidance & Control
Litton Systems, Canada, Ltd.
Loral IR & Imaging Systems
Lumonics Laser Systems Group
Luxtron Corporation
M-Tron Industries, Inc.
Mansol Ceramics Company
March Instruments
Marconi Circuit Tech. Corp.
Markem Corporation
Marpet Enterprises Inc.
Martin Marietta Electronic Sys.
Materials Research Corporation
MC Systems, Inc.
McIntyre Associates
MCT/Browne Reflow Soldering
Meftech Inc.
Mentor Graphics
Mereco Technologies Group Co.
Metech, Inc.
Metz Metallurgical
MIC Technology Corporation
Micro Contacts, Inc.
Micro Crystal/Div. SMH
Micro Electronic Technologies
Micro Robotics Systems, Inc.
Micro-Ceramx Technology
Micro-Etch Div/Device Closures
Micro-Hybrid Dimensions Inc.
Micro-Hybrid Screens, Inc.
Micro-Screen
Microcircuit Engineering Corp.
Microcontamination Magazine
Microelectronic Assoc., Inc.
Micromanipulator Co., Inc.
Micron, Inc.
Micropac Industries
Micropen, Inc.
Microcross Components Corp.
Midas Technology, Inc.

ISHM '90 Proceedings

Minco Technology Labs, Inc.
Mini-Systems, Inc.
Minico/Asahi Chemical of Amer.
Mitel Semiconductor
Mitsui Toatsu Chemicals, Inc.
Mobile Data International
Mosaic Systems, Inc.
Mountaingate Engineering
MPM Corporation
MSN Products (PTY) Limited
MTI Corporation
MTW & Associates
Multicore Solders
Murata Erie North America
NAS Electronics
Natal Engineering Co., Inc.
National Training Center
Nicolet Instrument Corporation
Nihon Cement Co., Ltd.
Nikon Inc., Instrument Group
Nippon Electric Glass Co. Ltd.
Noritake Co., Inc.
Normell Associates, Inc.
Northern Telecom
Norton Co., Advanced Ceramics
Novacap
NTK Technical Ceramics
Nu-Concept Systems, Inc.
Ohmite Manufacturing Company
Ohmtek—A Vishay Company
Ohmtek, Inc.
Olin Electronics
Olin-Hunt Conductive Materials
Olympus Corporation
Oneida Research Services, Inc.
Optical Associates, Inc.
Optical Radiation Corporation
Orasis Corporation
Orbot Inc.
Oriel Corporation
Orthodyne Electronics
P/M Industries, Inc.
PAC, Inc.
Pacesetter Systems, Inc.
Pacific Hybrid Microelec.
Pacific Precision Labs
Paine Corporation
Palomar Systems
Panametrics, Inc.
Panasonic Factory Automation
Parts Technology, Inc.
PCK Technology Division
PCO, Inc.
Pease & Curren Refining, Inc.
PGP Industries, Inc.
Philips Circuit Assemblies
Philips Components
Phoenix Microwave Corp.
Photo Stencil Inc.
Photofabrication Engineering
Photometrics, Inc.
Pind Testers

Plasmatic Systems
Platronics Seals
Poco Graphite, Inc.
Polaris Electronics Corp.
Polese Company
Practical Engineering Inc.
Precision Photomask, Inc.
Presidio Components, Inc.
Proactive Marketing, Inc.
Probotech Inc.
Promex
Q-Bit Corporation
QRP, Inc.
Quad Group, Inc.
Quantum Chromodynamics Inc.
Questech Services Corporation
R. F. Hybrids
Racal-Milgo Inc.
Radiant Technology Corporation
Ransco Industries, Inc.
Raynet
Raytheon Company
Reeves-Hoffman
Research Devices/Amer. Optical
RFE Industries, Inc.
Rigsby Screen & Stencil
RIV Inc.
Robotics Inc.
Rodenstock
Royce Instruments, Inc.
Samsung Electromechanics Co.
Saxonburg Ceramics, Inc.
Schneider & Marquard
Schott Electronics
Scientific Sealing Technology
SCM Metal Products, Inc.
Scrantom Engineering, Inc.
Secon Metals Corporation
Seiko Instruments USA, Inc.
SEL-REX
Sellers & Associates
Semi Dice, Inc.
Semi-Alloys Inc.
Semicon Tools Inc.
Semiconductor Equipment Corp.
Semiconductor Packaging Matls.
Semtech Corporation
Sermed, Inc.
Sertech Labs
Sharp Data Ltd.
Sharp Precision
Shoei Chemical, Inc.
Siemens Prod. Ctr. Frankfurt
Sikama International
Silicon Detector Corporation
Small Precision Tools
SMEC
Soldermatics, Inc.
Solid State Equipment Corp.
Solitron Devices
Sonic Mill Albuquerque Div.
Sonoscan, Inc.

ISHM '90 Proceedings

Sorep Technology Corporation
Sparton Corporation
Spectrol Electronics
SPI Supplies/Structure Probe
Sprague Electric Company
SRT
State of the Art, Inc.
Statek Corporation
STC Components, Inc.
Stellar Industries Corp.
STS/Electrotech
Summit Corporation of America
Superior Technologies
SZ Testsystem/Semitech Int'l
Taiyo Yuden (USA), Inc.
Tangent Tool & Stamping, Inc.
TDK Corporation of America
Tech-Rep Electronics Ltd.
Technical Distributors, Inc.
Tegmen Corporation
Tektron Micro Electronics Inc.
Tektronix, Inc.
Telectronics Pacing Systems
Teledyne Microelectronics
Teledyne Philbrick
Teledyne Tac
Telegenix
Temptronic Corporation
Tencor Instruments
Tenney Engineering
Teradyne Laser Systems Inc.
Terra Universal, Inc.
Tetko, Inc.
Texas Instruments
Texel Components Corporation
TH Electronics
The Jade Corporation
The Micro-Tech Index
Thermid Polyimides/National
Thermonics, Inc.
Thermoset Plastics, Inc.
Thin Film Technology, Inc.
Tokuyama Soda Company, Ltd.
Towne Laboratories, Inc.
Trans-Tech, Inc.

Translogic Corporation
Trebtor Instrument Corporation
Trio-Tech Int'l Static Systems
Tronitec Comp. Elec, S.A.
Ultron Systems
Unichem Industries
Union Carbide Chem. & Plas. Co.
Union Carbide Industrial Gases
United Detector Technology
United Refining & Smelting Co.
Uthe Technology Corporation
V-Tek Inc.
Vacuum Industries, Inc.
Valid Logic Systems
Valley Design Corporation
Valtronic Technology, Inc.
Vanguard Electronics Company
Vanguard Research
Varian Associates, Inc.
Veeco Instruments Inc.
Veeco Instruments, Inc.
Viking Semiconductor Equip.
Villa Precision, Inc.
Viox Corporation
Vision Engineering, Inc.
Vitramon, Inc.
Vitronics Corporation
VSA Inc.
Watkins-Johnson Company
Web Technology
Weltek International, Inc.
Wenesco Inc.
Wentworth Labs, Inc.
West-Bond, Inc.
Western Technology Associates
Westrep
Wild Leitz USA, Inc.
Williams Advanced Materials
XMR Inc.
Yield Engineering Systems Inc.
Zenith Microcircuits Corp.
Zevatech, Inc.
Zuken America, Inc.
3M/Electronic Products Div
3M/ICPD

TABLE OF CONTENTS

Invited Plenary Session
 Dr. Alan P. Genis, Chair, Northern Illinois University

- 1 **Evolution of the Microelectronic Industry.** Robert E. Holmes, Hints Unlimited.
- 5 **Materials and Processes for the Hybrid Industry.** Dr. Alan L. Dow, Dupont.
- 6 **The Demand on Materials and Processes to Carry the Industry into the 21st Century.** John R. Thome, Motorola, Inc.

Aluminum Nitride As a Substrate
 Thomas Gilbertson, Chair, Motorola, Inc.

- 7 **Effect of Lot Variations on the Manufacturability of Thick and Thin Film AlN Substrates.** Anwar Mohammed, Azzam Abdo, George Scarlett, and Farage Sherrima, National Semiconductors.
- 13 **Processing of AlN for Thin Film Hybrid Applications.** John J. Reagan and Robert L. Beckman, Tektronix, Inc.
- 19 **Evaluation of the Hybrid Made of Surface Treated AlN Substrate.** Yoshirou Kuromitsu, Toshiyuki Nagase, and Hideaki Yoshida, Mitsubishi Metal Corporation; Fujio Miyazawa and Yasukazu Ikeda, Mitsubishi Electric Corporation, Japan.

Direct Writing Techniques for Microelectronic Applications
 Walter Mathias, Chair, Micropen, Inc.

- 27 **Direct Pattern Writing Using Laser Sensing Technology.** Ira G. Elias, MPM Corp.
- 31 **Direct Writing as a Subtractive Processing Tool.** Walter M. Mathias, Micropen, Inc.
- 36 **Direct Conversion of Conductors on Ceramic Substrates.** Dr. Nathaniel R. Quick, AppliCote Associates.

Failure Analysis and Reliability in Microelectronics Manufacturing
 Jack Sherman, Chair, Motorola, Inc.

- 42 **An Investigation of Wirebond Problems Associated with Glass in a Glass-Free Thick Film Conductor.** Eric Adamec and James Winschel, Honeywell Inc.
- 48 **ESD Characteristics of RuO₂-Based Thick Film Resistors.** Takashi Yamaguchi and Takashi Nakano, Keio University, Japan.
- 53 **Investigation on Void Formation in Die Attach Adhesives and Its Influence on Chip Reliability.** Shigeru Kohinata, Shyu Sekihara, and Kenji Fujimura, Sumitomo Metal Mining Co., Ltd., Japan.
- 61 **When Control Charting is not Enough. A Wirebond Process Improvement Experience.** Howard B. Eisenberg and Ingrid Jensen, Westinghouse Electric Corporation.
- 67 **Effects of Across Belt Temperature Uniformity on Fired Resistor Values.** Robert K. F. Teng, California State University; Tom Berdner, General Signal; M.P. Ethridge, Mississippi State University.

Reactive Atmosphere Technology
 Bruce Adams, Chair, Air Products

- 75 **Optimization of Atmosphere Doping for Firing Photoformable Copper Thick Film Materials.** Satish S. Tamhankar, The BOC Group Inc.; Roupun L. Keusseyan, DuPont Electronics.
- 80 **Reactive Gas Atmospheres for Firing Copper Dielectrics.** Satish S. Tamhankar and Mark J. Kirschner, The BOC Group, Inc.
- 84 **Controlled Atmospheres for Infrared Reflow Soldering of SMDs.** Benoit Lhote and Sylvie Mullul, L'Air Liquide; Benedicte Maire-Freysz and Dominique Navarro, Université de Bordeaux I, France.
- 92 **Properties of New Nitrogen Fireable Resistor System for Thick Film Circuits.** Ryuichi Tanabe, Jiro Chiba, Yoshiyuki Nishihara, Mikio Sasaki, and Keiichi Kawakami, Asahi Glass Company, Ltd., Japan.
- 98 **Controlled Atmospheres for Soldering Processes.** J.C. Ivankovits, Air Products and Chemicals, Inc.

Mixed Technologies for Hybrid/SMT Assembly
 Thomas Walsh, Chair, Motorola Inc.

- 119 **Automation: A Study in Integrated Technologies.** Jeffrey A. Beals, Motorola, Inc.
- 127 **No-Clean Flux Evaluation and Classification Methods.** Brian Deram, Litton Industries.
- 136 **Solder Paste Printing for Fine Pitch Devices.** Kevin L. Kent, Motorola Inc.
- 141 **Single Step Reflow Soldering and Cleaning for Surface Mount.** Gerry Waldron, BTU International, Inc.
- 153 **Solder Joint Reliability of Fine Pitch Solder Bumped Pad Array Carriers.** Kevin Moore and Steve Machuga, Motorola Inc.
- 159 **Establishing a No-Clean Wave Solder System In Production.** Tom Walsh, Motorola Inc.

Techniques for Improved Soldering
 Carl Missele, Chair, Motorola, Inc.

- 167 **Substrate Soldering in Microwave Hybrid Integrated Circuit Assembly.** Roy V. Winkle, Philips Research Laboratories, England.
- 174 **Measuring Solder Paste Metal Content Using Alternating Current Electrical Impedance Techniques.** Dr. Mark Polczynski, Thor Technology Corporation.
- 183 **Automated Solder Paste Dispensing Process Characterization Using Design of Experiment Techniques.** Susan M. Yarling, Motorola, Inc.
- 190 **Thermal Cycling of Soldered Thick Films. Part 1: Theory.** Roupun L. Keusseyan, Peter T. Goeller, Lynne E. Dellis, James R. Thrash, Tom G. Davenport and Robert F. Hazelwood, Dupont Electronics.
- 198 **Thermal Cycling of Soldered Thick Films. Part 2: Experiment.** Roupun L. Keusseyan, Peter T. Goeller, Lynne E. Dellis, James R. Thrash, Tom G. Davenport, and Robert F. Hazelwood, Dupont Electronics.
- 203 **Brazing to Silver-Based Thick Film Metallizations.** Roupun L. Keusseyan, Lynne E. Dellis, Robert F. Hazelwood and Peter T. Goeller, DuPont Electronics.

Recent Developments in Interconnect Technology

Arthur O. Capp, Jr., Chair, Laserage Technology Corp.

- 208 **Manufacture of Robust Matched-Glass Feedthroughs.** M.D. Grgas and G.G. Pinneo, TRW.
- 216 **High-Density, High-Speed Thick Film Interconnections Incorporating a New, Low Permittivity, High Resolution Dielectric.** Gary P. Shorthouse, Leanne Bricknell, Richard W.J. Russell, and Robin J. Morris, Johnson Matthey Technology Centre, England.
- 224 **Small Via Generation by Diffusion Patterning.** John J. Felten and Janice Collins, E. I. DuPont de Nemours & Co.
- 229 **Four Pure Cu Metallization Products, An Adhesion Value and Mechanism Comparison Study.** Michael L. Capp, Cirqon Technology Corporation; Kalman Zsamboky, Ceramic Packaging, Incorporated.

Advanced Packaging Technology for LCD Panel Devices in Japan

Fumio Miyashiro, Chair, Toshiba Corporation
Michael Alan Stein, Cochair, Electro Science Labs

- 239 **Technical Trend of Flat Panel Display.** T. Sasaki, SHM, Sharp, Japan.
- 244 **Process Technology of 158mm-COF Production Line.** Akinori Kawase and Tadashi Ogura, Casio Micronics Co., Ltd., Japan.
- 250 **Chip-On-Glass Technology with Standard Aluminized IC Chip.** K. Sakuma, K. Nozawa, E. Sato, Y. Yamasaki, K. Hanyuda, H. Miyasaka, and J. Takeuchi, Seiko Epson Corporation, Japan.
- 257 **LSI Chip Mounting Technology for Liquid Crystal Displays.** Takashi Nukii, Noriko Kakimoto, Hisashi Atarashi, Hiroshi Matsubara, Keiji Yamamura and Hirotohi Matsui, Sharp Corporation, Japan.
- 263 **COG (Chip-On-Glass) Technique for LCD Using a Low Melting Point Metal.** Masayuki Saito, Miki Mori, Akinori Hongu, and Akira Niitsuma, Toshiba Corporation, Japan.

Recent Advances in Materials for Hybrid Application: Inks I

Jerry Steinberg, Chair, Heraeus, Inc.

- 269 **High Performance Copper Paste for Applications.** Akinori Yokoyama, Tetsuro Dozono, Hitoshi Nakajima, and Tsutomu Katsumata, Asahi Chemical Industry Co., Ltd., Japan.
- 276 **Materials and Applications for Thick Film RC Networks.** Dr. Jerry Steinberg and Brian Kistler, Heraeus Inc.; Richard Cooper, Bourns Networks Inc.
- 285 **Material Science Aspects of a Thick Film Copper/Dielectric System.** Robert D. Gardner, Aziz S. Shaikh and Gautam Sarkar, Ferro Corporation; Charles Bauer, MicroLithics Corporation.
- 295 **A New Technique for Monitoring Curing of Polymer Thick Film Resistor Materials.** Dr. Martin Seitz and Richard Hirthe, Marquette University; Dr. Mark Polczynski, Thor Technology Corporation.
- 303 **The Adhesion Mechanism of Copper Thick Film on Alumina Substrate.** Jun'ichiro Murayama, Hisashi Ikezaki, Nozomi Tanifuji, and Toshio Kato, SMI Techno-Research, Ltd., Japan.

Advances in Materials for Hybrid Application: Substrates

Bernard Greenstein, Chair, Beltone Electronics Corp.

- 308 **New Fabrication Technology of Low Dielectric Permittivity Multilayer Ceramic Substrate.** Keiichiro Kata, Akihiro Sasaki, Yuzo Shimada, and Kazuaki Utsumi, NEC Corporation, Japan.
- 316 **The Development and Application of a High Strength, Fine Grained Beryllia Ceramic.** A.J. Dawe and M. Crutchley, CBL Ceramics, Ltd., England; Bret Ericson and Mel Clark, Tektronix, Inc.; R. Stevens, University of Leeds, England.
- 321 **More on the Role of Residual Stresses in Ceramic Substrate Materials and Metallization.** Noel N. Schulz, Robert W. Hendricks, and Aicha Elshabini-Riad, Virginia Polytechnic Institute and State University.
- 329 **Insulated Metal Substrates for Power Hybrids.** Ellen Thomas, Mark Weil, Aaron Lippincott, and Wayne Johnson, Auburn University.
- 338 **Addition of Polymer Thick Films to the Internal Layers of FR-4.** Timothy A. Estes and Francis M. Long, University of Wyoming.
- 345 **The Application of Low Dielectric Constant Thick Film Material on Low Temperature Cofired Glass/Ceramic Material.** Dave Kellerman, Digital Equipment Corporation; Ray Peluso, Circuits Processing Technology.

Inspection Techniques for Microelectronic Packaging Technologies (SMT)

Greg Caswell, Chair, Galaxy Microsystems

- 352 **X-Ray Inspection and Testing of Multichip Modules.** Joseph E. Pascente, Lixi, Inc.
- 358 **Scanning Acoustic Microscopy of Multilayer Interconnect Structures.** J. Flannery and G.M. Crean, University College, Ireland.
- 364 **Boundary-Scan for Assembled Multichip Modules.** R.E. Tulloss and C.W. Yau, AT&T Bell Laboratories.
- 370 **Voltage Contrast Electron Beam Tester for Testing Unpopulated Multichip Modules.** Ollie C. Woodard Sr., R. R. Goruganthu, Fred Hartnett, Tom Myers, and Ronald Thompson, Microelectronics and Computer Technology Corp.
- 378 **Inspection of Fine-Pitch Technology for Solder Quality Using Scanned-Beam Laminography.** Dr. John A. Adams, Four Pi Systems.

Thermal Considerations for Microelectronic Application

Dr. Kinzy Jones, Chair, Florida International University

- 389 **Thermal Management of Hybrid Circuits: Effect of Metallization Layer, Substrate Material and Thermal Environment.** M.M. Hussein, D.J. Nelson and A. Elshabini-Riad, Virginia Polytechnic Institute and State University.
- 395 **Materials System for Stacked Thermal Vias.** R. Ross Getty and Rudolph J. Bacher, E. I. du Pont de Nemours & Company.
- 402 **Thermomechanical Modeling of Multichip Modules.** John A. Olenick, Sam Gazit, Mark F. Sylvester, and Robert B. Huntington, Rogers Corporation.
- 410 **Thermal Management of Low-Temperature Cofired Ceramic.** Jitu A. Gaglani and Mark A. Kuhlman, Rockwell International Corporation.

**Recent Advances in Materials for Hybrid Application:
Inks II**

Jerry Steinberg, Chair, Heraeus, Inc.

- 416 **Mixed Metal Multilayer Dielectric.** Paul Sayers, National Starch & Chemical Company.
- 423 **New Resistor System for Thick Film Chip Resistors.** L.H. Slack, J.D. Smith, and A.T. Walker, E. I. du Pont de Nemours & Company, Inc.; K. Hayakawa and T. Sato, Du Pont Japan Technical Center, Japan.
- 431 **Thick Film Alloy Resistor Systems For Surge Protection—Part I.** Charles C.Y. Kuo and Tom O. Martin, CTS Corp.
- 438 **Thick Film Alloy Resistor Systems For Surge Protection—Part II.** Charles C.Y. Kuo and Tom O. Martin, CTS Corp.
- 445 **Preferable Gold Paste for High Density Hybrid IC Application.** Yashushi Seko and Naofumi Ohashi, Tanaka Matthey K.K., Japan.

Manufacturing Concerns for "TAB and COB" (SMT)

Steve Stach, Chair, Austin American Technology

- 453 **Worldwide TAB Developments: A Market/Technology Comparison.** E. Jan Vardaman, TechSearch International, Inc.
- 460 **Beginning the Automation of Class S TAB Module Manufacturing.** William C. Whitworth, Rama P. Sood, Luke M. Flaherty, and Donald E. Brothers, Grumman Space Systems Division.
- 468 **Microwave Performance of a TAB Interconnect Structure in Comparison with Conventional Wire Bonding.** John R. Tyler, Avantek, Inc.
- 474 **COB (Chip On Board) Technology: Flip Chip Bonding Onto Ceramic Substrates and PWB (Printed Wiring Boards).** Akiteru Rai, Yoshihisa Dotta, Hiroaki Tsukamoto, Takeshi Fujiwara, Hiromitsu Ishii, Takashi Nukii and Hirotooshi Matsui, Sharp Corporation, Japan.
- 482 **T-BTAB Application for Vertically Integrated Interconnect.** K. Hatada, H. Fujimoto, and T. Kawakita, Matsushita Electric Industrial Co., Ltd., Japan; V.B. Dutta, TechSearch International, Inc.
- 487 **A New CCD Module Using the Chip On Glass (COG) Technique.** You Kondoh and Masayuki Saito, Toshiba Corporation, Japan.

RF and Microwave Circuits and Devices

Dr. Achia Elshabini-Riad, Chair
Virginia Polytech and State University

- 495 **Wide-Band Characterization of Developed Magnetic Materials.** M.M. Riahi Kashani, M.B. Hayes, and A. Elshabini-Riad, Virginia Polytechnic Institute and State University.
- 503 **High Frequency Dielectric and Loss Tangent Properties of Aluminum Nitride Over Temperature Range.** Hessam Sadri, Keramont Corporation.
- 507 **Substrate Anisotropy Effects on the Electrical Parameters of the Interconnection Lines.** G. Maze and J-L. Bonnefoy, CEA-CESTA; S. Tedjini, LEMO-CNRS-URA, France.
- 513 **Modeling Thick Film Resistor Configurations at Microwave Frequencies Using the Transmission Line Matrix (TLM) Method.** Kevin D. Robb, Fred J. German, and R. Wayne Johnson, Auburn University.
- 518 **Broad Band Dielectric Characterization of Substrates for Subnanosecond Hybrid Circuits.** G. Angenieux and P. Ferrari, LAHC, University de Savoie; B. Flechet and J. Chilo, LEMO-INPG, France.

Poster Session

Dr. Alan P. Genis, Chair, Northern Illinois University

- 529 **The Adhesion of Copper Thick Film in Newly Developed Firing System.** Nozomi Tanifuji and Toshio Kato, Sumitomo Metal Industries, Ltd.; Hisashi Ikezaki, SMI Techno-Research, Ltd., Japan.
- 534 **Feasibility Study of a Nonrosin-Based Water-Soluble Flux Solder Paste.** Janice Frazier, IBM Almaden Research Center; Richard Reich, Wallace Ables, Laura Bosworth and Robert Enno, IBM Systems Technology Division.
- 539 **Texture Characterization of High T_c Thick Films.** A.C. Biondo and J.S. Kallend, Illinois Institute of Technology; R.B. Poeppel and M.T. Lanagan, Argonne National Laboratory; T.C. Schofield, Los Alamos National Laboratory.
- 543 **Acetylene-Terminated Low-Stress Polyimide Oligomer for Interlayer Dielectric Applications.** P.G. Jobe, C. Puglisi, J. McMahon, R.D. Rossi, National Starch and Chemical Company.
- 555 **A Vision Guided Robotic System for Assembly of Monolithic Microwave Integrated Circuits.** Bill Stout, Pisen Chiang, and Byong Pak, University of California, Santa Barbara; Stacey Bilski and Mark Wohlwend, Raytheon Company.

**High-Temperature Superconductors
For Microelectronic Applications**

Roger Poeppel, Chair, Argonne National Laboratory
Mike Lanagan, Cochair, Argonne National Laboratory

- 560 **"Systolic Networks" for Massively Parallel Scaled Computers: A Vehicle For Demonstration of Advanced Technologies.** Stuart K. Tewksbury and Lawrence A. Hornak, AT&T Bell Laboratories.
- 570 **Applications of Superconductors of Hybrid Electronics.** Harry Kroger, Uttam Ghoshal, C. Nathan Potter, and Scott Sommerfeldt, MCC.
- 573 **Temperature, Frequency, and RF Field Dependence of the Surface Resistance of Polycrystalline High-T_c Superconductors.** Jean R. Delayen, Courtlandt L. Bohn, and Charles T. Roche, Argonne National Laboratory.
- 580 **Multilayer YBA₂ CU₃ O₇ Thick Film Superconductors on Metal and Ceramic Substrates.** Kevin J. Scoles, Mian Heng Jiang, Mehdi Fardmanesh, Allen Rothwarf and Som Tyagi, Drexel University.
- 588 **Optimization of Superconductive Properties on Ceramic Substrates.** Keith Kasprak, Ryp Walters, Shinzo Onishi, and Aicha Elshabini-Riad, Virginia Polytechnic Institute and State University.
- 593 **High Critical Current Laser Zone-Melted Thick Films in the Bi-Sr-Ca-Cu-O System.** M. Levinson, GTE Laboratories Inc.

Applications of Thick Film Technology I

Mark Naretto, Chair, Microswitch

- 597 **Unified Family of Hybrid Circuits for Sensor Signal Processing.** A. Brandolini and A. Gandelli, Politecnico di Milano, Italy.
- 604 **A New Type of Optical Print Head Consisting of Thin and Thick Films.** Masao Ikehata, Hideo Sawai, Hiroshi Furuya, Masaru Kimura, Susumu Shibata, Ichimatsu Abiko, Kenzou Tsuji, and Kohji Nihei, OKI Electric Industry Co., Ltd., Japan.
- 610 **High Reliability Hybrid Circuits For Automotive Applications.** Keiji Yamamoto, Masakazu Moriyama, and Shigekatsu Uchida, Toyota Motor Corporation; Masafumi Tominaga, Fujitsu Limited, Japan.

Recent Improvements in Packaging Techniques and Adhesives I

Larry Frazee, Chair, Microswitch

- 618 **High Density Electronic Packaging Utilizing Vertical Integration and Low-Temperature Cofired Ceramics.** Alvin Weinberg, Pacesetter Systems, Inc.
- 626 **Electrical Properties of Aluminum-Coated Fine Pitch Lead Frame For High-Pin-Count Ceramic Quad Flat Package.** Shosaku Yamanaka, Takao Maeda, and Tomohiko Ihara, Sumitomo Electric Industries, Ltd., Japan.
- 632 **Thermoplastic Films—A Novel Material For Attachment of Hybrid Microcircuit Substrates-to-Metal Cases.** K. Mahadevan, K.V. Thomas, G. Yadagiri and B.V. Seshadri, ISRO Satellite Centre, India.
- 640 **New Generation Adhesives for Die and Substrate Attachment.** Henry C. Syn, Staystik, Inc.

Poster Session

Richard W. Gehman, Chair, Microswitch

- 644 **Nondestructive Evaluation of TAB Outer Lead Bonding Using Acoustic Microscopy.** Janet E. Semmens and Lawrence W. Kessler, Sonoscan.
- 652 **A Design Advisor and Model Building Tool for the Analysis of Switching Noise in Multichip Modules.** Peter A. Sandborn and Hassan Hashemi, Microelectronics and Computer Technology Corporation.
- 658 **Combinational Test—Surface Mount's Answer To Process Reliability.** Ken Johnson, Testech, Ltd.
- 663 **Microwave Tantalum Nitride Thin Film Resistor Stability Guidelines.** Stephen G. Corwin, Craig P. Stephens, and Sean E. Wright, Lockheed Missiles and Space Company.
- 669 **Mechanical Behavior of 60 Tin/40 Lead Solder at Various Strain Rates and Temperatures.** Dr. Elaine I. Savage and Gregory D. Getzan, The Charles Stark Draper Laboratory.
- 675 **Placement For Producibility and Assembly.** Jonathon D. Watts and Michael G. Pecht, University of Maryland.

Applications of Thick Film Technology II

Mark Naretto, Chair, Microswitch

- 685 **Optimization of a Thick Film Resistor for Use as a Pulsed Infrared Emitter.** Daniel E. Knodle, Paul Graham, and Joseph O. Sams, Novamatrix Medical Systems, Inc.
- 691 **Laser Trimming Techniques for High Accuracy Thermistors.** J.A. Graves and John M. Moorman, PPG Industries, Inc.
- 699 **Materials, Substrates and Designs for Manufacturing Heaters Using Thick Film Technology.** Per Baumbach, Richard Tait and John Whitmarsh, Agmet Limited, England; Michael A. Stein, Electro-Science Laboratories Inc.

- 706 **Microelectronic Sensor of the Velocity of the Flow of Gas.** Janusz J. Gondek and Tadeusz H. Wojewodzki, PZT "TECHNICS" Lt., Poland.
- 711 **Benefits in Using Complementary Hybrid Circuit Technologies.** Soren Norlyng, Bruel & Kjaer, Denmark.

Recent Improvements in Packaging Techniques and Adhesives II

Larry Frazee, Chair, Microswitch

- 717 **Process Engineering for Prototype Multichip Module Development.** James T. Cook, Promex.
- 725 **Controlled Porosity Dielectrics and Etchable Conductors for High-Density Packages.** Sidney J. Stein, Richard L. Wahlers, Cornelius Y.D. Huang, Thomas Grunstein, and Glenn P. Sykora, Electro-Science Laboratories, Inc.
- 733 **Evaluation of Braze Processes for Large Area Aluminum Nitride Packages.** R.W. Harshbarger and W. Kinzy Jones, Florida International University.
- 739 **Multiple-Chip Module for Surface Mounting.** Toshio Matsuzaki, Toshio Nakajima, Mitsuo Takeuchi, Kunio Obata, Ken-ich Ohki, and Kohichi Maruyama, Fujitsu Limited, Japan.
- 747 **The Development of Composite Multilayer Hybrid Components.** Minoru Takaya, A. Fujisawa, and Y. Mochizuki, TDK Corporation, Japan.

Fine Pitch Surface Mount Manufacturing

Phil Bois, Chair, Digital Equipment

- 752 **Solder Paste Requirements for Fine Pitch Applications.** James P. Langan, Enthone-OMI Inc.
- 756 **Metal Mask Stencils—Meeting the Challenge of Fine Pitch Technology.** Dr. William E. Coleman, Photo Stencil Inc.
- 762 **Solder Deposition Process Automation for Fine Pitch Applications.** Philip Bois, Digital Equipment Corp.

How to Achieve World Class Manufacturing for High Volume Production of SMT and Future Interconnect Technology

Winston H. Chen, Chair, Solectron

- 769 **Surface Mount Technology at Motorola.** Dr. Margaret Eastwood, Motorola, Inc.
- 770 **World Class SMT Strategies at IBM.** Kari Barbar, Tucker Garrison, and Stan Jensen, IBM.
- 777 **The Start of In-House PCB Manufacturing at Sun: An Engineer's View.** Gill Shook, Sun Microsystems, Inc.
- 782 **High Volume SMT: Maintaining Flexibility in a Dynamic Environment.** Ronald S. Tarter, Apple Computer, Inc.

ISHM '90 Proceedings

EVOLUTION OF THE MICROELECTRONIC INDUSTRY

Robert E. Holmes
HINTS Unlimited
902 Spanish Wells Drive
Melbourne, FL 32940

ABSTRACT

Microelectronics were developed to solve specific problems. This has become a key factor in the evolution of the industry. Problems of space, weight reliability, power, thermal management, and manufacturing had to be solved. The industry throughout the years has worked with the systems designers to provide the products that were needed to solve important issues. Four elements have contributed to the evolution of microelectronics: materials, processes, equipment, and design requirements.

Documentation of the evolution of microelectronics is scattered throughout literature. The ISHM Symposium proceedings is one of the valuable sources of the industries evolution. Roger Cadenhead and Donald DeCoursey initiated a series of articles on the History of Microelectronics. Part one of the series has been published in the ISHM Journal of September 1985.

DISCUSSION

The microelectronic industry had its beginnings during World War II. There was a need for smaller electronic circuits as part of proximity fuses. It took almost a decade for the industry to develop into a viable force in the electronic industry.

To simplify the discussion of the evolution in microelectronics, I have chosen to divide the evolutionary process into decades beginning with 1940.

The decade 1940-1949.

This is the decade of developing the first hybrid microelectronic circuits. The substrates were steatite. The materials and equipment used to make the first hybrids were crude by today's standards. Conductors were made of silver oxide that, when fired, reduced to silver. Resistors were formulated using carbon and organic binders. Carbon resistors could be trimmed using a rubber eraser to remove material after it was cured.

The developers of these early products considered their materials and processes to be proprietary. Thus there was no interchange of information within the industry. This attitude of keeping technology a closely guarded secret continued until the late 1960's.

The decade 1950-1959

This was a decade that created many of the fundamental technologies that became the basis of the microelectronic industry.

Circuits etched into copper laminated onto a variety of substrate materials provided improved reliability and the ability to mass produce electrical circuits. This was the beginning of the printed circuit board industry as we know it today.

Discrete semiconductors, diodes and transistors were another key development during this decade. The semiconductor devices promised to reduce power requirements as well as save space in electronic circuits. All of these devices were provided as packaged components. Hybrids and printed circuit boards were able to take advantage of these devices. These were the fore-runner of the integrated circuits that are so vital to electronics today.

Thin film circuits on glass, quartz, alumina, and glazed alumina were developed. Thin films were primarily used as resistor networks to provide improved stability and lower temperature coefficient of resistance. Since these circuits were processed using the photolithographic techniques developed for semiconductors, these circuits were considerably smaller than their thick film counterparts. However, they were limited in sheet resistance value by the materials available at the time. Most resistors were nickel-chromium alloys deposited by evaporation.

The ruthenium based thick film resistor compositions were developed during this decade. This development is the backbone of the thick film resistor materials still used today.

Tape cast 96% alumina substrates became available late in this decade. Because tape casting provided a more consistent and less expensive substrate, it became the standard process for providing thick film substrates. Tape casting proved to be the basis for many technologies still in use today.

ISHM '90 Proceedings

The decade 1960 - 1969

The 1960's saw the rapid expansion in the use of hybrids. Hybrid engineers visualized hybrids replacing printed circuit boards within a short time. Thick and thin film engineers developed a strong competitive attitude toward the other technology. This attitude prevailed throughout the decade. There was a strong feeling within companies that their processes were proprietary and they had a leading edge over their competitors.

The military and space programs started to demand smaller, more complex circuits that used less power with improved reliability. Reliability studies demonstrated that a major cause of system failures was due to interconnections - solder joints, sockets, and wire bonds.

The military made an effort at standardizing on hybrid size, shape, and format. The initial effort at standardization became known as the RCA module. The module was made up of 0.3 inch square substrates with notches in all four sides. Each substrate contained a portion of the circuit. The substrates were stack assembled and spaced with vertical wires being soldered into the notches forming a module that was 0.3 inches square and could be of most any height. This technology met with very limited success. Manufacturers did not want to accept the idea of a competitor.

Thick film material development continued with the availability of new conductor, dielectric and resistor materials. Ruthenium based resistor compositions became commercially available.

With the new thick film resistor materials a change in the trimming method was required. Abrasive trimming was introduced and rapidly became the prevalent technique for adjusting resistors.

Thin film advancements included the introduction of tantalum nitride resistors. Tantalum nitride was formed by sputtering tantalum in a partial pressure of nitrogen. Western Electric was a dominant force in developing tantalum nitride for thin film hybrids. Western Electric developed equipment for the continuous sputter deposition of tantalum nitride and licensed the process to a number of companies. At the same time a larger size substrate 3.75 X 4.5 X 0.025 inches became available from several ceramic suppliers. This larger substrate was tape cast using 99.5% alumina.

Assembly of hybrids consisted of soldering packaged transistors and diodes to the thick or thin film substrates. Capacitors,

inductors and other components were off-the-shelf leaded components that were also joined to the substrate by soldering.

The integrated circuit was introduced in this decade. Some IC engineers predicted that their devices would replace hybrids (just as some hybrid engineers predicted that hybrids would replace printed circuit boards). Unpackaged ICs and discrete devices became available. The unpackaged devices required that wire bonders be used in assembling the hybrids.

Researchers worked on interconnecting methods to eliminate wire bonding. Two technologies appeared in the mid-sixties. Beam leads were electroplated gold beams that extended over the edge of the silicon chip. The chip was bonded face down using the gold ribbon to attach the IC to the hybrid circuit. (Beam leads are still used today to provide interconnections for high speed semiconductor chips.) The second process was the solder bump or flip chip technology. Flip chips have been used in computer assemblies as well as in the automotive industry. These technologies rely on the interconnection to remove the heat from the IC. Elaborate systems have been developed to remove heat from flip chips used in computers.

Multilayer ceramic assemblies, utilizing molybdenum and manganese as the metalization between layers, was developed during this decade. A primary use for this technology was for the fabrication of hermetic packages for semiconductor devices.

In 1966 four individuals: George Doyle, John Hinchey, Robert Waer and George West began discussions on what could be done to improve communication within the micro-electronic industry. Their discussions lead to two technical thick film symposia, one held in Palo Alto and the other in Los Angeles. A proceedings was printed of all papers presented at the two meetings and distributed to all attendees. The symposia were so successful, as shown by the attendance and interest at both locations, that an organization was formed to provide communication within the industry. The organization became the International Society for Hybrid Microelectronics (ISHM). ISHM has provided a forum to discuss issues and problems related to microelectronics for 23 years.

The decade 1970 to 1979

The military and space programs continued to have influence on microelectronics during this decade. The emphasis was still on reliability while increasing circuit density. There was some continued attempts at standardization - with little success.