

Advanced Metallization Conference 2000 (AMC 2000)

EDITORS

Dan Edelstein

Girish Dixit

Yukio Yasuda

Takayuki Ohba

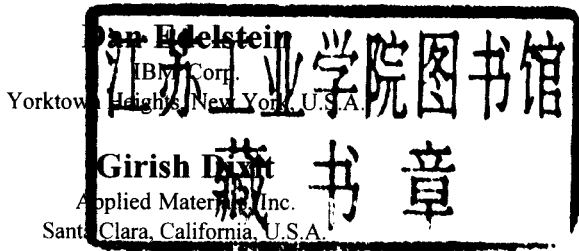


**Materials
Research
Society**

Advanced Metallization Conference 2000 (AMC 2000)

Proceedings of the Conference held October 2–5, 2000, in San Diego, California, U.S.A., and October 19–20, 2000, University of Tokyo, Tokyo, Japan. This Conference is sponsored by Continuing Education in Engineering, University Extension, University of California at Berkeley, California, U.S.A.

EDITORS:



Yukio Yasuda

Nagoya University
Nagoya, Japan

Materials Research Society
Warrendale, Pennsylvania

Single article reprints from this publication are available through
University Microfilms Inc., 300 North Zeeb Road, Ann Arbor, Michigan 48106

CODEN: MRSPDH

Copyright 2000 by Materials Research Society.
All rights reserved.

This book has been registered with Copyright Clearance Center, Inc. For further information, please contact the Copyright Clearance Center, Salem, Massachusetts.

Published by:

Materials Research Society
506 Keystone Drive
Warrendale, PA 15086
Telephone (724) 779-3003
Fax (724) 779-8313
Web site: <http://www.mrs.org/>

Library of Congress Cataloging-in-Publication Data

Advanced Metallization Conference 2000 (AMC 2000) : proceedings of the conference held
October 2-5, 2000, San Diego, California, U.S.A. and October 19-20, 2000, Tokyo,
Japan / editors, Dan Edelstein, Girish Dixit, Yukio Yasuda, Takayuki Ohba
p.cm.—(Materials Research Society conference proceedings)
"Sponsored by Continuing Education in Engineering, University Extension, University
of California at Berkeley, California, U.S.A."
ISBN 1-55899-574-9
ISSN: 1048-0854
I. Edelstein, Dan II. Dixit, Girish III. Yasuda, Yukio IV. Ohba, Takayuki V. Series:
Materials Research Society conference proceedings

Manufactured in the United States of America

2001

PREFACE

The 2000 Advanced Metallization Conference (AMC) held October 2–5, 2000, in San Diego, California, U.S.A., and the associated ADMETA Asian Session held October 19–20, 2000 at the University of Tokyo, Tokyo, Japan, consisted of recent work on topics in on-chip interconnects and other aspects of advanced metallization. The timeliness of this topic led to excellent contributions, and very well-attended sessions. There was a very positive reception of the invited presentations, where we endeavored to bring new perspectives and several individuals outside (but related to) the interconnect arena to these sessions. We believe all of the authors' contributions represented here are of high quality and appearance, and that this collection represents a sharp view of the state of the art in this area.

This year there were several trends and differences of note relative to last year. First, no AMC panel discussion was held this year, in favor of an offsite meeting and sponsored event for the attendees; this was highly received. Second, in order to concentrate more fully on the rapid advances in copper and low- κ , the AMC Committee decided to reduce the number of topics solicited in the Call for Papers, and in particular to eliminate Silicides and Contacts from the list (although papers on these were still included in the ADMETA Session). New emphasis in the papers and short courses was put on copper reliability and copper electrochemistry, including plating, corrosion, CMP, and cleaning. Finally, the number of accepted posters was reduced to improve interactions at the single poster session. The net result was fewer accepted papers in 2000 compared to 1999 for the same number of submissions and, we believe, a high quality of selections and audience attention. The trends in breakdown by subject of the papers relative to 1999 were: a significant increase in all aspects of realized copper metallization including integration, integration with low- κ , electrochemistry and cleaning, reliability, barriers, methods of characterizing low- κ materials, and a decrease in Al(Cu) and W-related papers.

This volume is divided into nine parts: Part I contains an invited perspective on the state of semiconductor research and development in Japan; Part II focuses on performance aspects of interconnect architectures; Part III includes some of the most significant recent advances in copper/low- κ integration; Part IV is the in-depth collection of electrochemical and chemical processes, mainly pertaining to copper; Part V contains state-of-the-art papers on thin-film diffusion barriers, again mainly for copper wiring; Part VI covers reliability engineering and results; Part VII is a collection of alternative and novel processes and systems related to circuit interconnection; Part VIII contains papers on specific low- κ dielectrics and their properties, and new methods of their characterization; and Part IX covers continuing advances in the Al(Cu)/W metallization system.

The 2001 U.S.A. Conference will be held October 9–11 in Montreal, Canada, and will be chaired by Dr. Andrew McKerrow, Texas Instruments, and Prof. Yosi Shacham-Diamand, Tel Aviv University, Israel. The 2001 ADMETA Asian Session will be held October 30–31 at the University of Tokyo, Bunkyo-ku, Tokyo, Japan, and will be chaired by Dr. T. Ohba, Fujitsu, and Prof. S. Zaima, Nagoya University, Japan. Starting with the 2001 Conference, the AMC has been accepted for sponsorship by the Materials Research Society, U.S.A. For further information, please contact Linda Reid, University of California at Berkeley, by phone 510-642-4151; fax 512-642-6027; or e-mail at course@unx.berkeley.edu, or visit the web site at <http://www.berkeley.edu/unex/eng/metal>. For ADMETA, please contact Y. Doshida by phone 81-3-5821-7210; fax 81-3-5821-7439; or e-mail at admata@mba.nifty.ne.jp, or visit the web site at <http://member.nifty.ne.jp/sofiel/admeta.html>. We encourage you to participate in the Conference, and look forward to meeting you there in 2001.

Dan Edelstein
Girish Dixit
Yukio Yasuda
Takayuki Ohba

January 2001

ACKNOWLEDGMENTS

The continued success of the "Advanced Metallization Conference" relies on the efforts of many people. It is primarily based on the strong support and contributions from its speakers, authors, panelists, and attendees, and from the semiconductor metallization community in general. The editors would like to thank the members of the Executive Committees for the United States and Asian Conferences, listed below, who actively participated throughout the year, served as session chairs, and reviewed the manuscripts. The editors also thank Linda Reid, Jenny Black Deer, and Roxanne Hernandez of the University of California at Berkeley, and H. Doshida, ADMETA Secretary, for their organizational and logistical support.

2000 Conference Executive Committee - United States

Daniel Edelstein, IBM T.J.Watson Research Center (Co-Chair)
Girish Dixit, Applied Materials (Co-Chair)

Robert S. Blewer, Sandia National Laboratories
Timothy S. Cale, Rensselaer Polytechnic Institute
Robin Cheung, Applied Materials
Darrell Erb, Advanced Micro Devices
Thomas Gessner, Chemnitz University of Technology
Mihal Gross, Lucent Technologies, Bell Laboratories
Rajiv Joshi, IBM T.J.Watson Research Center
Ki-Bum Kim, Seoul National University
Heinrich Koerner, Infineon Technologies AG
Karen Maex, IMEC
Andrew McKerrow, Texas Instruments Inc.
Bradley Melnick, Motorola - APRDL
Peter Moon, Intel Corporation
Takayuki Ohba, Fujitsu
Gary W. Ray, Novellus Systems
Linda Reid, University of California, Berkeley
Gurtej Sandhu, Micron Technology, Inc.
Yosi Shacham-Diamand, Tel-Aviv University
Tom Smy, Carleton University
Shih-Wei Sun, United Microelectronics Corporation
Tom Taylor, Shipley Co.
Joaquin Torres, STMicroelectronics
Shi-Qing Wang, Genus, Inc.
Yukio Yasuda, Nagoya University
Chris Yu, Cabot Corporation

2000 Conference Executive Committee - Asia

Executive Committee

Y. Yasuda, Nagoya University (Chair)
T. Ohba, Selete/Fujitsu (Vice Chair)
S. Zaima, Nagoya University (Program)
K. Masu, Tohoku University
K. Ueno, NEC
Y. Shimogaki, University of Tokyo
S. Shingubara, Hiroshima University

Committee Members (Asia continued)

Y. Harada, Oki
S. Hasegawa, Novellus
A. Tsukune, Fujitsu
Y. Kusumoto, ULVAC
A. Ohsaki, Mitsubishi
N. Yokoyama, Hitachi
Y. Ohta, Tokyo Electron
T. Nogami, Sony
S. Ogawa, Matsushita
H. Kawasaki, Motorola
Sang-In Lee, Samsung
Ming-Shih Tsai, National Nano Device Laboratory
N. Awaya, Sharp
M. Aruga, AMJ
A. Sekiguchi, ANELVA
S.C. Sun, Wafertech
Shi-Woo Rhee, POSTECH
T. Yoda, Toshiba
N. Aoi, ASET

Advisory

Y. Horiike, University of Tokyo
M. Kashiwagi, AMJ
H. Komiyama, University of Tokyo
K. Tsubouchi, Tohoku University
M. Murakami, Kyoto University
N. Kobayashi, Hitachi

Secretary

H. Doshida, ADMETA Secretary

MATERIALS RESEARCH SOCIETY CONFERENCE PROCEEDINGS

Tungsten and Other Refractory Metals for VLSI Applications, Robert S. Blewer,
1986; ISSN 0886-7860; ISBN 0-931837-32-4

Tungsten and Other Refractory Metals for VLSI Applications II, Eliot K. Broadbent,
1987; ISSN 0886-7860; ISBN 0-931837-66-9

Tungsten and Other Refractory Metals for VLSI Applications III, Victor A. Wells,
1988; ISSN 0886-7860; ISBN 0-931837-84-7

Tungsten and Other Refractory Metals for VLSI Applications IV, Robert S. Blewer,
Carol M. McConica, 1989; ISSN 0886-7860; ISBN 0-931837-98-7

Tungsten and Other Advanced Metals for VLSI/ULSI Applications V,
S. Simon Wong, Seijiro Furukawa, 1990; ISSN 1048-0854; ISBN 1-55899-068-2

Tungsten and Other Advanced Metals for ULSI Applications in 1990,
Gregory C. Smith, Roc Blumenthal, 1991; ISSN 1048-0854; ISBN 1-55899-112-3

Advanced Metallization for ULSI Applications, Virendra V.S. Rana, Rajiv V. Joshi,
Iwao Ohdomari, 1992; ISSN 1048-0854; ISBN 1-55899-152-2

Advanced Metallization for ULSI Applications 1992, Timothy S. Cale,
Fabio S. Pintchovski, 1993; ISSN 1048-0854; ISBN 1-55899-192-1

Advanced Metallization for ULSI Applications in 1993, David P. Favreau,
Yosi Shacham-Diamand, Yasuhiro Horiike, 1994; ISSN 1048-0854;
ISBN 1-55899-235-9

Advanced Metallization for ULSI Applications in 1994, Roc Blumenthal,
Guido Janssen, 1995; ISSN 1048-0854; ISBN 1-55899-279-0

Advanced Metallization and Interconnect Systems for ULSI Applications in 1995,
Russell C. Ellwanger, Shi-Qing Wang 1996; ISSN 1048-0854; ISBN 1-55899-341-X

Advanced Metallization and Interconnect Systems for ULSI Applications in 1996,
Robert Havemann, John Schmitz, Hiroshi Komiyama, Kazuo Tsubouchi, 1997;
ISSN 1048-0854; ISBN 1-55899-385-1

Advanced Metallization and Interconnect Systems for ULSI Applications in 1997,
Robin Cheung, Jeffrey Klein, Kazuo Tsubouchi, Masanori Murakami,
Nobuyoshi Kobayashi, 1998; ISSN 1048-0854; ISBN 1-55899-412-2

Advanced Metallization Conference in 1998 (AMC 98), Gurtej S. Sandhu,
Heinrich Koerner, M. Murakami, Y. Yasuda, N. Kobayashi, 1999; ISSN 1048-0854;
ISBN 1-55899-484-X

Advanced Metallization Conference 1999 (AMC 1999), Mihal E. Gross, Thomas Gessner,
N. Kobayashi, Y. Yasuda, 1999; ISSN 1048-0854; ISBN 1-55899-539-0

Advanced Metallization Conference 2000 (AMC 2000), Dan Edelstein, Girish Dixit,
Yukio Yasuda, Takayuki Ohba, 2001; ISSN 1048-0854; ISBN 1-55899-574-9

CONTENTS

Preface	xvii
Acknowledgments	xix
Materials Research Society Symposium Proceedings	xxi

PERSPECTIVES

*Cooperative R&D on Semiconductor Technology in Japan	3
Hiroyoshi Komiya	

PERFORMANCE

*Clock Tree and Power Grid Design > 1 GHz	11
Phillip J. Restle, Albert Ruehli, and Steven Walker	

Characterization of Dual Damascene Cu-SiO₂ Interconnects in Time and Frequency Domains	19
C. Bermond, B. Flechet, V. Arnal, A. Farcy, J. Torres, Y. Morand, G. Le Carval, R. Salik, S. Bauzac, and G. Angenieux	

*Technology and Design Challenges for Low Power and High Performance Microprocessors	25
Vivek De and Shekhar Borkar	

The Comparison of NMOS Devices With Al Interconnect and Cu Interconnect	35
Mu-Kyeung Jung, Seong-Ho Liu, Jong-Hyon Ahn, Kyung-Tae Lee, Hee-Sung Kang, Young-Wug Kim, and Kwang-Pyuk Suh	

*Strategy of Future ULSI Metallization	41
L.J. Chen, S.L. Cheng, and L.W. Cheng	

*Interconnection from Design Perspective	53
Takayasu Sakurai	

***Invited Paper**

*Chip-Level Performance Improvement Using Triple Damascene Wiring Design Concept for the Future CMOS Devices	59
Noriaki Oda	

Cu/LOW- κ INTEGRATION

A Novel SiO₂-Air Gap Low-k for Copper Dual Damascene Interconnect	71
Vincent Arnal, Joaquin Torres, Philippe Gayet, Michel Haond, Christophe Vérove, Brigitte Descouts, and Philippe Spinelli	
Integration Issues of Low-k Materials in Damascene Structure	77
G. Passemard and O. Demolliens	
Dual Damascene Integration of SiLK™ Semiconductor Dielectric	85
W. Mlynko, B. Havemann, D. Sesler, G. Rajagopalan, M. Daniels, M. Mills, L. Booms, and E. Shafer	
*Dual Inlaid Copper and Fluorine-Doped TEOS BEOL Integration for a High-Performance 0.18 μm Technology	91
M. Angyal, A. Anandakugan, B. Boeck, G. Braeckelmann, J. Brown, C. Capasso, R. Carter, R. Chowdhury, A. Das, D. Denning, S. Filipiak, P. Gilbert, C. Goldberg, H. Kawasaki, K. McGuffin, J. Mendonca, A. Michel, M. Moosa, R. Nelson, A. Nghiem, C. Pettinato, D. Rose, D. Smith, T. Sparks, T. Stephens, J. Sun, S. Thrasher, S. Veeraraghavan, and H. Zawaideh	

Cu CHEMICAL AND ELECTROCHEMICAL PROCESSES

Effects of Copper Contamination by Copper Implantation Through the Backside of Wafer on MOS Device Performance	105
K.C. Tee, K. Prasad, C.S. Lee, H. Gong, L. Chan, A.K. See, and C.L. Cha	
*Volume Production Copper Plating Control	111
Tom Ritzdorf	
Development of New Chemistry for Copper Electroplating Process	121
Sun-Jung Lee, Kyu-Hwan Chang, Seung-Man Choi, Ki-Chul Park, Hyeon-Deok Lee, Ho-Kyu Kang, and Joo-Tae Moon	

***Invited Paper**

*Cu Corrosion Mechanisms and Control	127
Vlasta Brusic	
An Alternative Metallic Seeding Technique for Subsequent Electrochemical Deposition of Copper Onto Barrier Metals	137
R. Fang, H. Gu, T.J. O'Keefe, M.J. O'Keefe, W-S. Shih, K.D. Leedy, and R. Cortez	
Direct Copper Electroplating	145
Yuri Lantsov, Roger Palmans, and Karen Maex	
Characterization of Cu Surface Cleaning by Downstream N₂/H₂ Plasma	153
M.R. Baklanov, D.G. Shamiryan, G.P. Beyer, T. Conard, S. Vanhaelemeersch, and K. Maex	
Stress and Impurities in Electroplated Copper	161
S.H. Brongersma, E. Kerr, I. Vervoort, E. Richard, and K. Maex	
The Relation Between Self-Annealing Behavior and Microstructure of Electroplated Copper Films	167
Kyu-Hwan Chang, Sun-Jung Lee, Seung-Man Choi, Ki-Chul Park, Hycon-Deok Lee, Ho-Kyu Kang, and Joo-Tae Moon	
In Situ STM Study of a Model Additive on Copper Single Crystal Surfaces	173
T. Dretschkow	
Bath Additive Concentration Effects on Super-Filling for Copper Damascene Electroplating	181
Aaron Frank, Q.T. Jiang, Linlin Chen, Brad Carpenter, Ron Carpio, Tom Ritzdorf, and Klaus Pfeifer	
Kinetic Mechanism of Self-Annealing in Electroplated Copper Thin Films	187
Hee Dong Yang and Choong-Un Kim	
Methodology of Quantitative Texture Analysis in Thin Films and Interconnects	193
K.J. Kozaczek, D.S. Kurtz, P.R. Moran, R. Martin, M.E. Gross, and K. Evans-Lutterodt	

*Invited Paper

Using SOM-Cu for ULSI Interconnections	199
Galif Kutluk, Hisashi Iwashige, Toshihiro Suzuki, Tomoyuki Abe, Shigeo Hayashi, Toshinobu Yoshida, Poong Kim, and Masaaki Oda	
Application of MESA™ Modeling for Chemical Mechanical Polishing	205
T. Laursen, S.R. Runnels, and A. Toprac	
Non-Contact, In-Line Process Monitoring of Cu Bond Pad Thickness and Dishing	211
Jon Madsen, Ji-Ping Li, Mira Bakshi, and Peter Borden	
Advanced Preelean Process for Cu Damascene Applications	217
R. Rozbicki, R. Powell, M. Khosla, E. Klawuhn, M. Danek, K. Pfeifer, and H. Cox	
Finite Element Analysis of CMP Pad Displacement and Slurry Flow Characteristics	223
Andrew T. Kim, John A. Tichy, and Timothy S. Cale	
Effect of Pd Catalyst Adsorption on Cu Filling Characteristics in Electroless Plating	229
S. Shingubara, T. Ida, H. Sawa, H. Sakaue, and T. Takahagi	
Convex-Surfaced, Cu-Damascene Interconnects Fabricated by Pad-Scanning, Local-CMP (PASCAL-CMP)	235
Yoshihiro Hayashi, Takahiro Onodera, and Masayuki Tagami	
Electrochemical Study of Reactivity for Cu Orientation in CMP Slurry	241
Y. Matsui, M. Kodera, N. Miyashita, and T. Yoda	
Effects of Process Parameters on CMP Performance	247
Manabu Tsujimura, Norio Kimura, Hirokuni Hiyama, and Masahiro Ota	
Development of a Semiconductor Device-Cleaning Method Using a Cavitation Jet	253
Manabu Tsujimura, Hiroshi Tomita, Soichiro Nadahara, and Masahiro Ota	
Filling Profile Simulations of Electroplated Copper Films in Trenches	259
Shigeki Hirasawa, Tatsuyuki Saito, and Hizuru Yamaguchi	

Evolution of Grain and Micro-Void Structure in Electroplated Copper Interconnection Lines	265
A. Hobbs, S. Murakami, T. Hosoda, S. Ohtsuka, M. Miyajima, S. Sugatani, and T. Nakamura	
H Assisted Control of Quality and Conformality in Cu Film Deposition Using Plasma CVD Method	271
Masaharu Shiratani, Hong Jie Jin, Kosuke Takenaka, Kazunori Koga, Toshio Kinoshita, and Yukio Watanabe	
 <i>DIFFUSION BARRIERS</i>	
TEM/SEM Investigation and Electrical Evaluation of a Bottomless I-PVD Ta(N) Barrier in Dual Damascene	279
H. Yamagishi, Zs. Tokei, G.P. Beyer, R. Donaton, H. Bender, T. Nogami, and K. Maex	
Studies of XLK™ Film Characterization and Integration in Copper Damascene Processes	287
F. Iacopi, R.A. Donaton, B. Coenegrachts, T. Komiya, H. Struyf, M. Lepage, J. Van Aelst, W. Boullart, D. De Roest, I. Vos, M.R. Baklanov, G. Vereecke, M. Van Hove, M. Stucchi, Zs. Tokei, H. Meynen, J.N. Bremmer, S. Vanhaelemeersch, and K. Maex	
The Atomic Layer CVD™ Growth of Titanium Nitride From an In Situ-Reduced Titanium Chloride	295
Kai-Erik Elers, Ville Saanila, Pekka J. Soininen, and Suvi Haukka	
WN_x Film Deposition by PECVD Using WF₆/N₂/H₂ Gas Mixture	301
K. Richter, S. Riedel, S.E. Schulz, and T. Gessner	
Growth of Tungsten Carbide Thin Films as Diffusion Barriers for Cu Metallization	307
S. Veldman, A.M. Lemonds, K. Kershen, Y.-M. Sun, I. Emesh, K. Pfeifer, J.M. White, and J.G. Ekerdt	
Chemical Vapor Deposition of Tantalum and Tantalum Nitride	313
Joseph Hillman, John Hautala, and Steven Caliendo	

Properties of Ta and TaN Barriers and Sputtered Cu Seed Layers on Capped and Non-Capped Porous Silicon Oxide	321
S.E. Schulz, H. Koerner, H. Helneder, M. Schwerdt, H. Wendt, C. Murray, I. Streiter, and T. Gessner	
The Novel Evaluation for Extremely Thin TaN_x Films as a Copper Barrier	329
Woo Sig Min, Sung Gyu Pyo, Heon Do Kim, Sibum Kim, Tae Kwon Lee, and Heung Lak Park	
Electroplating of Nickel-Tungsten Barrier Layers	337
O. Younes, Y. Diamand-Shacham, and E. Gileadi	
Fluorine Diffusion Through Si₃N₄, Ta, and TaN Barrier Layers	343
J. Gambino, M. Lavoie, R. Wistrom, G. Bomberger, E. Cooney, R. Kontra, C. Johnson, O. Dokumaci, and P. Dehaven	
Via Yield Improvement Due to Optimization of PVD Seed/Barrier Deposition Process	349
H. Ashihara, T. Oshima, K. Fukuda, K. Kawakami, K. Ishikawa, A. Satoh, H. Miyazaki, H. Yamaguchi, and T. Saito	
Reactively Sputtered Ta₂N and TaN Diffusion Barriers for Copper Metallization	355
Jyrki Molarius, Tomi Laurila, Tommi Riekkinen, Kejun Zeng, Antti Niskanen, Markku Leskelä, Ilkka Suni, and Jorma K. Kivilahti	
Simulation of Barrier Layer Deposition for VLSI Applications Using 3D-Films	361
T. Smy, R.V. Joshi, and S.K. Dew	
A Noble Metallization Process Using Preferential Metal Deposition (PMD)-Aluminum for Via	367
Byung Hee Kim, Jong Myeong Lee, Myoung Bum Lee, Gil Heyun Choi, Young Wook Park, Sang In Lee, and Joo Tae Moon	
Hillock Defects During Deposition of Thin PVD Titanium For Barrier Metal Deposition	373
Eric Paton, Bryan Tracy, Terri Kitson, Jeremias Romero, Alline Myers, Paul King, Janice Gray, Jeff Erhardt, and Anthony Grabowski	

Impact of Temperature During Interconnect Sputtering of Ti/TiN by Hollow Cathode Magnetron™	379
A. Ruf, C. D'Couto, S. Schmidbauer, G. Tkach, N. Urbansky, and M. Woitge	
A Study of CVD Cu Adhesion on Various Barrier Metals by XPS	385
Young Suk Kim and Yukihiro Shimogaki	
Barrier Properties of TiN Films Prepared by Flow Modulation Chemical Vapor Deposition (FMCVD)	391
Hirotaka Hamamura, Hiroshi Komiyama, and Yukihiro Shimogaki	
Characteristics of WN Barrier Films Grown Using Thermal CVD Process With NH₃ and SiH₄ Reduction	397
M. Harada, E. Mizuno, and N. Gonohe	
LPCVD of TaCN Thin Film for Barrier Layer in Cu Interconnection	403
A. Hoshino, T. Suzuki, S. Hiiro, H. Machida, A. Ogura, and Y. Ohshita	
The Structure Control of Sputtered TaN Films on SiO₂ Through the Study of Evolutionary Selection Growth	409
Kun Tepsanongsuk, Suguru Noda, Yoshiko Tsuji, and Hiroshi Komiyama	

RELIABILITY

*A Comparison of Reliability Aspects of a 0.35 μm and 0.18 μm Process Copper Metallization	415
A. von Glasow and A.H. Fischer	
Direct Observation of a Critical Length Effect in Dual Damascene Cu Interconnects	425
E.T. Ogawa, A.J. Bierwag, K-D. Lee, H. Matsushashi, P.R. Justison, A.N. Ramamurthi, P.S. Ho, V.A. Blaschke, D. Griffiths, A. Nelsen, M. Breen, and R.H. Havemann	
Non-Destructive High-Resolution <i>In Situ</i> Studies of the Electromigration in Passivated Cu Interconnects and Integrated Circuit Conductors by X-ray Microscopy	431
G. Schneider, D. Hambach, B. Kaulich, N. Hoffmann, W. Hasse, K. Hoffmann, S.E. Schulz, B. Niemann, and J. Susini	

*Invited Paper

Mechanical Properties of Damascene Cu Lines During Thermal Cycling	439
Mauro J. Kobrinsky, Mihal E. Gross, and Carl V. Thompson	
*Reliability Qualification of Copper BEOL for Manufacturing	447
R.A. Wachnik, D. Edelstein, B. Agarwala, C. Bergeron, M. Bilak, R. Bolam, N. Greco, C-K. Hu, M. Johnson, T. Kane, A. Katsetos, W. Klaasen, E. Levine, H. Longworth, T. McDevitt, P. McLaughlin, E. Moszczynski, W. Motsiff, D. Nguyen, R. Purvee, H. Rathore, M. Ricker, A. Stamper, and K. Stevens	
Copper Reliability of Using PVD/CVD Composite Cu Layers as Seed for 0.10 μm and Beyond Technology	457
C.S. Liu, J.C. Lin, S.L. Shue, C.H. Yu, and M.S. Liang	
Modeling Film and Via Electrical Resistance for 3D Structures Using 3D-Films	463
T. Smy, S. Crisan, R.V. Joshi, and S.K. Dew	
Mechanical Analysis of a SiLK/Cu Dual Damascene Interconnect System	469
J. Waeterloos, E. Shaffer II, T.M. Stokich, Jr., R.A. Donaton, and K. Maex	
3D Time-Depending Electro- and Thermomigration Simulation of Metallization Structures	477
D. Dalleau and K. Weide-Zaage	
A Computer Simulation of Void Dynamics Under the Action of Electromigration and Capillary Forces in Narrow Thin Interconnects	483
T. Ögurtani and E.E. Ören	
The Threshold Contact Area in Via Electromigration Lifetime	489
H. Park, B-Z. Lee, E.G. Seo, J.S. Kim, S.W. Woo, and J.G. Lee	
Stress Induced Void Formation in Co Silicide on Sub 100 nm Gate Poly	495
Ju-Hyuk Chung, Jang-Eun Lee, Ji-Soon Park, Ja-Hum Ku, Eung-Joon Lee, Sun-Hu Park, Sung-Tae Kim, Jeong-Lim Nam, and Sang-In Lee	
A New Evaluation Method of Contact Properties for the Establishment of Highly Reliable Copper Interconnects	499
N. Izumi, E. Kobori, M. Matsumoto, G. Nakatani, Y. Fuwa, and J. Hikita	

*Invited Paper

ALTERNATIVE SYSTEMS AND PROCESSES

*Large Area, Rubber Stamped Plastic Sheets of Active Matrix Backplane Circuitry for Electronic Paper	507
J.A. Rogers, K. Baldwin, Z. Bao, B. Crone, A. Dodabalapur, Y-Y. Lin, and V.R. Raju	
3D Integration Using Wafer Bonding	515
J-Q. Lü, A. Kumar, Y. Kwon, E.T. Eisenbraun, R.P. Kraft, J.F. McDonald, R.J. Gutmann, T.S. Cale, P. Belemjian, O. Erdogan, J. Castracane, and A.E. Kaloyeros	
Electroless Silver and Its Alloys for Interconnect Applications	523
I. Zhu, A. Inberg, N. Croitoru, and Y. Shacham-Diamand	
*Damascene Metal Gate Technology	529
K. Nakajima, Y. Akasaka, T. Saito, K. Matsuo, A. Yagishita, and K. Suguro	
Advanced Film Transfer System for STP Method in Planarization Technology	535
Norio Sato, Katsuyuki Machida, Kazuhisa Kudo, Masaki Yano, and Hakaru Kyuragi	
Low-Temperature SiO₂ Formation by Ultrahigh-Vacuum Chemical Vapor Deposition Using Plasma-Activated Oxygen and Disilane	541
K. Kanamoto, T. Yoshida, T. Oizumi, A. Murai, T. Kurabayashi, and J. Nishizawa	

LOW- κ DIELECTRIC MATERIALS AND CHARACTERIZATION

Study on CMP Pattern Erosion for the Integration of a PECVD Low-k Material into the W Dual Damascene Process	549
P. Wrschka, G. Lee, K-S. Low, K. Dev, D. Dobuzinsky, R. Conti, and P. Shafer	
*The Impact of Mesoporous Silica Material Properties on Cu/Damascene Integration	557
E. Todd Ryan, Simon Lin, David Nelsen, Jeff Wetzell, David Gidley, and Jim Drage	

*Invited Paper

Dielectric Barrier Material Evaluations for Cu/Low-k Interconnects	565
Qing-Tang Jiang, Mike Daniels, Bob Havemann, Gennadi Bersuker, Kelly Taylor, Paul Besser, Jim Werking, and Rod Augur	
Porosity Characterization of Mesoporous Dielectric Thin Films Using Positron Annihilation Spectroscopy	571
Mihail P. Petkov, Marc H. Weber, Kelvin G. Lynn, Kenneth P. Rodbell, Willi Volksen, and Robert D. Miller	
Characterization of Plasma-Polymerized Divinylsiloxane Benzocyclobutene (DVS-BCB) Polymer Film	579
Munehiro Tada, Jun Kawahara, and Yoshihiro Hayashi	
Novel Nanoporous Ultra Low-Dielectric Constant Poly(methyl silsesquioxane)	587
Shu Yang, C-S. Pai, J.C-H. Pai, Om Nalamasu, Elsa Reichmanis, Joko Seputro, and Yaw S. Obeng	
Characterization and Integration of a New Si-O-C Film Deposited by CVD	595
R.A. Donaton, H. Struyf, M. Lepage, B. Coenegrachts, M. Stucchi, D. De Roest, M.R. Baklanov, S. Vanhaelemeersch, K. Maex, F. Gaillard, L-Q. Xia, T-H. Lim, M. Gotuaco, E. Yieh, and L. Van Autryve	
Comparative Study of Physical and Electrical Characteristics of F- and C-Doped Low-k CVD Oxides	603
Zhen-Cheng Wu, Zhi-Wen Shiung, Chiu-Chih Chiang, Wei-Hao Wu, Mao-Chieh Chen, Shwang-Ming Jeng, Weng Chang, Pei-Fen Chou, Syun-Ming Jang, Chen-Hua Yu, and Mong-Song Liang	
Polysiloxane-Based Low-k Porous Silica Films Deposited by Plasma Enhanced CVD	611
H. Ikakura, T. Ishimaru, Y. Yamamoto, Y. Kotake, S. Ohgawara, Y. Shioya, K. Ohira, and K. Maeda	
The Effect of Deposition Parameters on the Trimethylsilane Based PECVD a-SiOC:H Low-k Films for Cu Damascene Process	619
Soo Geun Lee, Kyoung-Woo Lee, Il Goo Kim, Seung Pae Lee, Min Kim, Jae Hak Kim, Hong-Jae Shin, Jin-Gi Hong, Hyeon-Deok Lee, and Ho-Kyu Kang	