Materials Reliability Issues in Microelectronics

Symposium held April 30-May 3, 1991, Anaheim, California, U.S.A.

EDITORS:

James R. Lloyd
Digital Equipment Corporation, Hudson, Massachusetts, U.S.A.

Frederick G. Yost
Sandia National Laboratories, Albuquerque, New Mexico, U.S.A.

Paul S. Ho
IBM T.J. Watson Research Center, Yorktown Heights, New York, U.S.A.
Contents

PREFACE xi
DEDICATION xiii
A COMPUTER SIMULATION OF STRIPE DETERIORATION THROUGH ELECTROMIGRATION xv
H.B. Huntington, A. Kalukin, P.P. Meng, Y.T. Shy, and S. Ahmad

PART I: ELECTROMIGRATION I

*BASIC CONCEPTS IN ELECTROMIGRATION 3
Richard S. Sorbello

A STATISTICAL CHARACTERIZATION OF ELECTROMIGRATION-INDUCED OPEN FAILURES IN 2-LEVEL METAL STRUCTURES 15
H. Kahn and C.V. Thompson

TEXTURE AND MICROSTRUCTURE EFFECTS ON ELECTROMIGRATION BEHAVIOR OF ALUMINUM METALLIZATION 21
D.B. Knorr, K.P. Rodbell, and D.P. Tracy

INVESTIGATIONS ON A NEW FAILURE MODEL FOR ELECTROMIGRATION 27
J. Kitchin and J.R. Lloyd

*STRESS AND ELECTROMIGRATION IN THIN FILM METALLISATION 35
C.A. Ross

MECHANICAL STRESS AND ELECTROMIGRATION FAILURE 47
J.R. Lloyd

MICROSTRUCTURAL ANALYSIS OF ELECTROMIGRATION-INDUCED Voids AND HILLOCKS 53
John E. Sanchez, Jr. and J.W. Morris, Jr.

$1/f^2$ NOISE AND ELECTROMIGRATION IN Al-Cu INTERCONNECTS 59
Michael L. Dreyer

PART II: ELECTROMIGRATION II

*SUB-MICRON CONTACT FILLING AND ELECTROMIGRATION OF SELF-ION-ENHANCED PHYSICAL VAPOR DEPOSITED ALUMINUM FILMS 67
R.E. Hummel and D.W. Malone

CHARACTERIZATION STUDY OF Al-PLUG TECHNOLOGY 79

*Invited Paper
ELECTROMIGRATION CHARACTERISTICS UNDER HIGH FREQUENCY PULSED CURRENT STRESSING
Thomas Kwok, R. Kaufman, and B. Davari

ELECTROMIGRATION BEHAVIOR IN LAYERED Ti/AlCu/Ti FILMS AND ITS DEPENDENCE ON INTERMETALLIC STRUCTURE
K.P. Rodbell, P.W. DeHaven, and J.D. Mis

ELECTROMIGRATION IN Al/W AND Al(Cu)/W INTERCONNECT STRUCTURES
C-K. Hu, P.S. Ho, M.B. Small, and K. Kelleher

ELECTROMIGRATION LIFETIME AND STEP COVERAGE IN Al/Cu/Si THIN FILM CONDUCTORS
Larisa Kisselgof, L.J. Elliott, J.J. Maziarz, and J.R. Lloyd

THE EFFECTS OF PLASMA IMMERSION ION IMPLANTATION ON THERMAL HILLOCK FORMATION
Carey A. Pico, Jiang Tao, and Nathan Cheung

THE KINETICS OF ELECTROMIGRATION DAMAGE IN COPPER FILMS STUDIED BY ISOTHERMAL RESISTANCE CHANGE ANALYSIS
C.W. Park and R.W. Vook

IN-SITU TEM OBSERVATION OF ELECTROMIGRATION DAMAGE BY SURFACE OR INTERFACE DIFFUSION IN Al AND Al ALLOY FILMS
C.Y. Chang and R.W. Vook

PART III: STRESS EFFECTS ON RELIABILITY

*MECHANISMS OF INELASTIC DEFORMATION AND STRESS RELAXATION IN THIN METALLIZATIONS BONDED TO HARD SUBSTRATES
M.A. Korhonen, P. Børgesen, and Che-Yu Li

STRESS INDUCED VOID NUCLEATION IN NARROW ALUMINUM ALLOY LINES
P. Børgesen, M.A. Korhonen, C. Basa, W.R. LaFontaine, B. Land, and C.-Y. Li

THE EFFECT OF LINE GEOMETRY ON VOID GROWTH IN THIN, NARROW ALUMINUM LINES
P. Børgesen, J.K. Lee, M.A. Korhonen, and C.-Y. Li

VOID GROWTH AS A FUNCTION OF RESIDUAL STRESS LEVEL IN THIN, NARROW ALUMINUM LINES
M.A. Korhonen, P. Børgesen, C.A. Paszkiet, J.K. Lee, and Che-Yu Li

THE EFFECT OF A PASSIVATION OVER-LAYER ON THE MECHANISMS OF STRESS RELAXATION IN CONTINUOUS FILMS AND NARROW LINES OF ALUMINUM
C.A. Paszkiet, M.A. Korhonen, and Che-Yu Li

*Invited Paper
EVALUATION ON ELECTROMIGRATION AND STRESSMIGRATION OF METAL INTERCONNECTIONS BY HARDNESS MEASUREMENTS
T. Nakagawa, H. Miyatake, T. Maeda, K. Kuroda, N. Tokushige, R. Inoue, J. Kudo, and T. Ashida

PART IV: STRESS AND PACKAGING

MECHANICAL MODELING OF STRESS GENERATION DURING CURE OF ENCAPSULATING RESINS
R.R. Lagasse, R.S. Chambers, T.R. Guess, D.J. Plazek, and C. Bero

SILICON CARBIDE WHISKER REINFORCED ALUMINUM WITH IMPROVED TEMPERATURE RESISTANCE DUE TO THE USE OF A PHOSPHATE BINDER
Jeng-Maw Chiou and D.D.L. Chung

*CREEP-FATIGUE BEHAVIOR OF MICROELECTRONIC SOLDER JOINTS
R.G. Ross, Jr., L.C. Wen, G.R. Mon, E. Jetter, and J. Winslow

NUMERICAL SIMULATION AND EXPERIMENTAL INVESTIGATION OF SMT LASER MICROSOLDERING THERMAL PROCESS
Wang Chunqing, Qian Yiyu, and Jiang Yihong

NUMERICAL ANALYSIS OF THE BALL FORMING PROCESS IN COPPER BALL BONDING
Fang Hongyuan, Qian Yiyu, and Jiang Yihong

PART V: METALLIZATION

*INDUSTRIAL PERSPECTIVE ON RELIABILITY OF VLSI DEVICES
P.B. Ghate

COMPUTER SIMULATION OF GRAIN GROWTH IN THIN-FILM INTERCONNECT LINES
D.T. Walton, H.J. Frost, and C.V. Thompson

HIGH-ENERGY BACKSCATTERED ELECTRON IMAGING OF VOIDS IN ALUMINUM METALLIZATIONS
D.M. Pollstaedt, J.A. Van Den Avyle, A.D. Romig, Jr., and J.A. Knapp

INTERMETALLIC REACTIONS BETWEEN COPPER AND MAGNESIUM AS AN ADHESION/BARRIER LAYER

THERMAL STABILITY OF SPUTTER DEPOSITED TANTALUM SILICIDE FILMS
G.A. Dixit, R. Sundaresan, F.S. Chen, Y.S. Lin, C.C. Wei, and F.T. Liou

*Invited Paper
PART VI: DEVICE, OXIDE AND
DIELECTRIC RELIABILITY

MODELLING AND CHARACTERIZATION OF SUBMICRON P-CHANNEL
MOSFET's LOCALLY DEGRADED BY HOT CARRIER INJECTION 247
A. Hassein-Bey and S. Cristoloveanu

IMPACT OF OXYGEN DURING POST-GATE PROCESSING ON MOS
DEVICE CHARACTERISTICS 253
Steven S. Lee, G.Q. Lo, and D.L. Kwong

ENHANCED GATE OXIDE RELIABILITY THROUGH FLUORINE
INCORPORATION AND THE INFLUENCE OF POLYSILICON
PROCESS VARIATIONS 259
K.P. MacWilliams, L.E. Lowry, S.T. Lin, M. Song,
R. Cole, and S. Brown

AUTOMATIC DETERMINATION OF IN-DEPTH PROFILES OF
RECOMBINATION LIFETIME IN EPITAXIAL Si LAYER WITH
P'-N''-N' STRIPE TEST PATTERN DIODES 265
Akira Usami, Yoshimaro Fujii, Hideki Fujiwara,
Tomiyasu Sone, and Takao Wada

CHARACTERIZATION OF FAILURE MECHANISMS AND FAILURE
RATE OF OXIDE WEAROUT BY HOT ELECTRON USING d.c.
AND a.c. SUBSTRATE ELECTRON INJECTION 271
Toshikazu Nishida, Scott E. Thompson, and
Jack T. Kavalieros

PROPERTIES OF SiO2 FILMS FABRICATED BY MICROWAVE
ECR PLASMA PROCESSING WITH AND WITHOUT ENERGETIC
PARTICLE BOMBARDMENT DURING FILM DEPOSITION.
PART II: ELECTRONIC PROPERTIES 277
T.T. Chau, S.R. Mejia, and K.C. Kao

TEM INVESTIGATION OF ARSENIC PRECIPITATES IN
SEMI-INSULATING GaAs 283
S. Yegnasubramanian and M.A. Shahid

*PART VII: NEW INVESTIGATIVE TECHNIQUES

*MODULATED REFLECTANCE AND SURFACE TOPOGRAPHY
IMAGING: NEW TOOLS FOR MICROELECTRONICS RELIABILITY 291
W. Lee Smith

SYNCHROTRON X-RAY TOPOGRAPHIC STUDY OF THE
BEHAVIOR OF DEFECTS IN HIGH CARBON-CONTENT
Si WAFERS DURING RTP 301
Thomas Fanning, Michael Dudley,
Franklyn F.Y. Wang, David Gordon-Smith,
and David T. Hodul

SHADOW STEP STRUCTURES FOR CV DOT FORMATION AND
EVALUATION 307
Nitin B. Shah and Warren C. Rosvold

*Invited Paper
OXIDIZED POROUS SILICON MOISTURE SENSORS FOR EVALUATION OF MICROELECTRONIC PACKAGING

*INVESTIGATION OF SURFACE ION FAILURE MECHANISMS BY CORONA DISCHARGE
Robert B. Comizzoli

PART VIII: CORROSION

INVESTIGATIONS OF RESIDUAL CHLORINE ON ETCHED AlCu METAL LINES BY TOTAL REFLECTION X-RAY FLUORESCENCE (TXRF)
R.S. Hockett, M.H. Herman, X.C. Mu, and Li-Jia Ma

EFFECT OF MOISTURE AND CONTAMINANTS ON THE DIELECTRIC CONSTANT OF THIN-FILM ALUMINA SUBSTRATES
Indira Chatterjee, Manoranjan Misra, Garry W. Warren, and Cathy Neve

METASTABLE PITTING CORROSION OF ALUMINUM, Al-Cu, AND Al-Si THIN FILMS IN DILUTE HF SOLUTIONS AND ITS RELEVANCY TO THE PROCESSING OF INTEGRATED CIRCUIT INTERCONNECTIONS
J.R. Scully and D.E. Peebles

A TECHNIQUE FOR THE EXAMINATION OF SURFACE EFFECTS IN ALUMINUM NITRIDE CERAMICS
M. Grant Norton, Stuart McKernan, and C. Barry Carter

AUTHOR INDEX

SUBJECT INDEX

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

*Invited Paper