High Resolution Microscopy of Materials

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS VOLUME 139

High Resolution Microscopy of Materials

Symposium held November 29-December 1, 1988, Boston, Massachusetts, U.S.A.

EDITORS:

William Krakow
IBM T. J. Watson Research Center, Yorktown Heights, New York, U.S.A.

Fernando A. Ponce
Xerox PARC, Palo Alto California, U.S.A.

David J. Smith
Arizona State University, Tempe, Arizona, U.S.A.

MRS MATERIALS RESEARCH SOCIETY
Pittsburgh, Pennsylvania

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Mexico City

Cambridge University Press
32 Avenue of the Americas, New York NY 10013-2473, USA

Published in the United States of America by Cambridge University Press, New York

www.cambridge.org
Information on this title: www.cambridge.org/9781107410800

Materials Research Society
506 Keystone Drive, Warrendale, PA 15086
http://www.mrs.org

First published 1989
First paperback edition 2012

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

CODEN: MRSPDH

ISBN 978-1-107-41080-0 Paperback

Contents

PREFACE xi

PART I: ATOMIC IMAGING OF DEFECTS

*SOLVING THE STRUCTURE OF INTERFACES BY HIGH RESOLUTION ELECTRON MICROSCOPY 3
Alain Bourret

*SPECTROSCOPY OF METAL ADSORBATES ON THE GaAs(110) SURFACE STUDIED WITH THE SCANNING TUNNELING MICROSCOPE 15
R.M. Feenstra, P. Mårtensson, and R. Ludeke

*STUDY OF THE STRUCTURE AND CHEMISTRY OF POINT, LINE AND PLANAR IMPERFECTIONS VIA FIELD-ION AND ATOM-PROBE FIELD-ION MICROSCOPY 25
David N. Seidman

STRUCTURAL AND CHEMICAL IMAGING OF SUPERCONDUCTORS AND SEMICONDUCTORS BY HIGH-RESOLUTION STEM 39
S.J. Pennycook

APPLICATION OF A POSITION SENSITIVE ATOM PROBE TO THE ANALYSIS OF THE CHEMISTRY AND MORPHOLOGY OF MULTI-QUANTUM WELL INTERFACES 45
Alfred Cerezo, J. Alex Liddle, Chris R.M. Grovenor, Andrew G. Norman, and George D.W. Smith

FIELD ION MICROSCOPY OF QUASICRYSTALS 51
H.B. Elswijk and J.Th.M. De Hosson

PART II: SURFACES AND INTERFACES

*HIGH RESOLUTION UHV ELECTRON MICROSCOPY ON SURFACES AND HETEROEPITAXY 59
K. Takayanagi, Y. Tanishiro, K. Murooka, and M. Mitome

IN-SITU STUDIES OF SILICON OXIDATION 67
J.M. Gibson and M.Y. Lanzerotti

SURFACE OXIDATION PROCESSES IN COMPOUND SEMICONDUCTORS STUDIED BY PROFILE IMAGING 75
Ping Lu and David J. Smith

APPLICATIONS OF IN-SITU UHV AND HIGH RESOLUTION TEM TO THE STUDY OF SMALL PARTICLES 81
M. Avalos-Borja, D. Su, F.A. Ponce, J.C. Tramontana, Q.-H. Guo, K. Heinemann, H. Poppa, and M. Boudart

*HIGH RESOLUTION ELECTRON MICROSCOPY OF INTERFACES IN TOPOTAXIAL AND EPITAXIAL REACTIONS 87
U. Dahmen, J. Douin, C.J.D. Hetherington, and K.H. Westmacott

*Invited Paper

RECONSTRUCTION OF (100) SILICON/DISILICIDE INTERFACES 97
D. Loretto, J.M. Gibson, Alice E. White, K.T. Short, R.T. Tung, S.M. Yalisove, and J.L. Batstone

HIGH RESOLUTION ELECTRON MICROSCOPY OF TWIST GRAIN BOUNDARIES 103
William Krakow

HIGH RESOLUTION OBSERVATION AND IMAGE SIMULATION ON CLEAVED WEDGES OF III-V SEMICONDUCTORS 111
P.A. Buffat, J.D. Ganiere, and P. Stadelmann

HIGH RESOLUTION ELECTRON MICROSCOPY STUDIES OF MBE GROWN InSb LAYERS ON GaAs (100) 117
C.J. Kiely, J-I. Chyi, A. Rockett, and H. Morkoç

PART III: QUASICRYSTALS, INTERFACES AND SUPERCONDUCTORS

*HIGH-RESOLUTION ELECTRON MICROSCOPY OF QUASICRYSTALS 125
K. Hiraga

ON THE INDIUM PRECIPITATION IN SILICON 135
E. Ganin and W. Krakow

STRUCTURE DETERMINATION OF THE Si(111)-CaF_2 INTERFACE 141
R.M. Tromp, W. Krakow, and F.K. LeGoues

*HRTEM OF HIGH T_c SUPERCONDUCTOR MATERIALS 147
J.C. Barry, B.L. Ramakrishna, and Z. Iqbal

STRUCTURES AND INTERGROWTHS IN THALLIUM SUPERCONDUCTORS 163
J.P. Zhang, D.J. Li, and L.D. Marks

SCANNING TUNNELING MICROSCOPY OF THE CLEAVED SURFACES OF Bi-CONTAINING SUPERCONDUCTORS 169
S.L. Tang, R.V. Kasowski, M.A. Subramanian, E.M. McCarron, and W.Y. Hsu

δ_2-$Y_2Si_2O_7$ STRUCTURE CONFIRMED BY PROCESSING AND SIMULATION OF ATOMIC-RESOLUTION IMAGES 175
R.S. Rai, M.A. O'Keefe, and G. Thomas

FIELD ION IMAGES OF SOME NON-METALLIC MATERIALS 181
Chong-lin Chen and Tien T. Tsong

PART IV: CERAMICS, INTERFACES AND SURFACES

*HIGH-RESOLUTION MICROSCOPY OF CERAMICS 189
C.B. Carter, S. McKernan, D.R. Rasmussen, Y.K. Simpson, S.R. Summerfelt, D.W. Susnitzky, and L.A. Tietz

HEXAGONAL SILICON: A NEW HREM STUDY 199
P. Pirouz, J. Yang, F. Ernst, and H.-J. Möller

*Invited Paper

HREM IN SITU ANNEALING OF THE CdTe/GaAs HETEROJUNCTION 205
Alan Schwartzman and Robert Sinclair

EFFECTS OF COMPOSITION AND STRAIN ON IMAGE CONTRAST IN ATOMIC-RESOLUTION TRANSMISSION ELECTRON MICROSCOPY 211
James M. Howe and Duane Sundo

HIGH-RESOLUTION ELECTRON MICROSCOPY STUDIES OF Co/Cr MULTILAYERS 217
Shu-Chen Y. Tsen, Mary Beth Stearns, and David J. Smith

HIGH RESOLUTION STEM IMAGES AND NANODIFFRACTION PATTERNS ON HIGH T_c SUPERCONDUCTOR $YBa_2Cu_3O_{7-X}$ 223
H.-J. Ou, A.A. Higgs, and J.M. Cowley

A NEW APPROACH TO ATOMIC FORCE MICROSCOPY 229
Nabil M. Amer

ATOMIC FORCE MICROSCOPE DESIGNS AND APPLICATIONS 235
P.J. Bryant, R.G. Miller, R.H. Deeken, and M.A. Pederson

PART V: INSTRUMENTATION

*PERFORMANCE OF ULTRAHIGH RESOLUTION ELECTRON MICROSCOPE JEM-4000EX AND SOME APPLICATIONS OF HIGH Tc SUPERCONDUCTOR 241
Toshikazu Honda, Katsuhiko Ibe, Yukihisa Ishida, and Michael M. Kersker

*THE CM30-SUPERTWIN: A DEDICATED ULTRA-HIGH RESOLUTION TRANSMISSION ELECTRON MICROSCOPE 251
Max T. Otten

*RECENT DEVELOPMENT IN HITACHI TEM 259
K. Kubozoe, M. Tomita, I. Matsui, S. Isakozawa, and S. Kamimura

A NEW ULTRA-HIGH RESOLUTION TEM, EM-002B, WITH A UNIQUE UHR OBJECTIVE LENS CONFIGURATION 271
T. Yanaka, K. Moriyama, and R. Buchanan

THE BERKELEY ATOMIC RESOLUTION MICROSCOPE-AN UPDATE 277
C.J.D. Hetherington, E.C. Nelson, K.H. Westmacott, R. Gronsky, and G. Thomas

ATOM-PROBE STUDY OF SELECTIVE OXIDATION OF Ni FROM Cu-Ni ALLOY 283
K. Hono, M. Nakamura, H.W. Pickering, and T. Sakurai

INITIAL EXPERIENCES WITH A 300-KV HREM CONVERTED FOR UHV OPERATION 289
David J. Smith, J. Podbrdsky, P.R. Swann, and J.S. Jones

*Invited Paper

PART VI: GENERAL PAPERS

SCANNING TUNNELING MICROSCOPE WITH A FIELD ION MICROSCOPE 297
T. Hashizume, I. Kamiya, Y. Hasegawa, T. Ide, H.W. Pickering, and T. Sakurai

EFFECTS OF ENVIRONMENT ON TUNNELING SPECTROSCOPY OF GOLD FILMS 303
G.C. Wetsel, Z.M. Liu, T.L. Weng, M.W. Gosney, and R.J. Warmack

HIGH-RESOLUTION ELECTRON MICROSCOPY OF HEMATITE FORMED BY EXTERNAL OXIDATION OF IRON-BEARING OLIVINE 309
Stuart McKernan, D. René Rasmussen, and C. Barry Carter

HIGH RESOLUTION ELECTRON MICROSCOPY AND CATALYTIC STUDIES OF PURE AND COPPER INTERCHANGED Y FAUJASITES 315
Dwight R. Acosta, Jose Orozco, Mauro Briceño, and Mitsuo Ogura

ENHANCING OF SMALL ISOLATED DOMAINS AND SUPERSTRUCTURES IN HIGH RESOLUTION IMAGES OF OXIDES 321
J.G. Perez-Ramirez, D. Michel, and R. Portier

SELECTIVE DISPERSION OF THE Ru-RuO_x/TiO_2 CATALYST FOR METHANATION OF CO_2 AT ROOM TEMPERATURE AND ATMOSPHERIC PRESSURE 327
P. Ruterana, P-A. Buffat, K.R. Thampi, and M. Graetzel

HREM OF GOLD CLUSTERS ON MgO SMOKE PARTICLES 333
P.M. Ajayan and L.D. Marks

CHARACTERIZATION OF Mo/Si MULTILAYER STRUCTURES BY HIGH-RESOLUTION ELECTRON MICROSCOPY 339
Chung-Hee Chang, Mary Beth Stearns, and David J. Smith

HIGH-RESOLUTION TRANSMISSION ELECTRON MICROSCOPY: AN ESSENTIAL CHARACTERIZATION TECHNIQUE FOR OPTIMIZATION OF SEMICONDUCTOR EPITAXY AND INTERFACES 345
J.B. Posthill, G.G. Fountain, R.A. Rudder, S.V. Hattangady, G.S. Solomon, M.L. Timmons, and R.J. Markunas

BONDING CONFIGURATIONS AT EPITAXIAL CaF_2/Si INTERFACES 351
J.L. Batstone and Julia M. Phillips

HIGH RESOLUTION ELECTRON MICROSCOPY STUDY OF AS-PREPARED AND ANNEALED TUNGSTEN-CARBON MULTILAYERS 357
Tai D. Nguyen, Ronald Gronsky, and Jeffrey B. Kortright

TRANSMISSION ELECTRON MICROSCOPY STUDY OF DIAMOND FILMS GROWN BY PLASMA DEPOSITION 363
M.S. Wong, W.A. Chiou, F.R. Chen, D.X. Li, and R.P.H. Chang

MICROSTRUCTURAL INVESTIGATION OF THE $TiSi_2$/Si (111) INTERFACE 369
A. Catana, M. Heintze, P.E. Schmid, P. Stadelmann, and F. Levy

ELECTRON MICROSCOPE STUDY OF INITIAL STAGE OF GROWTH OF ZnSe ON GaAs 375
J.M. Gonsalves, N. Otsuka, J. Qiu, M. Kobayashi, R.L. Gunshor, and L.A. Kolodziejski

HIGH RESOLUTION TEM STUDIES OF SOLID-PHASE EPITAXIAL Si AT CONTACT HOLES THROUGH Al-Si ALLOY 381
Norio Hirashita, Masako Kinoshita, and Tsuneo Ajioka

THE ATOMIC STRUCTURE OF THE Si/$CoSi_2$ INTERFACE 387
J.H. Mazur and P. Grodzinski

AUTHOR INDEX 393

SUBJECT INDEX 395

Preface

This proceedings volume contains the papers which were presented at the symposium on "High Resolution Microscopy of Materials" held in Boston, Massachusetts, November 28 to December 3, 1988, and sponsored by the Materials Research Society. The symposium provided an interdisciplinary forum for scientists engaged in the use of microscope characterization techniques to study materials. This year the particular focus was towards atomic level imaging and included various types of instruments such as transmission electron microscopes, scanning tunneling microscopes, and field ion microscopes. The proceedings is divided into six sections which follow the order of presentation at the meeting. They are as follows: atomic imaging of defects; surfaces and interfaces; quasicrystals, interfaces and superconductors; ceramics, interfaces and surfaces; instrumentation; and general papers presented as posters. One of the features of the symposium was to emphasize advances in materials applications areas and to effectively cover aspects of instrumentation appropriate to the materials science community.

A large part of the success of the symposium was due to financial contributions from electron microscope manufacturers. We would like to specifically acknowledge JEOL U.S.A. Inc., Hitachi Scientific Instruments and Philips Electronic Instruments for their generous assistance. Finally, we would like to extend our sincere thanks to Loretta Holness for her secretarial services before and after the conference.

W. Krakow
F.A. Ponce
D.J. Smith

June 1989

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

ISSN 0272 - 9172

Volume 1—Laser and Electron-Beam Solid Interactions and Materials Processing, J. F. Gibbons, L. D. Hess, T. W. Sigmon, 1981, ISBN 0-444-00595-1

Volume 2—Defects in Semiconductors, J. Narayan, T. Y. Tan, 1981, ISBN 0-444-00596-X

Volume 3—Nuclear and Electron Resonance Spectroscopies Applied to Materials Science, E. N. Kaufmann, G. K. Shenoy, 1981, ISBN 0-444-00597-8

Volume 4—Laser and Electron-Beam Interactions with Solids, B. R. Appleton, G. K. Celler, 1982, ISBN 0-444-00693-1

Volume 5—Grain Boundaries in Semiconductors, H. J. Leamy, G. E. Pike, C. H. Seager, 1982, ISBN 0-444-00697-4

Volume 6—Scientific Basis for Nuclear Waste Management IV, S. V. Topp, 1982, ISBN 0-444-00699-0

Volume 7—Metastable Materials Formation by Ion Implantation, S. T. Picraux, W. J. Choyke, 1982, ISBN 0-444-00692-3

Volume 8—Rapidly Solidified Amorphous and Crystalline Alloys, B. H. Kear, B. C. Giessen, M. Cohen, 1982, ISBN 0-444-00698-2

Volume 9—Materials Processing in the Reduced Gravity Environment of Space, G. E. Rindone, 1982, ISBN 0-444-00691-5

Volume 10—Thin Films and Interfaces, P. S. Ho, K.-N. Tu, 1982, ISBN 0-444-00774-1

Volume 11—Scientific Basis for Nuclear Waste Management V, W. Lutze, 1982, ISBN 0-444-00725-3

Volume 12—In Situ Composites IV, F. D. Lemkey, H. E. Cline, M. McLean, 1982, ISBN 0-444-00726-1

Volume 13—Laser-Solid Interactions and Transient Thermal Processing of Materials, J. Narayan, W. L. Brown, R. A. Lemons, 1983, ISBN 0-444-00788-1

Volume 14—Defects in Semiconductors II, S. Mahajan, J. W. Corbett, 1983, ISBN 0-444-00812-8

Volume 15—Scientific Basis for Nuclear Waste Management VI, D. G. Brookins, 1983, ISBN 0-444-00780-6

Volume 16—Nuclear Radiation Detector Materials, E. E. Haller, H. W. Kraner, W. A. Higinbotham, 1983, ISBN 0-444-00787-3

Volume 17—Laser Diagnostics and Photochemical Processing for Semiconductor Devices, R. M. Osgood, S. R. J. Brueck, H. R. Schlossberg, 1983, ISBN 0-444-00782-2

Volume 18—Interfaces and Contacts, R. Ludeke, K. Rose, 1983, ISBN 0-444-00820-9

Volume 19—Alloy Phase Diagrams, L. H. Bennett, T. B. Massalski, B. C. Giessen, 1983, ISBN 0-444-00809-8

Volume 20—Intercalated Graphite, M. S. Dresselhaus, G. Dresselhaus, J. E. Fischer, M. J. Moran, 1983, ISBN 0-444-00781-4

Volume 21—Phase Transformations in Solids, T. Tsakalakos, 1984, ISBN 0-444-00901-9

Volume 22—High Pressure in Science and Technology, C. Homan, R. K. MacCrone, E. Whalley, 1984, ISBN 0-444-00932-9 (3 part set)

Volume 23—Energy Beam-Solid Interactions and Transient Thermal Processing, J. C. C. Fan, N. M. Johnson, 1984, ISBN 0-444-00903-5

Volume 24—Defect Properties and Processing of High-Technology Nonmetallic Materials, J. H. Crawford, Jr., Y. Chen, W. A. Sibley, 1984, ISBN 0-444-00904-3

Volume 25—Thin Films and Interfaces II, J. E. E. Baglin, D. R. Campbell, W. K. Chu, 1984, ISBN 0-444-00905-1

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

Volume 26—Scientific Basis for Nuclear Waste Management VII, G. L. McVay, 1984, ISBN 0-444-00906-X

Volume 27—Ion Implantation and Ion Beam Processing of Materials, G. K. Hubler, O. W. Holland, C. R. Clayton, C. W. White, 1984, ISBN 0-444-00869-1

Volume 28—Rapidly Solidified Metastable Materials, B. H. Kear, B. C. Giessen, 1984, ISBN 0-444-00935-3

Volume 29—Laser-Controlled Chemical Processing of Surfaces, A. W. Johnson, D. J. Ehrlich, H. R. Schlossberg, 1984, ISBN 0-444-00894-2

Volume 30—Plasma Processing and Synthesis of Materials, J. Szekely, D. Apelian, 1984, ISBN 0-444-00895-0

Volume 31—Electron Microscopy of Materials, W. Krakow, D. A. Smith, L. W. Hobbs, 1984, ISBN 0-444-00898-7

Volume 32—Better Ceramics Through Chemistry, C. J. Brinker, D. E. Clark, D. R. Ulrich, 1984, ISBN 0-444-00898-5

Volume 33—Comparison of Thin Film Transistor and SOI Technologies, H. W. Lam, M. J. Thompson, 1984, ISBN 0-444-00899-3

Volume 34—Physical Metallurgy of Cast Iron, H. Fredriksson, M. Hillerts, 1985, ISBN 0-444-00938-8

Volume 35—Energy Beam-Solid Interactions and Transient Thermal Processing/1984, D. K. Biegelsen, G. A. Rozgonyi, C. V. Shank, 1985, ISBN 0-931837-00-6

Volume 36—Impurity Diffusion and Gettering in Silicon, R. B. Fair, C. W. Pearce, J. Washburn, 1985, ISBN 0-931837-01-4

Volume 37—Layered Structures, Epitaxy, and Interfaces, J. M. Gibson, L. R. Dawson, 1985, ISBN 0-931837-02-2

Volume 38—Plasma Synthesis and Etching of Electronic Materials, R. P. H. Chang, B. Abeles, 1985, ISBN 0-931837-03-0

Volume 39—High-Temperature Ordered Intermetallic Alloys, C. C. Koch, C. T. Liu, N. S. Stoloff, 1985, ISBN 0-931837-04-9

Volume 40—Electronic Packaging Materials Science, E. A. Giess, K.-N. Tu, D. R. Uhlmann, 1985, ISBN 0-931837-05-7

Volume 41—Advanced Photon and Particle Techniques for the Characterization of Defects in Solids, J. B. Roberto, R. W. Carpenter, M. C. Wittels, 1985, ISBN 0-931837-06-5

Volume 42—Very High Strength Cement-Based Materials, J. F. Young, 1985, ISBN 0-931837-07-3

Volume 43—Fly Ash and Coal Conversion By-Products: Characterization, Utilization, and Disposal I, G. J. McCarthy, R. J. Lauf, 1985, ISBN 0-931837-08-1

Volume 44—Scientific Basis for Nuclear Waste Management VIII, C. M. Jantzen, J. A. Stone, R. C. Ewing, 1985, ISBN 0-931837-09-X

Volume 45—Ion Beam Processes in Advanced Electronic Materials and Device Technology, B. R. Appleton, F. H. Eisen, T. W. Sigmon, 1985, ISBN 0-931837-10-3

Volume 46—Microscopic Identification of Electronic Defects in Semiconductors, N. M. Johnson, S. G. Bishop, G. D. Watkins, 1985, ISBN 0-931837-11-1

Volume 47—Thin Films: The Relationship of Structure to Properties, C. R. Aita, K. S. SreeHarsha, 1985, ISBN 0-931837-12-X

Volume 48—Applied Materials Characterization, W. Katz, P. Williams, 1985, ISBN 0-931837-13-8

Volume 49—Materials Issues in Applications of Amorphous Silicon Technology, D. Adler, A. Madan, M. J. Thompson, 1985, ISBN 0-931837-14-6

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

Volume 50—Scientific Basis for Nuclear Waste Management IX, L. O. Werme, 1986, ISBN 0-931837-15-4

Volume 51—Beam-Solid Interactions and Phase Transformations, H. Kurz, G. L. Olson, J. M. Poate, 1986, ISBN 0-931837-16-2

Volume 52—Rapid Thermal Processing, T. O. Sedgwick, T. E. Seidel, B.-Y. Tsaur, 1986, ISBN 0-931837-17-0

Volume 53—Semiconductor-on-Insulator and Thin Film Transistor Technology, A. Chiang. M. W. Geis, L. Pfeiffer, 1986, ISBN 0-931837-18-9

Volume 54—Thin Films—Interfaces and Phenomena, R. J. Nemanich, P. S. Ho, S. S. Lau, 1986, ISBN 0-931837-19-7

Volume 55—Biomedical Materials, J. M. Williams, M. F. Nichols, W. Zingg, 1986, ISBN 0-931837-20-0

Volume 56—Layered Structures and Epitaxy, J. M. Gibson, G. C. Osbourn, R. M. Tromp, 1986, ISBN 0-931837-21-9

Volume 57—Phase Transitions in Condensed Systems—Experiments and Theory, G. S. Cargill III, F. Spaepen, K.-N. Tu, 1987, ISBN 0-931837-22-7

Volume 58—Rapidly Solidified Alloys and Their Mechanical and Magnetic Properties, B. C. Giessen, D. E. Polk, A. I. Taub, 1986, ISBN 0-931837-23-5

Volume 59—Oxygen, Carbon, Hydrogen, and Nitrogen in Crystalline Silicon, J. C. Mikkelsen, Jr., S. J. Pearton, J. W. Corbett, S. J. Pennycook, 1986, ISBN 0-931837-24-3

Volume 60—Defect Properties and Processing of High-Technology Nonmetallic Materials, Y. Chen, W. D. Kingery, R. J. Stokes, 1986, ISBN 0-931837-25-1

Volume 61—Defects in Glasses, F. L. Galeener, D. L. Griscom, M. J. Weber, 1986, ISBN 0-931837-26-X

Volume 62—Materials Problem Solving with the Transmission Electron Microscope, L. W. Hobbs, K. H. Westmacott, D. B. Williams, 1986, ISBN 0-931837-27-8

Volume 63—Computer-Based Microscopic Description of the Structure and Properties of Materials, J. Broughton, W. Krakow, S. T. Pantelides, 1986, ISBN 0-931837-28-6

Volume 64—Cement-Based Composites: Strain Rate Effects on Fracture, S. Mindess, S. P. Shah, 1986, ISBN 0-931837-29-4

Volume 65—Fly Ash and Coal Conversion By-Products: Characterization, Utilization and Disposal II, G. J. McCarthy, F. P. Glasser, D. M. Roy, 1986, ISBN 0-931837-30-8

Volume 66—Frontiers in Materials Education, L. W. Hobbs, G. L. Liedl, 1986, ISBN 0-931837-31-6

Volume 67—Heteroepitaxy on Silicon, J. C. C. Fan, J. M. Poate, 1986, ISBN 0-931837-33-2

Volume 68—Plasma Processing, J. W. Coburn, R. A. Gottscho, D. W. Hess, 1986, ISBN 0-931837-34-0

Volume 69—Materials Characterization, N. W. Cheung, M.-A. Nicolet, 1986, ISBN 0-931837-35-9

Volume 70—Materials Issues in Amorphous-Semiconductor Technology, D. Adler, Y. Hamakawa, A. Madan, 1986, ISBN 0-931837-36-7

Volume 71—Materials Issues in Silicon Integrated Circuit Processing, M. Wittmer, J. Stimmell, M. Strathman, 1986, ISBN 0-931837-37-5

Volume 72—Electronic Packaging Materials Science II, K. A. Jackson, R. C. Pohanka, D. R. Uhlmann, D. R. Ulrich, 1986, ISBN 0-931837-38-3

Volume 73—Better Ceramics Through Chemistry II, C. J. Brinker, D. E. Clark, D. R. Ulrich, 1986, ISBN 0-931837-39-1

Volume 74—Beam-Solid Interactions and Transient Processes, M. O. Thompson, S. T. Picraux, J. S. Williams, 1987, ISBN 0-931837-40-5

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

Volume 75—Photon, Beam and Plasma Stimulated Chemical Processes at Surfaces, V. M. Donnelly, I. P. Herman, M. Hirose, 1987, ISBN 0-931837-41-3

Volume 76—Science and Technology of Microfabrication, R. E. Howard, E. L. Hu, S. Namba, S. Pang, 1987, ISBN 0-931837-42-1

Volume 77—Interfaces, Superlattices, and Thin Films, J. D. Dow, I. K. Schuller, 1987, ISBN 0-931837-56-1

Volume 78—Advances in Structural Ceramics, P. F. Becher, M. V. Swain, S. Sōmiya, 1987, ISBN 0-931837-43-X

Volume 79—Scattering, Deformation and Fracture in Polymers, G. D. Wignall, B. Crist, T. P. Russell, E. L. Thomas, 1987, ISBN 0-931837-44-8

Volume 80—Science and Technology of Rapidly Quenched Alloys, M. Tenhover, W. L. Johnson, L. E. Tanner, 1987, ISBN 0-931837-45-6

Volume 81—High-Temperature Ordered Intermetallic Alloys, II, N. S. Stoloff, C. C. Koch, C. T. Liu, O. Izumi, 1987, ISBN 0-931837-46-4

Volume 82—Characterization of Defects in Materials, R. W. Siegel, J. R. Weertman, R. Sinclair, 1987, ISBN 0-931837-47-2

Volume 83—Physical and Chemical Properties of Thin Metal Overlayers and Alloy Surfaces, D. M. Zehner, D. W. Goodman, 1987, ISBN 0-931837-48-0

Volume 84—Scientific Basis for Nuclear Waste Management X, J. K. Bates, W. B. Seefeldt, 1987, ISBN 0-931837-49-9

Volume 85—Microstructural Development During the Hydration of Cement, L. Struble, P. Brown, 1987, ISBN 0-931837-50-2

Volume 86—Fly Ash and Coal Conversion By-Products Characterization, Utilization and Disposal III, G. J. McCarthy, F. P. Glasser, D. M. Roy, S. Diamond, 1987, ISBN 0-931837-51-0

Volume 87—Materials Processing in the Reduced Gravity Environment of Space, R. H. Doremus, P. C. Nordine, 1987, ISBN 0-931837-52-9

Volume 88—Optical Fiber Materials and Properties, S. R. Nagel, J. W. Fleming, G. Sigel, D. A. Thompson, 1987, ISBN 0-931837-53-7

Volume 89—Diluted Magnetic (Semimagnetic) Semiconductors, R. L. Aggarwal, J. K. Furdyna, S. von Molnar, 1987, ISBN 0-931837-54-5

Volume 90—Materials for Infrared Detectors and Sources, R. F. C. Farrow, J. F. Schetzina, J. T. Cheung, 1987, ISBN 0-931837-55-3

Volume 91—Heteroepitaxy on Silicon II, J. C. C. Fan, J. M. Phillips, B.-Y. Tsaur, 1987, ISBN 0-931837-58-8

Volume 92—Rapid Thermal Processing of Electronic Materials, S. R. Wilson, R. A. Powell, D. E. Davies, 1987, ISBN 0-931837-59-6

Volume 93—Materials Modification and Growth Using Ion Beams, U. Gibson, A. E. White, P. P. Pronko, 1987, ISBN 0-931837-60-X

Volume 94—Initial Stages of Epitaxial Growth, R. Hull, J. M. Gibson, David A. Smith, 1987, ISBN 0-931837-61-8

Volume 95—Amorphous Silicon Semiconductors—Pure and Hydrogenated, A. Madan, M. Thompson, D. Adler, Y. Hamakawa, 1987, ISBN 0-931837-62-6

Volume 96—Permanent Magnet Materials, S. G. Sankar, J. F. Herbst, N. C. Koon, 1987, ISBN 0-931837-63-4

Volume 97—Novel Refractory Semiconductors, D. Emin, T. Aselage, C. Wood, 1987, ISBN 0-931837-64-2

Volume 98—Plasma Processing and Synthesis of Materials, D. Apelian, J. Szekely, 1987, ISBN 0-931837-65-0

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

Volume 99—High-Temperature Superconductors, M. B. Brodsky, R. C. Dynes, K. Kitazawa, H. L. Tuller, 1988, ISBN 0-931837-67-7

Volume 100—Fundamentals of Beam-Solid Interactions and Transient Thermal Processing, M. J. Aziz, L. E. Rehn, B. Stritzker, 1988, ISBN 0-931837-68-5

Volume 101—Laser and Particle-Beam Chemical Processing for Microelectronics, D.J. Ehrlich, G.S. Higashi, M.M. Oprysko, 1988, ISBN 0-931837-69-3

Volume 102—Epitaxy of Semiconductor Layered Structures, R. T. Tung, L. R. Dawson, R. L. Gunshor, 1988, ISBN 0-931837-70-7

Volume 103—Multilayers: Synthesis, Properties, and Nonelectronic Applications, T. W. Barbee Jr., F. Spaepen, L. Greer, 1988, ISBN 0-931837-71-5

Volume 104—Defects in Electronic Materials, M. Stavola, S. J. Pearton, G. Davies, 1988, ISBN 0-931837-72-3

Volume 105—SiO_2 and Its Interfaces, G. Lucovsky, S. T. Pantelides, 1988, ISBN 0-931837-73-1

Volume 106—Polysilicon Films and Interfaces, C.Y. Wong, C.V. Thompson, K-N. Tu, 1988, ISBN 0-931837-74-X

Volume 107—Silicon-on-Insulator and Buried Metals in Semiconductors, J. C. Sturm, C. K. Chen, L. Pfeiffer, P. L. F. Hemment, 1988, ISBN 0-931837-75-8

Volume 108—Electronic Packaging Materials Science II, R. C. Sundahl, R. Jaccodine, K. A. Jackson, 1988, ISBN 0-931837-76-6

Volume 109—Nonlinear Optical Properties of Polymers, A. J. Heeger, J. Orenstein, D. R. Ulrich, 1988, ISBN 0-931837-77-4

Volume 110—Biomedical Materials and Devices, J. S. Hanker, B. L. Giammara, 1989, ISBN 0-931837-78-2

Volume 111—Microstructure and Properties of Catalysts, M. M. J. Treacy, J. M. Thomas, J. M. White, 1988, ISBN 0-931837-79-0

Volume 112—Scientific Basis for Nuclear Waste Management XI, M. J. Apted, R. E. Westerman, 1988, ISBN 0-931837-80-4

Volume 113—Fly Ash and Coal Conversion By-Products: Characterization, Utilization, and Disposal IV, G. J. McCarthy, D. M. Roy, F. P. Glasser, R. T. Hemmings, 1988, ISBN 0-931837-81-2

Volume 114—Bonding in Cementitious Composites, S. Mindess, S. P. Shah, 1988, ISBN 0-931837-82-0

Volume 115—Specimen Preparation for Transmission Electron Microscopy of Materials, J. C. Bravman, R. Anderson, M. L. McDonald, 1988, ISBN 0-931837-83-9

Volume 116—Heteroepitaxy on Silicon: Fundamentals, Structures,and Devices, H.K. Choi, H. Ishiwara, R. Hull, R.J. Nemanich, 1988, ISBN: 0-931837-86-3

Volume 117—Process Diagnostics: Materials, Combustion, Fusion, K. Hays, A.C. Eckbreth, G.A. Campbell, 1988, ISBN: 0-931837-87-1

Volume 118—Amorphous Silicon Technology, A. Madan, M.J. Thompson, P.C. Taylor, P.G. LeComber, Y. Hamakawa, 1988, ISBN: 0-931837-88-X

Volume 119—Adhesion in Solids, D.M. Mattox, C. Batich, J.E.E. Baglin, R.J. Gottschall, 1988, ISBN: 0-931837-89-8

Volume 120—High-Temperature/High-Performance Composites, F.D. Lemkey, A.G. Evans, S.G. Fishman, J.R. Strife, 1988, ISBN: 0-931837-90-1

Volume 121—Better Ceramics Through Chemistry III, C.J. Brinker, D.E. Clark, D.R. Ulrich, 1988, ISBN: 0-931837-91-X

Volume 122—Interfacial Structure, Properties, and Design, M.H. Yoo, W.A.T. Clark, C.L. Briant, 1988, ISBN: 0-931837-92-8

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

Volume 123—Materials Issues in Art and Archaeology, E.V. Sayre, P. Vandiver, J. Druzik, C. Stevenson, 1988, ISBN: 0-931837-93-6

Volume 124—Microwave-Processing of Materials, M.H. Brooks, I.J. Chabinsky, W.H. Sutton, 1988, ISBN: 0-931837-94-4

Volume 125—Materials Stability and Environmental Degradation, A. Barkatt, L.R. Smith, E. Verink, 1988, ISBN: 0-931837-95-2

Volume 126—Advanced Surface Processes for Optoelectronics, S. Bernasek, T. Venkatesan, H. Temkin, 1988, ISBN: 0-931837-96-0

Volume 127—Scientific Basis for Nuclear Waste Management XII, W. Lutze, R.C. Ewing, 1989, ISBN: 0-931837-97-9

Volume 128—Processing and Characterization of Materials Using Ion Beams, L.E. Rehn, J. Greene, F.A. Smidt, 1989, ISBN: 1-55899-001-1

Volume 129—Laser and Particle-Beam Chemical Processes on Surfaces, G.L. Loper, A.W. Johnson, T.W. Sigmon, 1989, ISBN: 1-55899-002-X

Volume 130—Thin Films: Stresses and Mechanical Properties, J.C. Bravman, W.D. Nix, D.M. Barnett, D.A. Smith, 1989, ISBN: 0-55899-003-8

Volume 131—Chemical Perspectives of Microelectronic Materials, M.E. Gross, J. Jasinski, J.T. Yates, Jr., 1989, ISBN: 0-55899-004-6

Volume 132—Multicomponent Ultrafine Microstructures, L.E. McCandlish, B.H. Kear, D.E. Polk, and R.W. Siegel, 1989, ISBN: 1-55899-005-4

Volume 133—High Temperature Ordered Intermetallic Alloys III, C.T. Liu, A.I. Taub, N.S. Stoloff, C.C. Koch, 1989, ISBN: 1-55899-006-2

Volume 134—The Materials Science and Engineering of Rigid-Rod Polymers, W.W. Adams, R.K. Eby, D.E. McLemore, 1989, ISBN: 1-55899-007-0

Volume 135—Solid State Ionics, G. Nazri, R.A. Huggins, D.F. Shriver, 1989, ISBN: 1-55899-008-9

Volume 136—Fly Ash and Coal Conversion By-Products: Characterization, Utilization, and Disposal V, R.T. Hemmings, E.E. Berry, G.J. McCarthy, F.P. Glasser, 1989, ISBN: 1-55899-009-7

Volume 137—Pore Structure and Permeability of Cementitious Materials, L.R. Roberts, J.P. Skalny, 1989, ISBN: 1-55899-010-0

Volume 138—Characterization of the Structure and Chemistry of Defects in Materials, B.C. Larson, M. Ruhle, D.N. Seidman, 1989, ISBN: 1-55899-011-9

Volume 139—High Resolution Microscopy of Materials, W. Krakow, F.A. Ponce, D.J. Smith, 1989, ISBN: 1-55899-012-7

Volume 140—New Materials Approaches to Tribology: Theory and Applications, L.E. Pope, L. Fehrenbacher, W.O. Winer, 1989, ISBN: 1-55899-013-5

Volume 141—Atomic Scale Calculations in Materials Science, J. Tersoff, D. Vanderbilt, V. Vitek, 1989, ISBN: 1-55899-014-3

Volume 142—Nondestructive Monitoring of Materials Properties, J. Holbrook, J. Bussiere, 1989, ISBN: 1-55899-015-1

Volume 143—Synchrotron Radiation in Materials Research, R. Clarke, J.H. Weaver, J. Gland, 1989, ISBN: 1-55899-016-X

Volume 144—Advances in Materials, Processing and Devices in III-V Compound Semiconductors, D.K. Sadana, L. Eastman, R. Dupuis, 1989, ISBN: 1-55899-017-8

MATERIALS RESEARCH SOCIETY CONFERENCE PROCEEDINGS

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

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

Ternary and Multinary Compounds, S. Deb, A. Zunger, 1987; ISBN 0-931837-57-x

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

Atomic and Molecular Processing of Electronic and Ceramic Materials: Preparation, Characterization and Properties, Ilhan A. Aksay, Gary L. McVay, Thomas G. Stoebe, 1988; ISBN 0-931837-85-5

Materials Futures: Strategies and Opportunities, R. Byron Pipes, U.S. Organizing Committee, Rune Lagneborg, Swedish Organizing Committee, 1988; ISBN 0-55899-000-3

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