

# **Tungsten and Other Refractory Metals for VLSI Applications III**

---

**EDITOR**

**Victor A. Wells**

---





TN47-53

8963498

T926

1987

V. 3

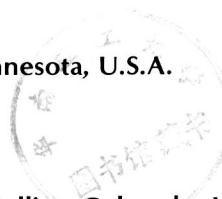
## **Tungsten and Other Refractory Metals for VLSI Applications III**

**Proceedings of the 1987 Workshop held October 7-9, 1987,  
IBM Thomas J. Watson Research Center, Yorktown Heights, New  
York, U.S.A.**

**EDITOR:**

**Victor A. Wells**

Unisys Corporation, St. Paul, Minnesota, U.S.A.



**ASSOCIATE EDITORS:**

**Carol M. McConica**

Colorado State University, Fort Collins, Colorado, U.S.A.

**Eliot K. Broadbent**

Philips Research Laboratories, Sunnyvale, California, U.S.A.

**Michael D. Strathman**

Charles Evans and Associates, Redwood City, California, U.S.A.

**Kie Y. Ahn**

IBM Corporation, Yorktown Heights, New York, U.S.A.

**Robert S. Blewer**

Sandia National Laboratories, Albuquerque, New Mexico, U.S.A.

**Russell C. Ellwanger**

Philips Research Laboratories, Eindhoven, The Netherlands

**Peter Hey**

AT&T Bell Laboratories, Allentown, Pennsylvania, U.S.A.



E8963498



**MATERIALS RESEARCH SOCIETY**  
**Pittsburgh, Pennsylvania**

**Copyright 1988 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  
9800 McKnight Road, Suite 327  
Pittsburgh, Pennsylvania 15237  
telephone (412) 367-3003**

**Library of Congress Cataloging in Publication Data**

**Printed in the United States of America**

Manufactured by Publishers Choice Book Mfg. Co.  
Mars, Pennsylvania 16046

# **Tungsten and Other Refractory Metals for VLSI Applications III**

## Preface

The ongoing evolution in the microelectronics industry is placing increasingly greater demands on the materials used in the interconnect technology. There is a need to provide greater reliability without impacting the electrical performance. At the same time the manufacturing methods must be capable of meeting the industrial needs of thruput, cost, yield, etc. if the process is to become accepted.

At this workshop, it is apparent that refractory materials have a place in the fabrication of VLSI circuits. First extensive investigations are being conducted to understand the materials and their interaction with silicon. Secondly, the process dynamics and methods are becoming better understood. Finally, the work on reliability and device structures show the advantages which these materials offer.

This volume is in the Materials Research Society series which was created to document the proceedings of this workshop. It contains fifty three papers which were presented at the Fourth Workshop on Tungsten and Other Refractory Metals for VLSI Applications. This workshop was held October 7-9, 1987 in Yorktown Heights, New York.

Future workshops on tungsten and other refractory metals will continue to be held in the fall of each year. Information on the date and location of upcoming workshops can be obtained from Ms. Linda Reid, University Extension, University of California, Berkley, (415) 642-4151, who is in charge of workshop administration.

Victor A. Wells  
1987 Symposium Chairman

December 1987

## Acknowledgments

### Executive Committee

Victor A. Wells, Chairman, Unisys Corporation  
Robert S. Blewer, Sandia National Laboratories  
Eliot K. Broadbent, Philips Research Laboratories (Sunnyvale)  
Martin L. Green, AT&T Bell Laboratories  
Carol M. McConica, Colorado State University  
Takahiko Moriya, Toshiba R&D Center  
\*Michael D. Strathman, Charles Evans & Associates  
\*Thomas E. Wade, University of South Florida

Executive Secretaries: Linda Reid and Karen Anderson  
University of California, Berkeley

### Local Arrangements

Kie Y. Ahn, IBM T.J. Watson Research Center

### 1987 Session Chairmen

Carol McConica, Colorado State University  
Victor A. Wells, Unisys Corporation  
Robert S. Blewer, Sandia National Laboratories  
Biejan Davari, IBM T.J. Watson Research Center  
Eliot Broadbent, Philips Research Laboratories (Sunnyvale)  
Peter Hey, AT&T Bell Laboratories  
Kie Y. Ahn, IBM T.J. Watson Research Center

\*Ex officio

---

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
- 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
- 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. Pearson, 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. Gottsch, 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

---

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

---

- 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
- 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 Overlays 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
- 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— $\text{SiO}_2$  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. Giannarini, 1988,  
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

---

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

## Contents

PREFACE	xi
ACKNOWLEDGMENTS	xiii
MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS	xv
<b>Keynote Presentation:</b>	
TUNGSTEN AND TUNGSTEN SILICIDES: A VIEW FROM MANUFACTURING Billy L. Crowder	3
RECENT DEVELOPMENTS IN CVD EQUIPMENT AND PROCESSES	
*CVD REACTOR DESIGN G.B. Raupp	15
DEPOSITION CHARACTERISTICS OF TUNGSTEN FILMS IN A COLD-WALL SINGLE-WAFER LPCVD SYSTEM K.Y. Ahn, T. Lin, J. Angilello, R.F. Foster, and S. Tseng	25
CHARACTERISTICS OF SELECTIVE LPCVD W FILMS IN A COLD WALL SYSTEM R.V. Joshi, D.A. Smith, S. Basavaiah, and T. Lin	39
STEP COVERAGE IN COLDWALL-DEPOSITED BLANKET CVD TUNGSTEN R. Blumenthal and G.C. Smith	47
CHARACTERIZATION OF PROCESS PARAMETERS FOR BLANKET TUNGSTEN CONTACT FILL J.E.J. Schmitz, R.C. Ellwanger, and A.J.M. van Dijk	55
MORE OBSERVATIONS ON SELECTIVITY LOSS DURING TUNGSTEN CVD J.R. Creighton and J.W. Rogers, Jr.	63
HIGH RATE LOW-TEMPERATURE SELECTIVE TUNGSTEN R.F. Foster, S. Tseng, L. Lane, and K.Y. Ahn	69
CVD TUNGSTEN: FUNDAMENTAL REACTION AND GROWTH STUDIES	
A STUDY ON THE REACTION OF WF <sub>6</sub> WITH Si (100) SURFACES M.L. Yu, B.N. Eldridge, and R.V. Joshi	75

\*Invited Paper

THE NATURE AND SIGNIFICANCE OF THE SELF-LIMITING EFFECT IN THE LOW PRESSURE CHEMICAL VAPOR DEPOSITION OF TUNGSTEN N. Lifshitz	83
CHEMICAL VAPOR DEPOSITION OF TUNGSTEN ON SILICON STUDIED WITH SOFT X-RAY PHOTOEMISSION J.A. Yarmoff and F.R. McFeely	87
METASTABLE $\beta$ -TUNGSTEN IN LPCVD CONTACTS TO SILICON D.C. Paine, J.C. Bravman, and C.Y. Yang	95
A NEW APPROACH TO THE SUPPRESSION OF TUNNELING Y. Kusumoto, K. Takakuwa, H. Hashinokuchi, T. Ikuta, and I. Nakayama	103
SOME RECENT OBSERVATIONS ON TUNNEL DEFECT FORMATION DURING HIGH TEMPERATURE POST-DEPOSITION ANNEAL OF CVD W ON Si E.K. Broadbent, D.K. Sadana, A.E. Morgan, J.M. Flanner, and R.C. Ellwanger	111
CONDITIONS FOR TUNNEL FORMATION IN LPCVD TUNGSTEN FILMS ON SINGLE CRYSTAL SILICON R.S. Blewer, T.J. Headley, and M.E. Tracy	115
SELECTIVE TUNGSTEN: SELECTIVITY LOSS AND $WF_6$ -Si INTERACTION	
MODELING SELECTIVITY LOSS DURING CVD TUNGSTEN DEPOSITION C.M. McConica, J.K. Hunter, K. Tan, and M.D. Szczepaniak	125
THE EFFECTS OF IMPURITIES AND BYPRODUCTS ON SELECTIVE W DEPOSITION I. Hirase, T. Sumiya, M. Schack, S. Ukishima, D. Rufin, M. Shishikura, M. Matsuura, and A. Ito	133
A QUANTITATIVE ANALYSIS OF THE EFFECTS OF REACTION BY-PRODUCTS ON SELECTIVITY DURING THE SELECTIVE DEPOSITION OF TUNGSTEN L.F.Tz. Kwakman, W.J.C. Vermeulen, E.H.A. Granneman, and M.L. Hitchman	141
CVD TUNGSTEN SOURCE GAS ANALYSIS AND INVESTIGATION	
GAS PHASE ANALYSIS OF $WF_6$ W.D. Reents, Jr., M.L. Green, and Y.S. Ali	151
MASS SPECTROMETRIC STUDIES ON SELECTIVE TUNGSTEN DEPOSITION - MECHANISM AND RELIABILITY R. Foster, L. Lane, and S. Tseng	159
THE EFFECT OF CHROMYL FLUORIDE ( $CrO_2F_2$ ) ON SELECTIVE TUNGSTEN DEPOSITION PROCESSES K.A. Aitchison, E.K. Broadbent, and R.A. Hogle	171

MICROSTRUCTURAL COMPARISON  
OF REFRactory METALS

- MICROSTRUCTURE OF DEPOSITED REFRACtORY METALS 183  
R.V. Joshi, A. Segmüller, K.K. Shih, D.A. Smith,  
and A.R. Taranko

CVD TUNGSTEN IN DEVICE STRUCTURES

- HIGH DENSITY, HIGH RELIABILITY TUNGSTEN INTERCONNECTION  
BY FILLED INTERCONNECT GROOVE (FIG) METALLIZATION 191  
E.K. Broadbent, J.M. Flanner, W.G.M. van den Hoek,  
and I-W.H. Connick

- SELECTIVE TUNGSTEN PLUG FOR CMOS DOUBLE AND TRIPLE LAYER  
METAL TECHNOLOGY 201  
Y.C. Chow, K.Y. Liao, and M.R. Chin

- THICK SELECTIVE CVD TUNGSTEN PLUGS IN A SALICIDED TWO  
LEVEL METAL CMOS TECHNOLOGY 209  
H.P.W. Hey and V.V.S. Rana

DEVICE CONTACT FILLING BY CVD TUNGSTEN

- CHARACTERISTICS OF AS-DEPOSITED AND SINTERED Mo/LPCVD W  
CONTACTS TO As, B, AND P DOPED SILICON 219  
K. Shenai, S. Al-Marayati, J.W. Kretchmer, and  
B.J. Baliga

- SHALLOW SILICIDED DIODES WITH LPCVD TUNGSTEN PLUG 225  
N. Lifshitz, J.M. Andrews, and R.V. Knoell

- ELECTROMIGRATION RELIABILITY STUDIES OF INTERMETAL  
CONTACTS HAVING CVD TUNGSTEN VIA PLUGS 231  
R.N. Hall, D.M. Brown, R.H. Wilson, and D.W. Skelly

- SELECTIVE LPCVD TaSi<sub>2</sub> FOR SOURCE & DRAIN METALLIZATION  
AND CONTACT HOLE FILLING 239  
T.P.H.F. Wendling and C. Mazure

- THICK SELECTIVE ELECTROLESS PLATED COBALT ALLOY CONTACTS  
TO SHALLOW JUNCTIONS BELOW CoSi<sub>2</sub> 249  
G.E. Georgiou, H.S. Luftman, F.A. Baiocchi,  
T.T. Sheng, and M.J. Vasile

- STEP COVERAGE PREDICTION DURING BLANKET CVD TUNGSTEN  
DEPOSITION 257  
C.M. McConica and S. Churchill

POSTER SESSION

- FORMATION OF PtSi IN THE PRESENCE OF Al: EFFECT OF  
W BARRIER LAYER 265  
C.-A. Chang

EVALUATION OF CVD TUNGSTEN FILMS FOR DIFFUSION BARRIER APPLICATIONS G.M. Gutierrez, R.S. Blewer, and M.E. Tracy	271
THERMAL STABILITY OF W/Si AND Al/W/Si STRUCTURES Y. Pauleau, F.C. Dassapa, Ph. Lami, J.C. Oberlin, and F. Romagna	275
TUNGSTEN-NITROGEN LAYERS DEPOSITED BY REACTIVE SPUTTERING AS DIFFUSION BARRIERS BETWEEN ALUMINUM AND SILICON O. Thomas, S.E. Hörnström, T. Lin, P. Fryer, and J.M.E. Harper	281
CRYSTALLIZATION OF AMORPHOUS TUNGSTEN-RHENIUM AND TUNGSTEN-NITROGEN THIN FILMS T. Lin, O. Thomas, S.E. Hörnström, P.M. Fryer, and J.M.E. Harper	287
ELECTRICAL CHARACTERIZATION AND ELECTROMIGRATION PERFORMANCES OF AlSi/TiN/Ti METALLIZATION SCHEME L. Bacci, C. Caprile, N. Circelli, G. Dalla Libera, and G. De Santi	293
INVESTIGATION OF SILICON LATTICE DAMAGE AND ITS INFLUENCE ON THE ELECTRICAL PROPERTIES OF CONTACTS AFTER SELECTIVE TUNGSTEN DEPOSITION S. Tseng, L. Lane, R. Foster, S. Felch, P. Geraghty, and W.L. Smith	299
HIGHLY SELECTIVE, HIGH RATE TUNGSTEN DEPOSITION USING "HOT PLATE" WAFER HEATING R.H. Wilson and R.W. Stoll	311
PROPERTIES OF MOLYBDENUM FILMS PREPARED BY HIGH-RATE MAGNETRON SPUTTERING FROM HIGH-PURITY TARGET K.Y. Ahn, J.M.E. Harper, P.M. Fryer, B. Davari, L. Krusin-Elbaum, and J. Karasinski	317
PHYSICOCHEMICAL PROPERTIES IN TUNGSTEN FILMS DEPOSITED BY RF MAGNETRON SPUTTERING P. Collot, M.C. Hugon, B. Agius, and M. Froment	327
HIGH TEMPERATURE STABILITY OF TiSi <sub>2</sub> /n <sup>+</sup> -POLYSILICON/SiO <sub>2</sub> /Si MOS STRUCTURES FORMED BY CONVENTIONAL THERMAL AND RAPID THERMAL ANNEALING K. Shenai, P.A. Piacente, G.A. Smith, N. Lewis, M.D. McConnell, and B.J. Baliga	333
ELECTRICAL CHARACTERISTICS OF PtSi SCHOTTKY DIODES FORMED BY CONVENTIONAL FURNACE AND RAPID THERMAL PROCESSING A. Kermani, J. Wang, and T.D. DeBolske	339
INVESTIGATIONS ON SELECTIVELY CVD W AND Si SYSTEM F. Hong, Y.F. Wang, H.S. Chen, B.Z. Li, and J.T. Wang	347