

A Publication of the Materials Research Society

Volume XX, Number 11 ISSN: 0883-7694 CODEN: MRSBEA

**METALLIZATION FOR INTEGRATED CIRCUIT MANUFACTURING****33 Metallization for Integrated Circuit Manufacturing**

R.V. Joshi, R.S. Blewer, and S. Murarka, Guest Editors

**38 Chemical Vapor Deposition of TiN for Sub-0.5  $\mu\text{m}$  ULSI Circuits**

M. Eizenberg

**42 Collimated Sputtering of Titanium and Titanium Nitride Films**

J.G. Ryan, S.B. Brodsky, T. Katata, M. Honda, N. Shoda, and H. Aochi

**46 Chemical-Vapor-Deposited Tungsten for Vertical Wiring**

T. Ohba

**53 Aluminum Reflow Sputtering**

K. Kikuta

**57 Aluminum-Based Metallurgy for Global Interconnects**

D. Pramanik

**61 Chemical-Mechanical Planarization of Aluminum-Based Alloys for Multilevel Metallization**

M.A. Fury, D.L. Scherber, and M.A. Stell

**65 Simulation of Microstructure and Surface Profiles of Thin Films for VLSI Metallization**

T. Smy, S.K. Dew, and M.J. Brett

**70 Mechanical Stress in VLSI Interconnections: Origins, Effects, Measurement, and Modeling**

P.A. Flinn

**74 New Rapid Failure Analysis Techniques for Multilevel Metallization**

E.I. Cole, Jr. and R.E. Anderson

**78 The Reliability of Aluminum/Tungsten Technology for VLSI Applications**

Y. Shacham-Diamand

**MRS NEWS****89 Walker, Chair of the House Committee on Science, to Give Plenary Talk****90 Mullins Receives Von Hippel Award****91 De Fontaine Selected for Turnbull Lectureship****91 Materials Research Society Election Results for 1996****92 Capasso, Tromp Receive 1995 MRS Medals****94 Graduate Student Award Finalists—1995 MRS Fall Meeting****98 New Symposium Tutorial Program Debuts at the 1995 MRS Fall Meeting****100 Subcommittee Reports on Special Projects****JMR ABSTRACTS****106 Abstracts for January 1996 *Journal of Materials Research*****DEPARTMENTS****5 Material Matters****8 Letters to the Editor****11 Research/Researchers****21 Washington News****22 Public Affairs Forum****29 Resources****56 Advertisers in This Issue****101 Historical Note****113 Calendar****116 Classified****120 Postterminaries**

**ON THE COVER:** (Top left) High aspect contact with collimated TiN/Ti liner. Taken from *Applied Physics Letters*. (Top right) Al-Cu reflow for via filling applications. (Bottom left) Cross section of multilevel Al-Cu metallization. (Bottom right) Failure analysis of an integrated circuit chip. Courtesy of Sandia National Laboratories. (Center) Top view of an Al(Cu) metallized state-of-the-art dynamic random access memory chip, courtesy of IBM. Photograph by Tom Way. For more information, see section that begins on page 33.

## About the Materials Research Society

The Materials Research Society (MRS), a non-profit scientific association founded in 1973, promotes interdisciplinary goal-oriented basic research on materials of technological importance. Membership in the Society includes over 12,000 scientists, engineers, and research managers from industrial, government, and university research laboratories in the United States and nearly 50 countries.

The Society's interdisciplinary approach differs from that of single-discipline professional societies because it promotes information exchange across the many technical fields touching materials development. MRS sponsors two major international annual meetings encompassing approximately 60 topical symposia, and also sponsors numerous single-topic scientific meetings. The Society recognizes professional and technical excellence, conducts short courses, and fosters technical interaction in local geographic regions through Sections and University Chapters.

MRS participates in the international arena of materials research through the International Union of Materials Research Societies (IUMRS). MRS is a member of the Federation of Materials Societies and is an affiliate of the American Institute of Physics.

MRS publishes symposium proceedings, *MRS Bulletin*, *Journal of Materials Research*, and other publications related to current research activities.

*MRS Bulletin* (ISSN: 0883-7694) is published 12 times a year by the Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237. Application to mail at second class rates has been approved at Pittsburgh, PA and at additional mailing offices. POSTMASTER: Send address changes to *MRS Bulletin* in care of the Materials Research Society, at the address listed; phone (412) 367-3003; fax (412) 367-4373. Printed in the U.S.A.

Additional copies of articles in the *MRS Bulletin* may be made at \$2.50 per article. This fee can be paid to the Materials Research Society through the Copyright Clearance Center, Inc., 27 Congress Street, Salem, MA 01970.

Membership in MRS is \$75 annually for regular members, \$25 for students. Dues include an allocation of \$29 (\$17 for students) to a subscription to *MRS Bulletin*. Individual member subscriptions are for personal use only. Non-member subscription rates are \$120 for one calendar year (12 issues) within the U.S.A. and \$175 elsewhere. Single copies may be purchased for \$16 each. Send subscription orders to Subscription Department, Materials Research Society, 9800 McKnight Road, Pittsburgh, PA 15237.

*MRS Bulletin* is included in *Current Contents/Engineering, Computing, and Technology*; *Current Contents/Physical, Chemical, and Earth Sciences*; the *SciSearch* online database, *Research Alert*, and the *Materials Science Citation Index*. Back volumes of *MRS Bulletin* are available in 16mm microfilm, 35mm microfilm, or 105mm microfiche through University Microfilms Inc., 300 North Zeeb Road, Ann Arbor, Michigan 48106.

**Materials Research Society**  
9800 McKnight Road  
Pittsburgh, PA 15237-6006

Tel. (412) 367-3003; Fax (412) 367-4373

# MRS BULLETIN

Editorial Office • 9800 McKnight Road • Pittsburgh, PA 15237-6006  
Tel. (412) 367-3003; fax (412) 367-4373

### Editor

E.L. Fleischer

### Managing Editor

J. Meiksin

### Assistant Editor

L.R. Gallagher

### Copy Editor

L.A. Krysinski

### Art Director

C. Love

### Design/Production

T. Aiello and S. Franklin

### Editorial Assistants

M.M. Costello and J. Dininny

### Advertising

M.E. Kaufold

### Circulation

S.E. Krasa

### Guest Editors

R.V. Joshi, R.S. Blewer, and S. Murarka

### Special Contributors

I. Amato, B. Appleton, S.R. Beckerman, R.J. Nemanich, E. Pennisi, S.L. Simonds, and B. Stadler

### Special Consultant

M. Goodway

### Associate Editor—Europe

I.W. Boyd  
University College London  
Dept. of Electronic and  
Electrical Engineering  
Torrington Place  
London WC1E 7JE, U.K.  
Tel. 44-171-380-7300 or 7302

### Book Review Editor

C.J. McHargue  
University of Tennessee  
Knoxville, Tennessee

### MRS Office of Public Affairs

555 13th Street NW, Suite 900 East  
Washington, DC 20004  
Tel. (202) 383-8809, Fax (202) 383-8877

## CHAIR—EDITORIAL BOARDS

E.N. Kaufmann • Argonne National Laboratory • Argonne, Illinois, USA

## INTERNATIONAL ADVISORY BOARD

M. Balkanski  
University of Pierre and Marie Curie  
Paris, France

R.G. Elliman  
Australian National University  
Canberra, Australia

S. Hsu  
Chung Shan Institute of Science  
and Technology, Retired  
Taiwan, China

L.C. Ianniello  
U.S. Department of Energy, Retired  
Washington, DC, USA

H-D. Li  
National Science Foundation-China  
Beijing, China

P. Rama Rao  
Ministry of Science and Technology  
New Delhi, India

R. Roy  
The Pennsylvania State University  
University Park, Pennsylvania, USA

T. Sugano  
Toyo University  
Tokyo, Japan

D.L. Weaire  
University of Dublin  
Dublin, Ireland

## TECHNICAL EDITORIAL BOARD

J.C. Bravman  
Stanford University  
Stanford, California, USA

C.W. Draper  
AT&T Engineering Research Center  
Princeton, New Jersey, USA

E. Fogarassy  
Centre de Recherches Nucléaires  
Strasbourg, France

F.Y. Fradin  
Argonne National Laboratory  
Argonne, Illinois, USA

B.M. León  
Universidad de Vigo  
Vigo, Spain

G.L. Liedl  
Purdue University  
West Lafayette, Indiana, USA

S. Namba  
Nagasaki Institute of Applied Science  
Tokyo, Japan

A.D. Romig Jr.  
Sandia National Laboratories  
Albuquerque, New Mexico, USA

J. Soares  
Universidade de Lisboa  
Lisboa, Portugal

K.C. Taylor  
General Motors R&D Center  
Warren, Michigan, USA

## MRS BULLETIN PUBLICATIONS SUBCOMMITTEE

M. Nastasi, Chair  
Los Alamos National Laboratory  
Los Alamos, New Mexico

R.C. Ewing  
University of New Mexico  
Albuquerque, New Mexico

R.L. Fleischer  
Rensselaer Polytechnic Institute  
Troy, New York

A.J. Hurd  
Sandia National Laboratories  
Albuquerque, New Mexico

M. Libera  
Stevens Institute of Technology  
Hoboken, New Jersey

F. Shapiro  
Drexel University  
Philadelphia, Pennsylvania

C.W. White  
Oak Ridge National Laboratory  
Oak Ridge, Tennessee

## 1995 MRS EXECUTIVE COMMITTEE

### President

J.M. Phillips  
Sandia National Laboratories

### First Vice President and President-Elect

C.V. Thompson  
Massachusetts Institute of Technology

### Second Vice President

R. Hull  
University of Virginia

### Secretary

C.C. Koch  
North Carolina State University

### Treasurer

A.K. Hays  
Sandia National Laboratories

### Immediate Past President

J.C. Bravman  
Stanford University

### Executive Director

Materials Research Society  
John B. Ballance

## INTERNATIONAL UNION OF MATERIALS RESEARCH SOCIETIES

### President

M. Doyama  
Nishi-Tokyo University  
Tokyo, Japan

### Vice President

R.C. Ewing  
University of New Mexico  
Albuquerque, New Mexico  
USA

### Secretary

G-C. Chi  
National Central University  
Chung-Li, Taiwan

### Treasurer

L-C. Lee  
ITRI  
Taiwan

### Immediate Past President

P. Siffert  
Centre de Recherches Nucléaires  
Strasbourg, France

### General Secretary

R.P.H. Chang  
Northwestern University  
Evanston, Illinois  
USA

### IUMRS ADHERING BODIES

Australian Materials Research Society (A-MRS)  
J.S. Williams, Australian National University

Chinese Materials Research Society (C-MRS)  
H-D. Li, National Science Foundation—China

European Materials Research Society (E-MRS)  
P.A. Glasow, Siemens AG

Materials Research Society (MRS)  
J.M. Phillips, Sandia National Laboratories

Materials Research Society of India (MRS-I)  
P. Rama Rao, Technology Bhavan

Materials Research Society of Japan (MRS-J)  
T. Takagi, Ion Engineering Research Institute Corp.

Materials Research Society of Korea (MRS-Korea)  
J-T. Song, Hanyang University

Materials Research Society of Russia (MRS-Russia)  
I.V. Gorynin, Prometey Institute

Materials Research Society of Taiwan (MRS-T)  
L.J. Chen, National Tsing Hua University

Mexican Materials Research Society (Mexican-MRS)  
L. Martinez, Instituto de Fisica-Cuernavaca, UNAM