MATERIALS RESEARCH SOCIETY

February 2011 Vol. 36 No. 2 www.mrs.org/bulletin

Contact materials for nanoelectronics

ALSO IN THIS ISSUE

Ultrafast materials science and 4D imaging with atomic resolution both in space and time

> CAMBRIDGE UNIVERSITY PRESS

PARTICLE ACCELERATOR SYSTEMS



High Voltage Engineering Europa B.V.
P.O. Box 99, 3800 AB Amersfoort, The Netherlands
Tel: 31 33 4619741 • info@highvolteng.com
www.highvolteng.com



The Materials Theory Award recognizes exceptional advances made by materials theory to the fundamental understanding of the structure and behavior of materials. The Award is intended to honor both those who have pioneered the development of a new theoretical approach and those who have used existing approaches to provide significant new

The Materials Research Society proudly introduces the

THE AWARD

insight into materials behavior.

The annual Award consists of a \$5000 cash prize, a presentation trophy and a certificate of recognition. Meeting registration fee and transportation and hotel expenses to attend the MRS Fall Meeting at which the award is presented will be reimbursed.

NOMINATE A COLLEAGUE TODAY FOR THIS PRESTIGOUS NEW AWARD

- · Nominations are open to scientists and engineers who have made exceptional advances in some aspect of materials theory including computational materials science and simulations.
- · Nominees need not be members of the Materials Research Society.
- · Current members of the Materials Theory Award Subcommittee and MRS Board members are not eligible.
- · The Award is presented at the MRS Fall Meeting.
- The Award will not be bestowed in absentia except in extraordinary circumstances.

DEADLINE FOR NOMINATIONS—April 1, 2011

For more information on the Materials Theory Award, including administration and nomination requirements, visit www.mrs.org/mta.

MRS acknowledges the generosity of Professors Gwo-Ching Wang and Toh-Ming Lu for endowing this award.

For additional information on any of the MRS Awards noted above. visit www.mrs.org/awards.





MRSBulletin February 2011 Volume 36 Number 2 ISSN: 0883-7694 CODEN: MRSBEA

CONTENTS

CONTACT MATERIALS FOR NANOELECTRONICS



- 90 Contact materials for nanoelectronics
 H.N. Alshareef, M.A. Quevedo-Lopez, and P. Majhi,
 Guest Editors
- 95 Meet Our Authors



97 Junction contact materials and interfaces in Si channel devices Wei-Yip Loh and Brian Coss



101 Gate contact materials in Si channel devices
Huang-Chun Wen and J.J. Chambers



106 Contact materials for nanowire devices and nanoelectromechanical switches

Muhammad Mustafa Hussain and Jinhui Song



112 Novel contact structures for high mobility channel materials

Jenny Hu, H.-S. Philip Wong, and Krishna Saraswat

TECHNICAL FEATURE



121 Ultrafast materials science and 4D imaging with atomic resolution both in space and time

Alexander Ziegler

DEPARTMENTS



NEWS & ANALYSIS

85 Research/Researchers

- Hyper-reflective cholesteric liquid crystal fabricated using surface-initiated photopolymerization
 Steven Trohalaki
- High-yield, low-cost approach developed to functionalize MWCNT surface
 Kaushik Chatterjee
- High-fidelity transfer of intricate photonic devices via nanomembranes demonstrated
 Soma Chattopadhyay
- Nanoscale study helps explain materials' ability to convert waste heat to electricity

88 Science Policy

- U.S. Congress renews America COMPETES Act
- EU Metrology Program addresses diverse fields
- Joint R&D clean energy center established by India and U.S.



ON THE COVER

Contact materials for nanoelectronics. This issue of MRS Bulletin reviews current

development of contact materials for electronic and nanoelectronic devices. On the cover is a top-down view of transistors and associated electrical contacts to the transistor gate electrodes and junction silicides. The transistor channel length is nearly 90 nm. Transistor scaling to the nanoscale and adoption of new contact and channel materials has created many challenges and opportunities for materials scientists. Image courtesy of Texas Instruments, Inc. See the technical theme that begins on p. 90.



www.mrs.org/bulletin



133 SOCIETY NEWS

- Preview: 2011 Materials Research Society **Spring Meeting & Exhibit**
- In Memoriam: Rustum Roy Ron Roy and Della Roy
- MRS to launch new letters/prospective journal: MRS Communications
- MRS invites nominations for the Von Hippel Award, Turnbull Lectureship, MRS Medal, and Materials **Theory Award**





144 Image Gallery Look Again

DVERTISERS IN THIS ISSUE	Page No
American Elements	Outside back cover
Bruker	Inside back cover
High Voltage Engineering	Inside front cover
Janis Research Company, Inc	105
Lake Shore Cryotronics	111
MMR Technologies, Inc	131
National Electrostatics Corp	94
SVC TechCon 2011	119

www.mrs.org/bulletin

MRS members—access MRS Bulletin online

www.materialsforenergy.org

Join the conversation in the Materials for Energy blog

www.mrs.org/alerts

MRS Publications Alertreceive advance Table of Contents by e-mail

http://journals.cambridge.org/data/rss/ feed_MRS_rss_2.0.xml

Subscribe TODAY to the MRS Bulletin RSS Feed





EDITORIAL OFFICE 506 Keystone Drive, Warrendale, PA 15086-7573 USA Bulletin@mrs.org tel 724.779.2747 fax 724.779.8313 www.mrs.org

About the Materials Research Society

The Materials Research Society (MRS), a not-for-profit scientific association founded in 1973, promotes interdisciplinary goal-oriented basic research on materials of technological importance. Membership in the Society includes almost 16,000 scientists, engineers, and research managers from industrial, government, and university research laboratories in the United States and close to 70 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 70 topical symposia, and also sponsors numerous single-topic scientific meetings. The Society recognizes professional and technical excellence 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 ASTRA 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.

2011 MRS BOARD OF DIRECTORS

President James J. De Yoreo, Lawrence Berkeley National Laboratory, USA Immediate Past President David S. Ginley, National Renewable Energy Laboratory, USA

Vice President and President-Elect Bruce M. Clemens, Stanford University, USA

Secretary Sean J. Hearne, Sandia National Laboratories, USA

Treasurer Michael R. Fitzsimmons, Los Alamos National Laboratory, USA Executive Director Todd M. Osman, Materials Research Society, USA

Wade Adams, Rice University, USA Ana Claudia Arias, Palo Alto Research Center, USA Tia Benson Tolle, Air Force Research Laboratory, USA Flemming Besenbacher, Aarhus University, Denmark Eberhard Bodenschatz, Max Planck Institute for Dynamics

and Self Organization, Germany

Duane B. Dimos, Sandia National Laboratories, USA J. Murray Gibson, Argonne National Laboratory, USA Oliver Kraft, Karlsruhe Institute of Technology, Germany

Hideki Matsumura, Japan Advanced Institute of Science and Technology, Japan Chris Orme, Lawrence Livermore National Laboratory, USA Michael F. Rubner, Massachusetts Institute of Technology, USA

Takao Someya, The University of Tokyo, Japan Susan E. Trolier-McKinstry, The Pennsylvania State University, USA Pierre Wiltzius, University of California, Santa Barbara, USA

MRS OPERATING COMMITTEE CHAIRS

Academic Affairs Kalpana Katti. North Dakota State University, USA Awards Julia R. Weertman, Northwestern University, USA Awards Julia N. Weertman, Northwestern University, USA
Government Affairs Alan J. Hurd, Los Alamos National Laboratory
International Relations Julia W. P. Hsu, The University of Texas, Dallas, USA
Membership Shashi G. Jasty, Sigma-Aldrich, USA
Public Outreach Greta Zenner Petersen, University of Wisconsin, USA Publications Paul McIntyre, Stanford University, USA Technical Program Michael J. Aziz, Harvard University, USA

MRS OFFICE OF PUBLIC AFFAIRS

Ron Kelley 499 South Capitol St. SW, Suite 600, Washington, DC 20003

Editor

Elizabeth L. Fleischer, fleischer@mrs.org

Managing Editor

Judy Meiksin, meiksin@mrs.org

Technical Editor

Lori A. Wilson, lwilson@mrs.org

Editorial Assistant

Ben Moriarty, moriarty@mrs.org

Associate Technical Editor Tim Palucka

Art Director

Kasia M. Bruniany

Production/Design

Franklin Design, Andrea Pekelnicky, Christopher R. Roberts, and TNQ

Production Editor Catherine Paduani

Director of Publications and Marketing

Gail A. Oare

Guest Editors

H.N. Alshareef, M.A. Quevedo-Lopez, and P. Majhi

Special Consultants

Lhadi Merhari and Gopal R. Rao

Beyond the Lab

Carol Trager-Cowan (Chair), Y.-T. Cheng, Eric Marshall, Amit Misra, and U. Ramamurty

Book Review Board Linda J. Olafsen (Chair)

Energy Quarterly V.S. Arunachalam (Chair), Anshu Bharadwaj, David Cahen, Russell R. Chianelli, George Crabtree, Robin W. Grimes, Abdelilah Slaoui, Guillermo Solórzano, and Steve M. Yalisove

Advertising/Sponsorship

Mary E. Kaufold, kaufold@mrs.org Donna L. Watterson, watterson@mrs.org

Member Subscriptions

Michelle Judt, judt@mrs.org

Non-Member Subscriptions

subscriptions_newyork@cambridge.org

EDITORIAL BOARD

Paul S. Drzaic (Chair), Drzaic Consulting Services, USA

V.S. Arunachalam, Center for Study of Science, Technology & Policy, India

Marie-Isabelle Baraton, University of Limoges, France Robert C. Cammarata, Johns Hopkins University, USA

Laura Fornaro, University of Uruguay, Uruguay
Hanns-Ulrich Habermeier, Max Planck Institute for Solid State Research, Germany

Fiona C. Meldrum, University of Leeds, UK

Amit Misra, Los Alamos National Laboratory, USA

Julie A. Nucci, Cornell University, USA

Linda J. Olafsen, Baylor University, USA

David N. Seidman, Northwestern University, USA Carol Trager-Cowan, University of Strathclyde, UK Julia R. Weertman, Northwestern University, USA

Eric Werwa, Washington, DC, USA

Steve M. Yalisove, University of Michigan, USA

VOLUME ORGANIZERS

2012 Lei Jiang, Chinese Academy of Sciences, China Sergei V. Kalinin, Oak Ridge National Laboratory, USA Stéphanie P. Lacour, EPFL, Switzerland Steven C. Moss, Aerospace Corporation, USA

2011 Kyoung-Shin Choi, Purdue University, USA Reuben T. Collins, Colorado School of Mines, USA Sean E. Shaheen, University of Denver, USA Kathryn Uhrich, Rutgers, the State University of New Jersey, USA

T. John Balk, University of Kentucky, USA David Cahen, Weizmann Institute of Science, Israel Fiona C. Meldrum, University of Leeds, UK Stephen K. Streiffer, Argonne National Laboratory, USA

MRS Bulletin (ISSN: 0883-7694, print: ISSN 1938-1425, online) is published 12 times a year by the Materials Research Society, 506 Keystone Drive, Warrendale, PA 15086-7573, Copyright © 2011, Materials Research Society. Permission required to reproduce content. Periodical periodic paid at New York, NY, and at additional mailing offices. POSTMASTER: Send address changes to MRS Bulletin in care of the Journals Department, Cambridge University Press, 100 Brook Hill Drive, West Nyack, NY 10994-2113, USA. Printed in the U.S.A.

Membership in MRS is \$115 annually for regular members, \$30 for students. Dues include an allocation of \$29 (\$17 for students) to a subscription to MRS Bulletin. Indi-

vidual member subscriptions are for personal use only. Non-member subscription rates are \$330 for one calendar year (12 issues) within North America and \$396 elsewhere. Requests from subscripters for missing journal issues will be honored without charge only if received within six months of the issue's actual date of publication.

MRS Bulletin is included in Current Contents®/Engineering, Computing, and Technology; Current Contents®/Physical, Chemical, and Earth Sciences, the SciSearch® online database, Research Alert®, Science Citation Index®, and the Materials Science Citation Index®. Back volumes of MRS Bulletin are available on microfiche through University Microfilms Inc., 300 North Zeeb Road, Ann Arbor, MI 48106, USA

Send Letters to the Editor to Bulletin@mrs.org. Include your name, affiliation, and full contact information.