

August 2011 Vol. 36 No. 8
www.mrs.org/bulletin

MRS Bulletin



MATERIALS RESEARCH SOCIETY
Advancing materials. Improving the quality of life.

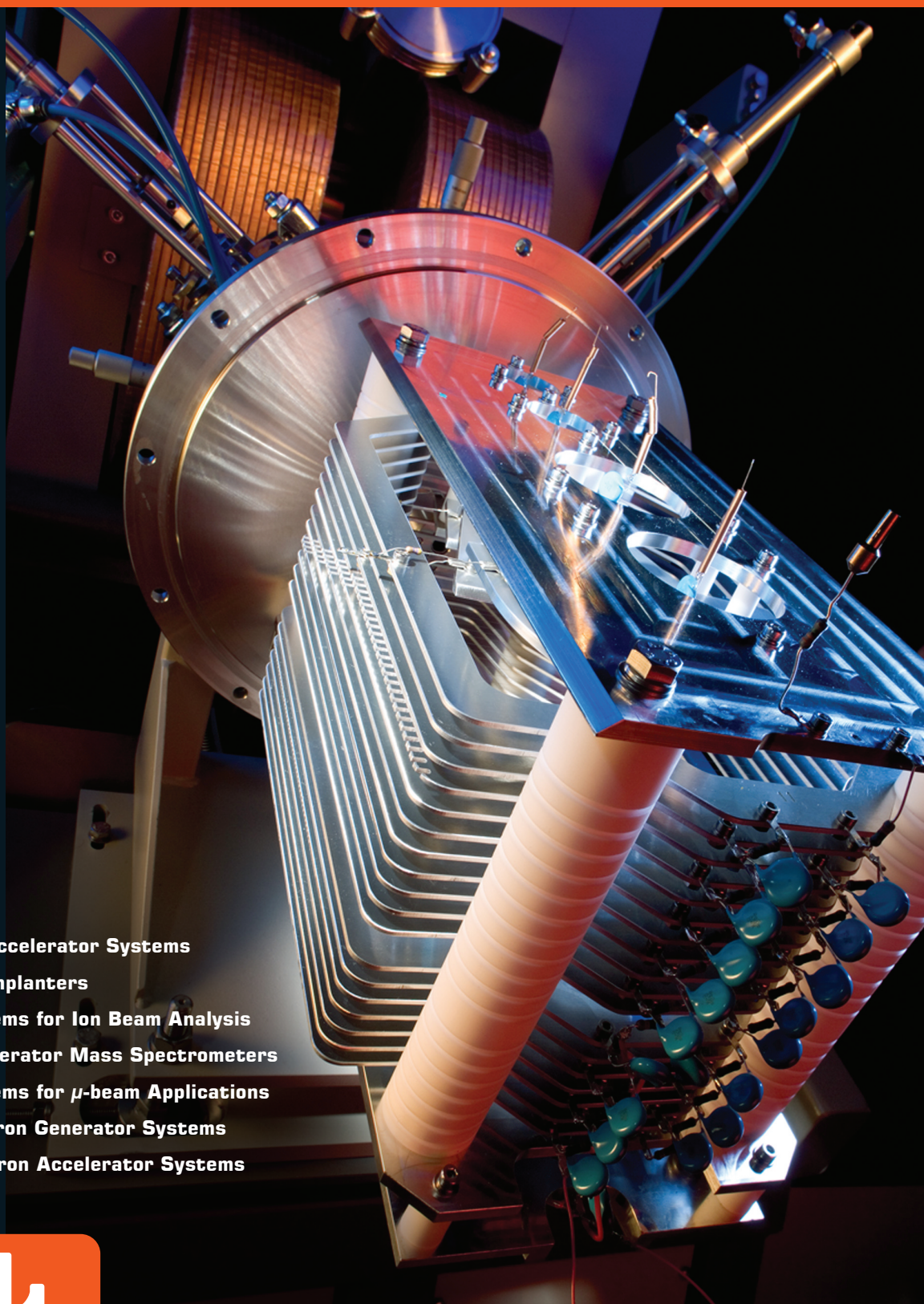
Superconductivity at 100— Where we've been and where we're going

ALSO IN THIS ISSUE

Epitaxial graphene:
A new electronic material
for the 21st century

CAMBRIDGE
UNIVERSITY PRESS

PARTICLE ACCELERATOR SYSTEMS



- Ion Accelerator Systems
- Ion Implanters
- Systems for Ion Beam Analysis
- Accelerator Mass Spectrometers
- Systems for μ -beam Applications
- Neutron Generator Systems
- Electron Accelerator Systems



High Voltage Engineering

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 first truly **global** foundry



In January 2010, the semiconductor foundry landscape changed forever with the launch of the new **GLOBALFOUNDRIES**. This new entrant to the market combined the **leading-edge** integrated device manufacturing heritage of Advanced Micro Devices (AMD) **with the pure-play semiconductor foundry** heritage of Chartered Semiconductor to create a company with an impressive capacity and technology footprint and a **world-class** customer base.

Headquartered in Silicon Valley, our leading edge technology company has well over 10,000 employees with an extensive 200mm and 300mm silicon wafer manufacturing campus in **Singapore**. This is complemented by a leading-edge 300mm manufacturing campus in **Dresden, Germany** and a third campus under construction in **Saratoga County, New York**, that once complete should be the most advanced in the world. These global operations provide a unique opportunity for us to attract and leverage the best engineering and technical talent from around the world to support **long-term growth and expansion** opportunities.



GLOBALFOUNDRIES

www.globalfoundries.com

CONTENTS

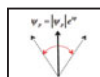
SUPERCONDUCTIVITY AT 100—WHERE WE'VE BEEN AND WHERE WE'RE GOING



- 590 **Superconductivity at 100—Where we've been and where we're going**

David Larbalestier and Paul C. Canfield, Guest Editors

- 594 **Meet Our Authors**



- 597 **Will higher T_c superconductors be useful? Fundamental issues from the real world**

M.R. Beasley



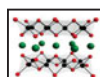
- 601 **Electric power grid application requirements for superconductors**

A.P. Malozemoff



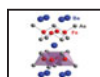
- 608 **MgB₂, a two-gap superconductor for practical applications**

Marina Putti and Giovanni Grasso



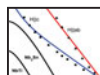
- 614 **Chemistry and electronic structure of iron-based superconductors**

Athena S. Sefat and David J. Singh



- 620 **Tuning the ground state of BaFe₂As₂: Phase diagrams and empirical trends**

Ni Ni and Sergey L. Bud'ko



- 626 **High-field properties of pure and doped MgB₂ and Fe-based superconductors**

C. Tarantini and A. Gurevich

TECHNICAL FEATURE



- 632 **Epitaxial graphene: A new electronic material for the 21st century**

2010 MRS Medalist Presentation

Walt A. de Heer

DEPARTMENTS



NEWS & ANALYSIS

573 Research/Researchers

- **Simulation of hyperdimensional waveguide models demonstrates new approach in metamaterial design**
Steven Trohalaki
- **Freeze-dried nanoparticles treat brain cancer**
- **Change in material boosts prospects of ultrafast single-photon detector**
- **Magnetofluidics used for tuning optical fibers**
Tobias Lockwood
- **Lithiation highway in Si nanopillars contributes to anisotropic shape changes**
Alia P. Schoen
- **Micro drum chilled to quantum ground state**
- **Electron clouds distortion on graphene surface harm conductivity**
- **Atomically smooth polycrystalline silicon waveguides fabricated**
Benjamin Scheiner
- **In Memoriam: Robert L. Fleischer**

581 Technology Advances

- **Sputtering technique forms versatile quasicrystalline coatings**
- **Process improves reliability of thin film igniters in safety devices**
- **Functionalized nanoporous particles allow single-step purification of DNA reactions**

ON THE COVER

Superconductivity at 100—Where we've been and where we're going. This issue of *MRS Bulletin* covers the applications and science of superconductivity through its history and its advances. The cover shows Heike Kamerlingh Onnes (right) and Gerrit Flim (left), head of the Cryogenics Department, Leiden University, in a contemporary photograph in Onnes's laboratory at the time of the discovery of superconductivity in or about 1911. The bottom overlay shows a strong magnet being levitated above a YBCO pellet cooled in liquid nitrogen, an easily visible manifestation of the strong critical current density in YBCO.

High critical current density wires were one of the earliest of Onnes's dreams for making high-field magnets. See the technical theme that begins on p. 590.



584 **Science Policy**

- **Materials vital to NSF and DOE strategic plans**
Kendra Redmond
- **NIST selects first Chief Manufacturing Officer**
- **Japan seeks to expedite commercialization of printed electronics**



640 **SOCIETY NEWS**

- **Proposed revised Bylaws and Articles of Incorporation**
- **Materials for energy and sustainability drive 2011 Materials Research Society Spring Meeting**
- ***MRS Communications* publishes inaugural article**
- **IUMRS seeks nominees for 2012 Sōmiya Award**



658 **CAREER CENTRAL**



FEATURES

586 **Beyond the Lab**

Science Museum in London features plastics
Susan Mossman

664 **Image Gallery**

Look Again

ADVERTISERS IN THIS ISSUE

Page No.

American Elements	Outside back cover
FEI Company	589, 596
GlobalFoundries	569
High Voltage Engineering	Inside front cover
Janis Research Company, Inc.	595
Lake Shore Cryotronics, Inc.	639
Kurt J. Lesker Company	577
MMR Technologies, Inc.	613
Solartron Analytical (AMETEK)	Inside back cover
SuperPower, Inc.	625
Thermo Scientific	575



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/mymrs

MRS Publications Alert—
receive advance Table of Contents by e-mail

<http://journals.cambridge.org/mrsbulletin-rss>

Subscribe TODAY to the *MRS Bulletin* RSS Feed

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

Government Affairs Alan J. Hurd, Los Alamos National Laboratory, USA

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

Gopal R. Rao, rao@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

Don Monroe

Art Director

Kasia M. Bruniany

Production/Design

Andrea Pekelnicky and TNQ

Production Editor

Catherine Paduani

Science News Editor

Tim Palucka

Principal Development Editor

Elizabeth L. Fleischer

Director of Publications and Marketing

Eileen Kiley Novak

Guest Editors

David Larbalestier and Paul C. Canfield

Special Contributors

Barton Bennett, Bob Braughler, Larry Fehrenbacher, Jeffrey Helfer, Alan J. Hurd, Reeja Jayan, and Laura Lutz

Special Consultants

Babu Chalamala, Renée G. Ford, and Alan Sellinger

Energy Quarterly

Steve M. Yalisove (Chair), V.S. Arunachalam, Anshu Bharadwaj, David Cahen, Russell R. Chianelli, George Crabtree, Robin W. Grimes, Abdelilah Slaoui, Guillermo Solórzano, and M. Stanley Whittingham; Katherine B. Sutton (Project Manager)

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), Apple, Inc., 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 Habermeyer, 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

2010 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 postage 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*. Individual 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 subscribers 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.