

MRS Bulletin



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

October 2020 Vol. 45 No. 10
mrs.org/bulletin

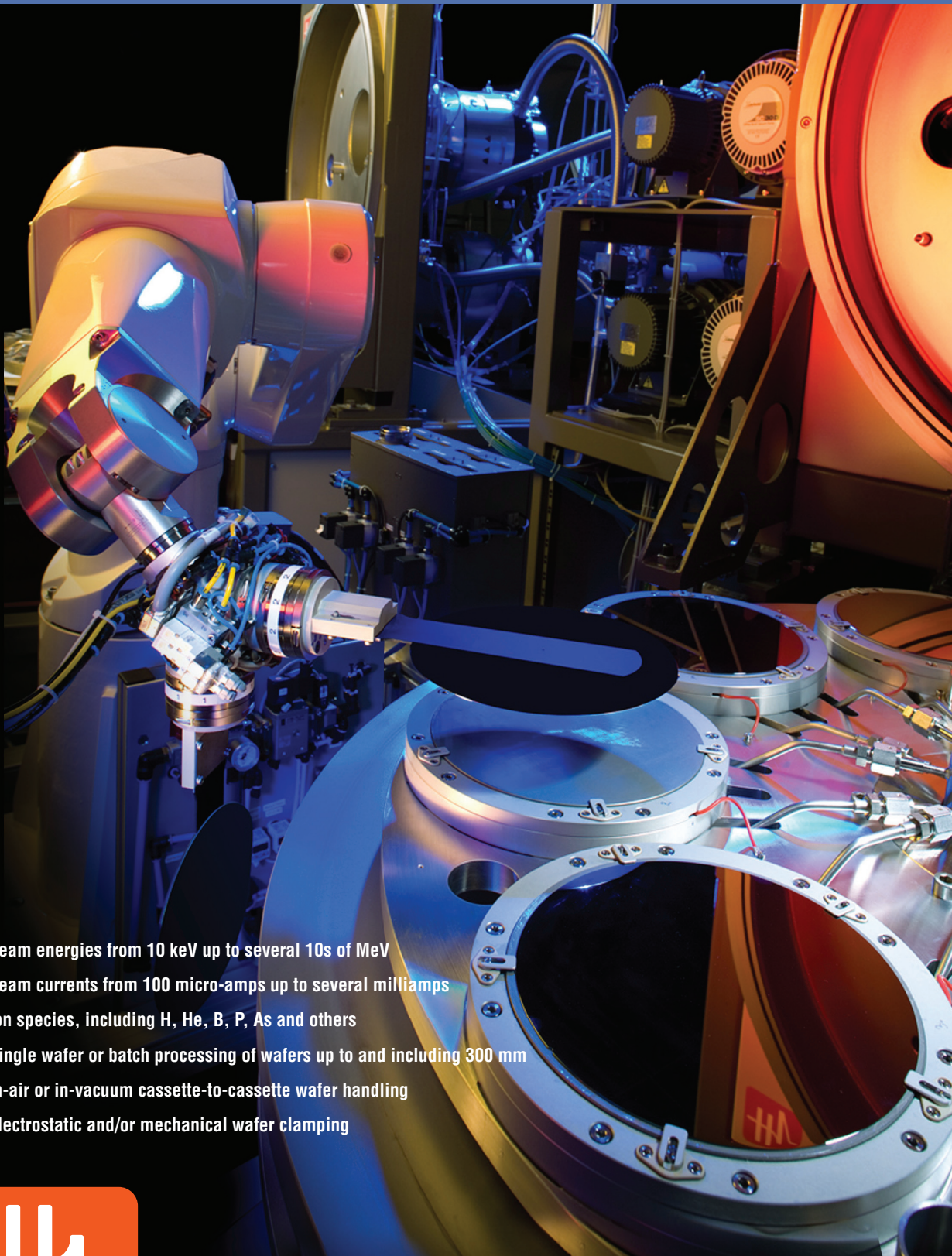
Functional materials and devices by self-assembly

ALSO IN THIS ISSUE

Double-transition-metal MXenes:
Atomistic design of 2D carbides
and nitrides

CAMBRIDGE
UNIVERSITY PRESS

CUSTOMIZED PRODUCTION ION IMPLANTERS



- Beam energies from 10 keV up to several 10s of MeV
- Beam currents from 100 micro-amps up to several milliamps
- Ion species, including H, He, B, P, As and others
- Single wafer or batch processing of wafers up to and including 300 mm
- In-air or in-vacuum cassette-to-cassette wafer handling
- Electrostatic and/or mechanical wafer clamping



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

Introducing:

EIKOS-UV™



The Workhorse Atom Probe for Research & Industry

CAMECA announces EIKOS-UV™, the new Atom Probe microscope that brings APT to the next generation of scientists, metallurgists, physicists, geologists, and engineers.

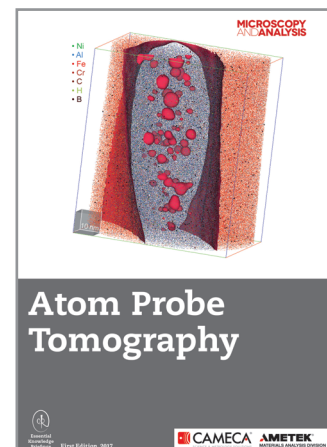
EIKOS-UV™ - optimized for efficiency and simplicity - delivers all the benefits of **Atom Probe Tomography**: three-dimensional nanoscale characterization of materials with the best combination of high spatial resolution and detection sensitivity in an easy to use, affordable instrument.

A new atom probe for academic and commercial environments addressing a wide range of applications: Metals • Coatings • Thin Films • Ceramics • Minerals • Functional Materials

CAMECA's range of APT instrumentation, including the LEAP® 5000, EIKOS™, and EIKOS-UV™, are driving research and production breakthroughs around the world. Learn how Atom Probe instruments can place your organization's research or processes at the forefront of your field. Contact CAMECA today.

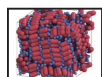
Download our free APT introductory guide at:
<https://www.cameca.com/focus/apt-tuto>

Full product information and contacts at: www.cameca.com

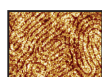


CONTENTS

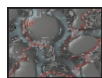
FUNCTIONAL MATERIALS AND DEVICES BY SELF-ASSEMBLY



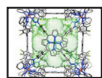
- 799 **Functional materials and devices by self-assembly**
Dmitri V. Talapin,* Michael Engel, and Paul V. Braun,*
Guest Editors*



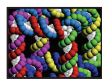
- 807 **Self-assembly for electronics**
Cherie R. Kagan, Taeghwan Hyeon, Dae-Hyeong Kim,
Ricardo Ruiz, Maryann C. Tung, and H.-S. Philip Wong



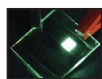
- 815 **Self-assembled materials for electrochemical energy storage**
Hao Chen, Peter Benedek, Khande-Jaé Fisher,
Vanessa Wood, and Yi Cui



- 823 **Separation using self-assembled materials**
Fan Chen, Gregory S. Day, and Hong-Cai Zhou

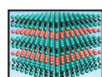


- 832 **Self-assembly of bioinspired and biologically functional materials**
E. Thomas Pashuck, Ned Seeman,
and Robert Macfarlane



- 841 **Superradiant emission from self-assembled light emitters: From molecules to quantum dots**
G. Rainò, H. Utzat, M.G. Bawendi, and M.V. Kovalenko

TECHNICAL FEATURE



- 850 **Double transition-metal MXenes: Atomistic design of two-dimensional carbides and nitrides**

Weichen Hong, Brian C. Wyatt,
Srinivasa Kartik Nemani, and Babak Anasori



ON THE COVER

Functional materials and devices by self-assembly. Self-assembly allows for the development of new paradigms for chemistry and materials science, where various, typically nanometer-sized, objects with precisely engineered sizes, shapes, compositions, and concomitant properties serve as “meta-atoms” or superatomic building blocks for hierarchically assembled materials and devices. The current state of the field reveals that self-assembly is making significant strides toward applications in nanoelectronics, photonics, energy storage, chemical separations, and as a path to form complex structures. The cover shows single-

crystal nanoparticle superlattices assembled via DNA hybridization. The cover image relates to US Department of Navy Award No. N00014-19-1-2213 issued by the Office of Naval Research. The United States Government has a royalty-free license throughout the world to the image. See the technical theme that begins on p. 799.



COMING IN NOVEMBER 2020

Processing metallic materials far from equilibrium

DEPARTMENTS



OPINION

- 789 **Letter to the Editor**
Elton Kaufmann



NEWS & ANALYSIS

790 **Materials News**

- **Research Highlights: Perovskites**
Pabitra K. Nayak
- **Nanoindentation on peeled high-performance polymeric fibers reveals failure mechanisms**
Hortense Le Ferrand
- **Electrochemical energy-storage material architecture built brick-by-brick**
Boris Dyatkin

794 **Science Policy**

- **COVID-19 pandemic highlights need for US policies that increase supply chain resilience**
Boris Dyatkin
- **EC announces actions to increase security and sustainability of Europe's raw materials supply**



SOCIETY NEWS

- 797 **MRS Journal Highlights**
- 863 **MRS authors recently elected to the US National Academy of Engineering**
- 864 **MRS Communications Abstracts**



FEATURES

867 **Book Reviews**

- **Graphene: Preparations, Properties, Applications, and Prospects**
Kazuyuki Takai, Seiya Tsujimura, Feiyu Kang, and Michio Inagaki
Reviewed by K.S.V. Santhanam
- **Nanostructured Materials**
T. Daniel Thangadurai, N. Manjubaashini, Sabu Thomas, and Hanna J. Maria
Reviewed by Mariana Amorim Fraga
- **Nanoparticles Induce Oxidative and Endoplasmic Reticulum Stresses: Antioxidant Therapeutic Defenses**
Loutfy H. Madkour
Reviewed by Aurelia Meghea

872 **Image Gallery**
Look Again



CAREER CENTRAL

- 870 **Career Feature**
Creating meaningful slide presentations
Duanduan Han

871 **Classified**

ADVERTISERS IN THIS ISSUE

Page No.

American Elements	Outside back cover
Cameca	785
Electron Microscopy Sciences	849
High Voltage Engineering	Inside front cover

connect

mrs.org/bulletin

mrs.org/energy-quarterly

mrs.org/mymrs

journals.cambridge.org

mrs.org/bulletin-podcast

[@mrsbulletin](https://twitter.com/mrsbulletin)

About the Materials Research Society

The Materials Research Society (MRS), a not-for-profit scientific association founded in 1973 and headquartered in Warrendale, Pennsylvania, USA, promotes interdisciplinary materials research. Today, MRS is a growing, vibrant, member-driven organization of more than 14,000 materials researchers spanning over 80 countries, from academia, industry, and government, and a recognized leader in the advancement of interdisciplinary materials research.

The Society's interdisciplinary approach differs from that of single-discipline professional societies because it promotes information exchange across many scientific and technical fields touching materials development. MRS conducts three major international annual meetings and also sponsors numerous single-topic scientific meetings. The Society recognizes professional and technical excellence and fosters technical interaction through University Chapters. In the international arena, MRS implements bilateral projects with partner organizations to benefit the worldwide materials community. The Materials Research Society Foundation helps the Society advance its mission by supporting various projects and initiatives.

2020 MRS BOARD OF DIRECTORS

President Matt Copel, IBM T.J. Watson Research Center, USA
Immediate Past President Michael R. Fitzsimmons, Oak Ridge National Laboratory and The University of Tennessee, USA
Vice President (President-Elect) Cherie R. Kagan, University of Pennsylvania, USA
Secretary Dawnielle Farrar-Gaines, Johns Hopkins University, USA
Treasurer Shenda Baker, Synedgen Inc., USA
Executive Director Todd M. Osman, Materials Research Society, USA

Griselda Bonilla, IBM T.J. Watson Research Center, USA
Leonard J. Brillson, The Ohio State University, USA
Kristen H. Brosnan, GE Global Research, USA
Coray M. Colina, University of Florida, USA
Catherine Dubourdieu, Helmholtz-Zentrum Berlin/Free Universität Berlin, Germany
Sarah Heilshorn, Stanford University, USA
Frances A. Houle, Lawrence Berkeley National Laboratory, USA
Mônica Jung de Andrade, The University of Texas at Dallas, USA
Sergei V. Kalinin, Oak Ridge National Laboratory, USA
Kisuk Kang, Seoul National University, Republic of Korea
Paul C. McIntyre, Stanford University, USA
Linda S. Schadler, The University of Vermont, USA
Christopher A. Schuh, Massachusetts Institute of Technology, USA
Rachel A. Segalman, University of California, Santa Barbara, USA
Ting Xu, University of California, Berkeley, USA
Yusheng Zhao, Southern University of Science and Technology, China
Ehrenfried Zschech, Fraunhofer Institute for Ceramic Technologies and Systems, Germany

MRS OPERATING COMMITTEE CHAIRS

Academic Affairs Sanjay Mathur, University of Cologne, Germany
Awards (Co-chairs) Suveen N. Mathaudu, University of California, Riverside, USA
Judith L. Driscoll, University of Cambridge, UK
Government Affairs David P. Norton, University of Florida, USA
Meetings Lincoln J. Lauthon, Northwestern University, USA
Public Outreach Elizabeth Kupp, The Pennsylvania State University, USA
Publications Shefford P. Baker, Cornell University, USA

MRS HEADQUARTERS

Todd M. Osman, Executive Director
J. Ardie Dillen, Director of Finance and Administration
Damon Dozier, Director of Government Affairs
Michele L. Feder, Associate Director of Engagement
Patricia Hastings, Director of Meetings Activities
Eileen M. Kiley, Director of Communications

Chief Editor for Technical Content

Gopal R. Rao, rao@mrs.org

Impact Editor

Markus J. Buehler

Theme Editor

Neville R. Moody

Managing Editor

Lori A. Wilson, lwilson@mrs.org

News Editor

Judy Meiksin, meiksin@mrs.org

Technical Editor

Lisa C. Oldham, oldham@mrs.org

Editorial Assistants

Suzanne Hite, hite@mrs.org,
Mary Wilmoth

Director of Communications

Eileen M. Kiley

Guest Editors

Dmitri V. Talapin and Paul V. Braun

Special Consultants

Ken Haenen and Enrico Traversa

Production/Design

Stephanie Gaborin, Heather Shick,
Felicia Turano, and Tech-Set Ltd

Production Editor

Rachel Altizio

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

Amit Misra (Chair), University of Michigan, USA
Ilke Arslan, Argonne National Laboratory, USA
N. (Balu) Balasubramanian, Bangalore, India (retired)
Christopher J. Bettinger, Carnegie Mellon University, USA
Tommie Kelley, 3M, USA
Igor Lubomirsky, Weizmann Institute, Israel
Fiona C. Meldrum, University of Leeds, UK
Steven C. Moss, The Aerospace Corporation, USA (retired)
Linda J. Olafsen, Baylor University, USA
Boaz Pokroy, Technion-Israel Institute of Technology, Israel
Zhiwei Shan, Xi'an Jiaotong University and Hysitron, China
Subhash L. Shinde, University of Notre Dame, USA
Eric Werwa, Washington, DC, USA
M. Stanley Whittingham, Binghamton University, The State University of New York, USA

IMPACT EDITORIAL BOARD

Katia Bertoldi, Harvard University, USA
Huiling Duan, Peking University, China
Peter Fratzl, Max Planck Institute of Colloids and Interfaces, Germany
Pupa Gilbert, University of Wisconsin-Madison/Berkeley National Laboratory, USA
Ali Khademhosseini, University of California, Los Angeles, USA
John A. Rogers, Northwestern University, USA
Francesco Stellacci, École Polytechnique Fédérale de Lausanne, Switzerland
Kathryn E. Urich, University of California, Riverside, USA

ADVISORY BOARD

V.S. Arunachalam, Center for Study of Science, Technology and Policy, India
Paul Drzaic, Apple Inc., USA
Yury Gogotsi, Drexel University, USA
Robert S. Langer, Massachusetts Institute of Technology, USA
Ke Lu, Chinese Academy of Sciences, China
Rodney S. Ruoff, Institute for Basic Science, Center for Multidimensional Carbon Materials and UNIST, South Korea
Edwin L. (Ned) Thomas, Rice University, USA
Peidong Yang, University of California, Berkeley, USA

VOLUME ORGANIZERS

2020 Hongyou Fan, Sandia National Laboratories, USA
Oleg Gang, Columbia University and Brookhaven National Laboratory, USA
Seokwoo Jeon, Korea Advanced Institute of Science and Technology, Republic of Korea
Tae-Woo Lee, Seoul National University, Republic of Korea

2021 Babu Chalamala, Sandia National Laboratories, USA
Paul Evans, University of Wisconsin-Madison, USA
Takao Someya, The University of Tokyo, Japan
Haiyan Wang, Purdue University, USA

MRS Bulletin (ISSN: 0883-7694, print; ISSN 1938-1425, online) is published monthly by the Materials Research Society, 506 Keystone Drive, Warrendale, PA 15086-7573. © 2020 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 \$135 annually for regular members, \$35 for students, and includes an electronic subscription to *MRS Bulletin*. Print subscriptions are available to MRS members for an additional \$25. Individual member subscriptions are for personal use only. Nonmember subscription rates are \$618 (USD) for one calendar year (12 issues). 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®, Materials Science Citation Index™, and Scopus.

Authors of each technical article appearing in *MRS Bulletin* are solely responsible for all content in their article(s), including accuracy of the facts, statements, and citing resources. Facts and opinions are solely the personal statements of the respective authors and do not necessarily represent the views of the editors, the Materials Research Society, or Cambridge University Press.

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