

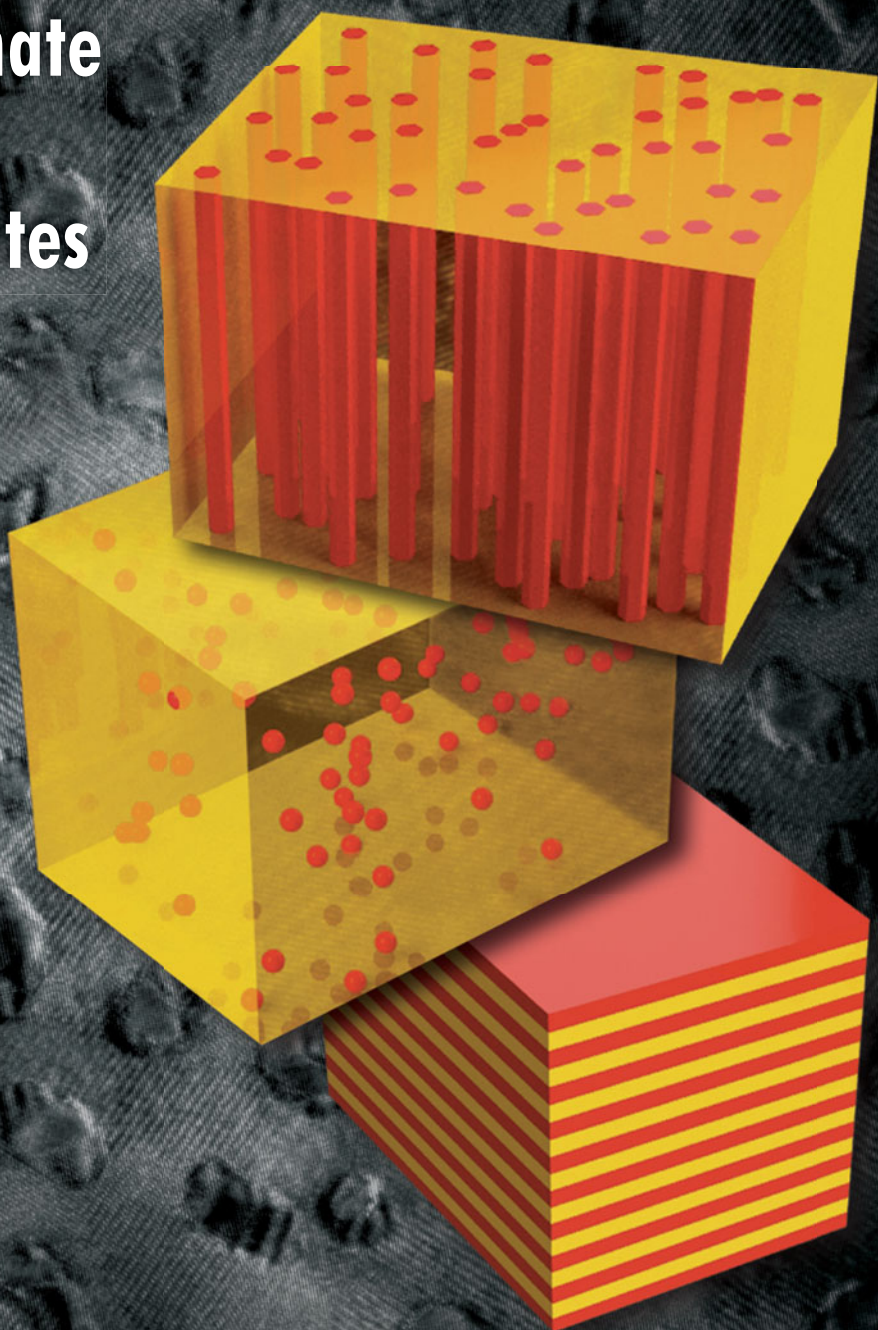
# MRS Bulletin

Celebrating  
40 YEARS

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

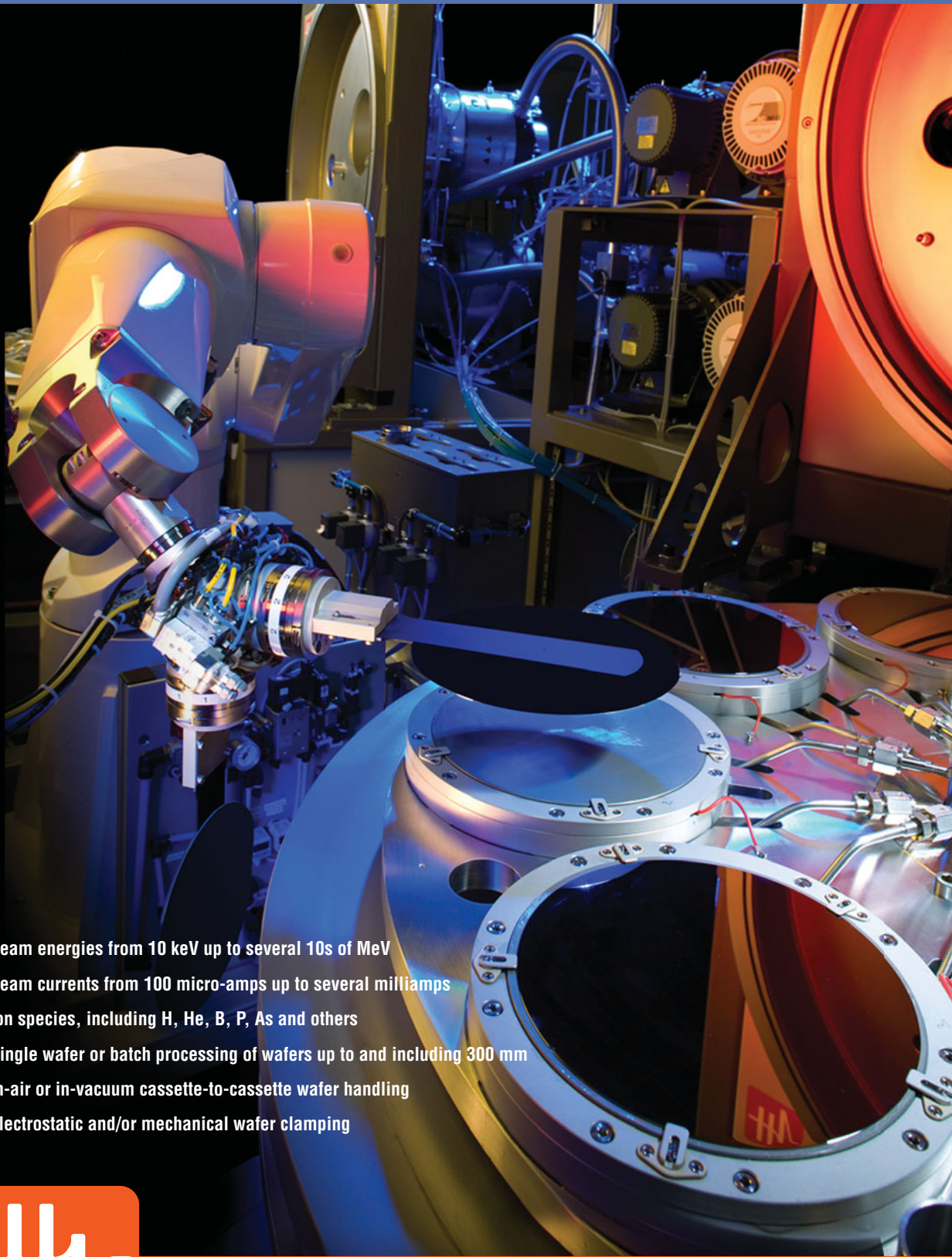
September 2015 Vol. 40 No. 9  
[www.mrs.org/bulletin](http://www.mrs.org/bulletin)

## Obtaining ultimate functionalities in nanocomposites



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](http://www.highvolteng.com)

# Advancing Materials Characterization



Lake Shore offers ▶  
precision platforms  
for materials research



## THz Material Characterization System

A non-contact measurement system that uses THz-frequency energy to measure across a wide range of frequencies, temperatures, and field strengths

**Ideal for:** semiconductor materials • complex oxide systems • thin films • superconducting metamaterials • 2D materials



## Hall Effect Measurement Systems

Robust hardware/software systems for performing DC field Hall measurements with options for AC field Hall, high or low resistances, and variable temperature

**Ideal for:** ZnO & other transparent conducting oxides • metal oxides • III-V, II-VI, & elemental semiconductors • complex oxide systems



## VSMs/AGMs

High-sensitivity electromagnet-based systems for accurately characterizing magnetic materials over a wide range of temperatures and fields to >3 T

**Ideal for:** magnetic thin films & multi-layers • magnetic nanomaterials • permanent magnets, including rare earth materials • MCE materials



## Cryogenic Probe Stations

Micro-manipulated stations for non-destructive on-wafer probing and measurement of materials in a tightly controlled environment

**Ideal for:** transition metal dichalcogenide & 2D material transistors • CNT & nanowire devices • GaN & other wide-bandgap devices • MEMs

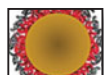


ADVANCING SCIENCE

614.891.2243 | [www.lakeshore.com](http://www.lakeshore.com)

# CONTENTS

## OBTAINING ULTIMATE FUNCTIONALITIES IN NANOCOMPOSITES



- 719 **Obtaining ultimate functionalities in nanocomposites: Design, control, and fabrication**

Ce-Wen Nan and Quanxi Jia, Guest Editors

- 725 **Meet Our Authors**



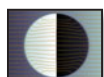
- 728 **Multiferroic magnetoelectric nanostructures for novel device applications**

Jia-Mian Hu, Tianxiang Nan, Nian X. Sun, and Long-Qing Chen



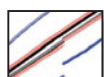
- 736 **Multifunctional, self-assembled oxide nanocomposite thin films and devices**

Wenrui Zhang, Ramamoorthy Ramesh, Judith L. MacManus-Driscoll, and Haiyan Wang



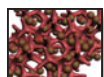
- 746 **Nanocomposites for thermoelectrics and thermal engineering**

Bolin Liao and Gang Chen



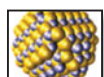
- 753 **Polymer nanocomposites with high energy storage densities**

Yang Shen, Yuanhua Lin, and Q.M. Zhang



- 760 **Greater than the sum: Synergy and emergent properties in nanoparticle-polymer composites**

Millicent A. Firestone, Steven C. Hayden, and Dale L. Huber



- 768 **When excitons and plasmons meet: Emerging function through synthesis and assembly**

Jennifer A. Hollingsworth, Han Htoon, Andrei Piryatinski, Stephan Götzinger, and Vahid Sandoghdar

## DEPARTMENTS



### NEWS & ANALYSIS

#### 710 **Materials News**

- **Scanning thermoelectric microscopy locates extra electrons outside quantum dots**  
Antonio Cruz
- **In pursuit of novel superconductors: Four years and ~1000 materials**  
Birgit Schwenzer
- **3D-printed octacalcium phosphate bone substitutes reduce defect region**  
Yung Chan
- **Stretchable carbon nanotube transistors are put to the test**  
Ian McDonald
- **Wound healing: Mind the gap, pull strings**  
Lukmaan Bawazer

#### 716 **Science Policy**

- **White House calls for nanotechnology-inspired grand challenges**  
Prachi Patel
- **Korea and China boost future nuclear technology partnership**
- **German and French national academies recommend collaborative energy policies**



### 777 SOCIETY NEWS

- **AUSTECH 2015 to be held October 12–14 in Nigeria**
- **M-STEM 2015 to be held November 1–3 in the United States**
- **SBNWM XXXIX to be held November 2–6 in France**
- **Magnetism 2016 to be held April 4–5 in the United Kingdom**
- **JEMS 2016 to be held August 22–26 in the United Kingdom**



## FEATURES

### 779 Books

- **Materials Kinetics Fundamentals: Principles, Processes, and Applications**  
Ryan O'Hayre  
Reviewed by Joshua Hertz
- **Superconductivity: Basics and Applications to Magnets**  
R.G. Sharma  
Reviewed by K. Kamala Bharathi
- **A Laboratory Course in Nanoscience and Nanotechnology**  
Gérrard Eddy Jai Poinern  
Reviewed by Sidney Cohen

### 783 Posterminaries

- Why can't we Google™ for the people we want to hire?**  
Merrilea Mayo



#### ON THE COVER

**Obtaining ultimate functionalities in nanocomposites.** Composites represent a class of materials that combine two or more constituents into a form suitable for technological applications. This issue of *MRS Bulletin* focuses on nanoscale composites, with an emphasis on approaches to the design and control of the functionalities of nanocomposite materials. On the cover in the background is a plan-

view transmission electron microscope image of a vertically aligned nanocomposite  $\text{LaFeO}_3:\text{CoFe}_2\text{O}_4$  (65:35 molar ratio) film with  $\text{CoFe}_2\text{O}_4$  nanopillars embedded in a  $\text{LaFeO}_3$  matrix. The schematic drawings show the most commonly investigated architectures of nanocomposites. (Top) 1–3-type nanocomposites with pillars or nanofibers aligned in a matrix. (Middle) 0–3-type nanocomposites with nanoparticles dispersed in a matrix. (Bottom) 2–2-type nanolaminates or heterostructured thin films or superlattices. Aiping Chen took the plan-view transmission electron microscope image, and Chris Sheehan drew the schematic drawings of the composites. See the technical theme that begins on page 719.



## 781 CAREER CENTRAL

#### ADVERTISERS IN THIS ISSUE

Page No.

Aldrich Materials Science .....	Inside back cover
American Elements .....	Outside back cover
CRAIC Technologies .....	723
High Voltage Engineering .....	Inside front cover
JEOL USA, Inc. ....	709
Lake Shore Cryotronics, Inc. ....	705
Nature Publishing Group .....	715
Physics Today, AIP Publishing .....	724
Rigaku Corporation .....	735



[www.mrs.org/bulletin](http://www.mrs.org/bulletin)

[www.mrs.org/energy-quarterly](http://www.mrs.org/energy-quarterly)

[www.mrs.org/mymrs](http://www.mrs.org/mymrs)

<http://journals.cambridge.org>

[mrsbulletin-rss](http://mrsbulletin-rss)

[@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 over 16,000 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.

### 2015 MRS BOARD OF DIRECTORS

**President** Oliver Kraft, Karlsruhe Institute of Technology, USA  
**Immediate Past President** Tia Benson Tolle, The Boeing Company, USA  
**Vice President and President-Elect** Kristi S. Anseth, University of Colorado Boulder, USA  
**Secretary** Sean J. Hearne, Sandia National Laboratories, USA  
**Treasurer** Michael R. Fitzsimmons, Oak Ridge National Laboratory, USA  
**Executive Director** Todd M. Osman, Materials Research Society, USA

**Charles Black**, Brookhaven National Laboratory, USA  
**Alexandra Boltasseva**, Purdue University, USA  
**C. Jeffrey Brinker**, Sandia National Laboratories and University of New Mexico, USA  
**David Cahen**, Weizmann Institute of Science, Israel  
**Steve Eglash**, Stanford University, USA  
**Sossina M. Haile**, Northwestern University, USA  
**Andrea M. Hodge**, University of Southern California, USA  
**Hideo Hosono**, Tokyo Institute of Technology, Japan  
**Karen L. Kavanagh**, Simon Fraser University, Canada  
**Fiona C. Meldrum**, University of Leeds, UK  
**Kornelius Nielsch**, Leibniz Institute of Solid State and Materials Research, Germany  
**Christine Ortiz**, Massachusetts Institute of Technology, USA  
**David J. Parillo**, The Dow Chemical Company, USA  
**Sabrina Sartori**, University of Oslo, Norway  
**Eric A. Stach**, Brookhaven National Laboratory, USA  
**Loucas Tsakalacos**, General Electric-Global Research Center, USA  
**Anke Weidenkaff**, University of Stuttgart, Germany

### MRS OPERATING COMMITTEE CHAIRS

**Academic Affairs** Bruce Clemens, Stanford University, USA  
**Awards** Albert Polman, FOM Institute AMOLF, The Netherlands  
**Government Affairs** Nabil Bassim, US Naval Research Laboratory, USA  
**Meetings Committee** David S. Ginley, National Renewable Energy Laboratory, USA  
**Member Engagement** Yves Chabal, The University of Texas at Dallas, USA  
**Public Outreach** Aditi Risbud, Gordon and Betty Moore Foundation, USA  
**Publications** Richard A. Vaia, US Air Force Research Laboratory

### MRS HEADQUARTERS

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

**Editor**  
Gopal R. Rao, rao@mrs.org

**Managing Editor**  
Lori A. Wilson, lwilson@mrs.org

**News Editor**  
Judy Meiksin, meiksin@mrs.org

**Technical Editors**  
Lisa C. Oldham, oldham@mrs.org  
Erica Ellison

**Editorial Assistants**  
Michelle S. Raley, raley@mrs.org  
Mary Wilmoth

**Associate Technical Editor**  
Tobias Lockwood

**Production/Design**  
Andrea Pekelniczy-Frye, Felicia Turano,  
Rebecca Yokum, and TNQ

**Senior Production Editor**  
Kim Daly

**Principal Development Editor**  
Elizabeth L. Fleischer

**Director of Communications**  
Eileen M. Kiley

**Guest Editors**  
Ce-Wen Nan and Quanxi Jia

**Special Consultant**  
Angelika Veziridis

**Energy Quarterly**  
M. Stanley Whittingham (Chair),  
Anshu Bharadwaj, David Cahen,  
Russell R. Chianelli, George Crabtree,  
Sabrina Sartori, Anke Weidenkaff,  
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), Apple, Inc., USA  
**V.S. Arunachalam**, Center for Study of Science, Technology & Policy, India  
**Hanns-Ulrich Habermeier**, Max Planck Institute for Solid State Research, Germany  
**Igor Lubomirsky**, Weizmann Institute, Israel  
**Fiona C. Meldrum**, University of Leeds, UK  
**Amit Misra**, University of Michigan, USA  
**Steven C. Moss**, Aerospace Corporation, USA  
**Julie A. Nucci**, Cornell University, USA  
**Linda J. Olafsen**, Baylor University, USA  
**James W. Stasiak**, Hewlett-Packard Co., USA  
**Carol Trager-Cowan**, University of Strathclyde, UK  
**Anke Weidenkaff**, University of Stuttgart, Germany  
**Eric Werwa**, Washington, DC, USA  
**M. Stanley Whittingham**, State University of New York at Binghamton, USA  
**Steve M. Yalisove**, University of Michigan, USA

### VOLUME ORGANIZERS

**2016** Ilke Arslan, Pacific Northwest National Laboratory, USA  
Rick Barto, Lockheed Martin Advanced Technology Laboratories, USA  
Boaz Pokroy, Technion-Israel Institute of Technology, Israel  
Zhiwei Shan, Xi'an Jiaotong University, China

**2015** Ying-Hao (Eddie) Chu, National Chiao Tung University, Taiwan  
Kalpana S. Katti, North Dakota State University, USA  
Tommy W. Kelley, 3M, USA  
W. Jud Ready, Georgia Institute of Technology, USA

**2014** Deborah E. Leckband, University of Illinois at Urbana-Champaign, USA  
Yuri Suzuki, Stanford University, USA  
Enrico Traversa, King Abdullah University of Science and Technology, Saudi Arabia  
Yonhua Tzeng, National Cheng Kung University, Taiwan

*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. Copyright © 2015 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 \$125 annually for regular members, \$30 for students. Dues include an allocation of \$29 for a subscription to *MRS Bulletin*. Individual member subscriptions are for personal use only. Non-member subscription rates are \$483 for one calendar year (12 issues) within North America and \$580 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.

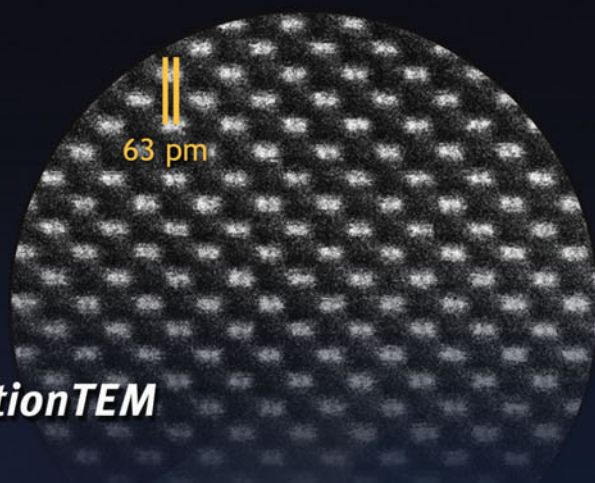
*MRS Bulletin* is included in Current Contents®/Engineering, Computing, and Technology; Current Contents®/Physical, Chemical, and Earth Sciences, the SciSearch® online database, Research Alert®, Science Citation Index®, and the Materials Science Citation Index™. Back volumes of *MRS Bulletin* are available 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.

# STELLAR RESULTS AT THE ATOMIC SCALE

## ARM-200F • ARM-300F Atomic Resolution TEM

- Highest resolution commercially-available S/TEM
- 200kV and 300kV models
- $C_s$  correctors – innovative options
- Cold FEG
- Superior SDD technology
- Ultimate stability



***Learn more at [jeolusa.com/atomicresolutionTEM](http://jeolusa.com/atomicresolutionTEM)***

*A leader never stops innovating*

[www.jeolusa.com](http://www.jeolusa.com) • [salesinfo@jeol.com](mailto:salesinfo@jeol.com)

Color image: Moon Kim, University of Texas at Dallas • 2014 Grand Prize Winner, JEOL Image Contest