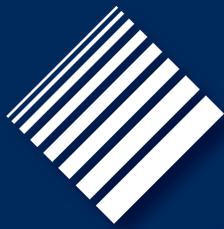


CELEBRATING
35
YEARS



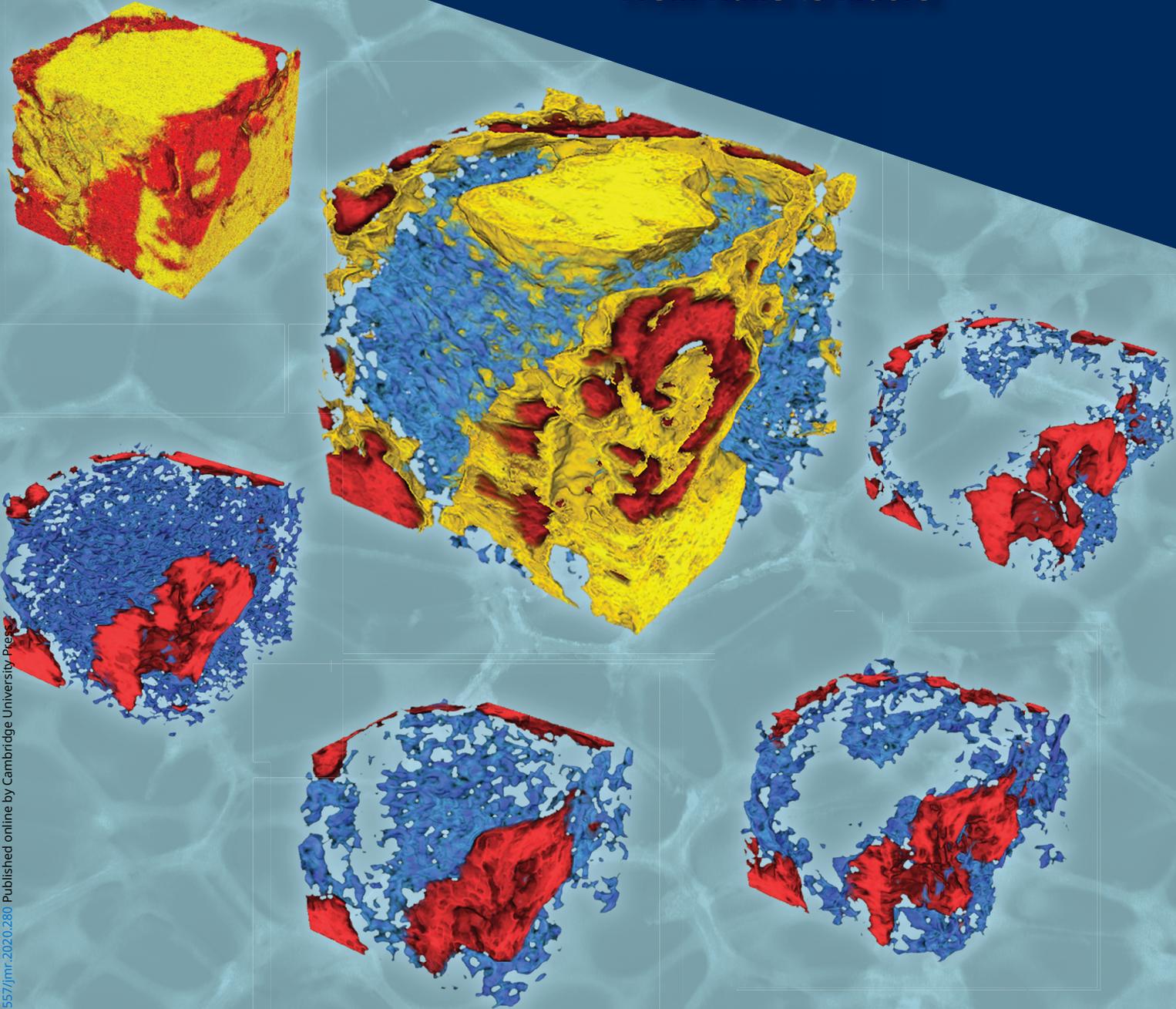
jmr

Journal of
MATERIALS RESEARCH

VOLUME 35 • NO 19
OCTOBER 14, 2020

FOCUS ISSUE

**Porous Metals:
From Nano to Macro**



Journal of MATERIALS RESEARCH

JOURNAL OF MATERIALS RESEARCH (JMR) is an interdisciplinary journal serving the materials research community through publication of original research articles and invited reviews encompassing the synthesis, processing, characterization, properties, and theoretical description of materials.

JMR publishes advances in new materials and novel functionalities and development of performance improvements relative to state of the art. Engineering studies and applications to commercial products are beyond the scope of *JMR* and should be submitted elsewhere. Manuscripts that report data without giving an analysis, interpretation, or discussion are only acceptable if the data are sufficiently important that publication is expected to lead to significant new studies or advancements in science or technology.

Manuscripts must be submitted to the *Journal of Materials Research* electronically via ScholarOne manuscripts, at the following website address: <http://mc.manuscriptcentral.com/jmr>. Electronic submission expedites the review process and also allows authors to track the status of their manuscripts at any time. Complete instructions are available on the ScholarOne site and authors will be prompted to provide all necessary information.

Manuscripts must be prepared in English, using a word processing program, formatted to fit 8½ × 11 in. paper, and saved as .doc or .pdf files. Separate graphics files (.eps and .tif) must be uploaded for each figure. Authors may also upload .xls or .ppt supplemental files as part of the manuscript submission process. All of these files will be converted to .pdf format. Detailed instructions are available on the submission web site. During submission, authors must enter all coauthor names and e-mail addresses. Manuscripts will not be considered for peer review until this information is provided. Authors must also enter manuscript keywords using the *JMR* keyword list (located on the submission web site). Authors who are not fluent in English must have their manuscript edited for correct English grammar and sentence structure before submission.

Authors are expected to follow the conventional writing, notation, and illustration style prescribed in *Scientific Style and Format: the CSE Manual for Authors, Editors and Publishers, 7th edition, 2006*. Authors should also study the form and style of printed material in this journal. SI units should be used. Authors should use an identical format for their names in all publications to facilitate use of citations and author indexes.

Manuscripts are accepted with the understanding that they represent original research, except for review articles, and that they have not been copyrighted, published, or submitted for publication elsewhere. Authors submitting manuscripts to *JMR* who have related material under consideration or in press elsewhere should send a copy of the related material to *JMR* at the time of submission. While their manuscripts are under consideration at *JMR*, authors must disclose any such related material. To expedite the review process, authors may provide names and contact information for up to four possible reviewers.

Articles are original research reports that include complete, detailed, self-contained descriptions of research efforts. All articles must contain an abstract and section headings.

Commentaries and Reviews: *Journal of Materials Research* occasionally publishes commentaries on topics of current interest or reviews of the literature in a given area. If an author proposes a review, the title, abstract, and a brief outline should be submitted to the Editorial Office via e-mail for prior consultation on the appropriateness of the topic.

Color policy: It is not necessary for authors to indicate that a figure should be displayed in color online. *JMR* will assume that any author who submits figures in color wants and agrees to their being produced in color online. Figures may be printed in color at the author's request for an additional charge. Color figures must be submitted before the paper is accepted for publication, and cannot be received later in the process. Authors cannot submit two versions of the same figure, one for color and one for black and white; only one version can be submitted. Authors need to carefully consider the following when submitting figures in color that will

be published in color online only: 1) The colors chosen must reproduce effectively and the colors should be distinguishable when printed in black and white; 2) The descriptions of figures in text and captions must be sufficiently clear for both online and print copy. When submitting figures to be in color online only, authors should include the phrase <<color online>> in the figure captions. This is the author's responsibility. Authors will see these color figures when viewing their author page proofs on screen. Authors should always print their page proofs in black and white to see how they will appear in print. Authors will NOT be allowed to submit color figures to replace black and white figures in the page proof stage. To maximize the probability that figures will be published in color online and also print as good quality black and white or grayscale graphics, authors are encouraged to follow these figure submission guidelines: 1) Submit a color graphic in Tagged Image File Format (.tif); 2) Submit color graphics with a resolution of at least 300 dpi (600 dpi if there is text or line art in the figure); 3) Submit color graphics in CMYK format; 4) Submit figures sized to fit the actual column or page width of the journal so that reduction or enlargement is not necessary; 5) Submit multipart figures in one single electronic file.

Copyright © 2020, Materials Research Society. All rights reserved. No part of this publication may be reproduced, in any form or by any means, electronic, photocopying, or otherwise, without permission in writing from Cambridge University Press. Policies, request forms and contacts are available at: <http://www.cambridge.org/rights/permissions/permission.htm>. Permission to copy (for users in the USA) is available from Copyright Clearance Center at: <http://www.copyright.com>, email: info@copyright.com.

Journal of Materials Research Subscription Prices (2020)

[includes on-line web access]

	USA and Poss.	Non-USA	Online Only
MRS Regular and Student Members	\$260.00	\$369.00	–
Institutions	\$2378.00	\$2313.00	\$2146.00

Journal of Materials Research (ISSN: 0884-2914) is published twenty-four times a year by Cambridge University Press, One Liberty Plaza, 20th Floor, New York, NY 10006 for the Materials Research Society. Periodical Postage Paid in New York, NY and additional mailing offices. **POSTMASTER:** Send address changes to *Journal of Materials Research*, c/o Journals Dept., Cambridge University Press, One Liberty Plaza, 20th Floor, New York, NY 10006, USA.

Subscriptions, renewals, address changes, and single-copy orders should be addressed to Subscription Fulfillment, *Journal of Materials Research*, Cambridge University Press, One Liberty Plaza, 20th Floor, New York, NY 10006, USA (for USA, Canada, and Mexico); or Cambridge University Press, University Printing House, Shaftesbury Road, Cambridge, CB2 8BS, England (for UK and elsewhere). Allow at least six weeks advance notice. For address changes, please send both old and new addresses and, if possible, include a mailing label from a recent issue. 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; otherwise, the issue may be purchased at the single-copy price.

Reprints of individual articles in *Journal of Materials Research* may be ordered. For information on reprints, please contact Cambridge University Press. Reprints of complete back issues older than the prior volume year may be ordered on an individual basis via Cambridge Core. To determine availability, visit the appropriate page for the *JMR* back issue desired (cambridge.org/jmr).

Individual member subscriptions are for personal use only.

Editor-in-Chief: Gary L. Messing, *Ceramic materials, The Pennsylvania State University, USA*

Associate Editor: Susmita Bose, *Biomaterials, Washington State University, USA*

Associate Editor: Mathias Göken, *Advanced metallic materials, Friedrich-Alexander-University Erlangen-Nürnberg, Germany*

Associate Editor: Sarah E. Morgan, *Polymeric materials, The University of Southern Mississippi, USA*

Guest Editors for the Focus Issue: Porous Metals: From Nano to Macro

Nihad Dukhan, *University of Detroit Mercy, USA*

Yu-Chen Karen Chen-Wiegart, *Stony Brook University, Brookhaven National Laboratory, USA*

Ashley Paz y Puente, *University of Cincinnati, USA*

Dinc Erdeniz, *Marquette University, USA*

David C. Dunand, *Northwestern University, USA*

2020 Principal Editors:

Kantesh Balani, *Biomaterials, high temperature ceramics
Indian Institute of Technology, India*

Amit Bandyopadhyay, *Hard biomaterials, Additive manufacturing,
Washington State University, USA*

Ricardo H.R. Castro, *Interfaces thermodynamics, Calorimetry, Ceramics,
University of California, Davis, USA*

Jinju Chen, *Soft materials/thin films, Nanoindentation,
Newcastle University, United Kingdom*

Xiaobo Chen, *Photocatalysis and batteries,
University of Missouri-Kansas City, USA*

Sung-Yoon Chung, *Energy, Electron microscopy, Interface science,
KAIST, Korea*

Sylvain Deville, *Ceramic materials, Processing, Bioinspired materials,
CNRS, France*

Franz Faupel, *Functional nanomaterials, VPD, Metallic glasses,
University of Kiel, Germany*

Michael C. Gao, *High entropy alloys, Computational materials science,
National Energy Technology Laboratory/AECOM, USA*

Erik G. Herbert, *Nanoindentation, Small-scale mechanical behavior
Michigan Technological University, USA*

Jon Ihlefeld, *Ferroelectrics, Thin films, Ionic conductors,
University of Virginia, USA*

Quanxi Jia, *Superconductors, Ferroelectric/magnetic materials,
Thin films
University of Buffalo, USA*

C. Robert Kao, *Metallic materials, Diffusion and joining,
National Taiwan University, Taiwan*

Edson Roberto Leite, *Materials chemistry, Nanocrystals, Synthesis,
Brazilian Nanotechnology National Laboratory, Brazil*

Lei Liu, *Semiconductors, Electronic structure, Spectroscopy,
Changchun Institute of Optics, Fine Mechanics and Physics,
China*

Michele Manuel, *Phase transformations, Materials design,
University of Florida, USA*

Michael E. McHenry, *Magnetic materials,
Carnegie Mellon University, USA*

Scott T. Misture, *In-situ diffraction, Electrochemically active ceramics,
Alfred University, USA*

Lakshmi S. Nair, *Biomaterials, Tissue regeneration, Drug delivery,
University of Connecticut, USA*

Takahito Ohmura, *Nanomechanical characterization, Lattice defects,
National Institute for Materials Science, Japan*

George M. Pharr, *Mechanical behavior, Nanoindentation,
Texas A&M University, USA*

Joshua A. Robinson, *2D material synthesis and properties,
The Pennsylvania State University, USA*

Fabrice Rossignol, *Ceramic processes, Additive manufacturing
CNRS, France*

Don W. Shaw, *Epitaxy, Vapor deposition, Semiconductors,
The University of Texas at Dallas, USA*

Ralph Spolenak, *Size effects in materials, Micro 3D printing,
ETH Zurich, Switzerland*

Ziqi Sun, *Energy nanomaterials, Wet chemical synthesis,
Queensland University of Technology, Australia*

Peng Tao, *Solar/thermal energy materials, polymer composites
Shanghai Jiao Tong University, China*

Venu G. Varanasi, *Amorphous materials, biomimetics, bioprinting
University of Texas at Arlington, USA*

Chongmin Wang, *Energy storage, Microscopy, In-situ/operando
technique,
Pacific Northwest National Laboratory, USA*

Xingcheng Xiao, *Energy storage materials, AFM, Nanoindentation,
General Motors, USA*

Sam Zhang, *Thin films/coatings,
Nanyang Technological University, Singapore*

Yanchun Zhou, *Structural ceramics, Electronic structure,
Aerospace Research Institute of Materials and Processing
Technology, China*

Editorial Office: Ellen W. Kracht, *Publications Manager, Materials Research Society, Warrendale, PA*

Leslie Truver, *JMR Editorial Assistant, Materials Research Society, Warrendale, PA*

Kirby L. Morris, *Editorial and Production Associate, Materials Research Society, Warrendale, PA*

Eileen M. Kiley, *Director of Communications, Materials Research Society, Warrendale, PA*

POROUS METALS: FROM NANO TO MACRO

2529–2534 **Introduction**

Nihad Dukhan, Yu-chen Karen Chen-Wiegart, Ashley Paz y Puente, Dinc Erdeniz, David C. Dunand

INVITED FEATURE PAPER - REVIEW

2535–2546 **Open-channel metals fabricated by the removal of template wires**

Hideo Nakajima

ARTICLES

2547–2555 **Free boundary effects and representative volume elements in 3D printed Ti–6Al–4V gyroid structures**

Anh Pham, Cambre Kelly, Ken Gall

2556–2566 **Temperature-dependent mechanical behavior of three-dimensionally ordered macroporous tungsten**

Kevin M. Schmalbach, Zhao Wang, R. Lee Penn, David Poerschke, Antonia Antoniou, Andreas Stein, Nathan A. Mara

2567–2574 **Mechanical properties and damping properties of carbon nanotube-reinforced foam aluminum with small aperture**

Mingying Chen, Bowen Liu, Zhen Ji, Chengchang Jia, Qiuchi Wu, Zhe Liu

2575–2586 **Dynamic mechanical properties of closed-cell aluminum foams with uniform and graded densities**

Ying Zhao, Chenyang Ma, Dabo Xin, Ming Sun

2587–2596 **Structure–processing relationships of freeze-cast iron foams fabricated with various solidification rates and post-casting heat treatment**

P.J. Lloreda-Jurado, S.K. Wilke, K. Scotti, A. Paúl-Escolano, D.C. Dunand, R. Sepúlveda

2597–2609 **Fabrication, mechanical property and *in vitro* bioactivity of hierarchical macro-/micro-/nano-porous titanium and titanium molybdenum alloys**

Farhad Saba, Elham Garmroudi-Nezhad, Faming Zhang, Lili Wang

2610–2619 **Influence of dealloying solution on the microstructure of nanoporous copper through chemical dealloying of Al₇₅Cu₂₅ ribbons**

Hailan Ma, Bingge Zhao, Kai Ding, Yuanheng Zhang, Guanzhi Wu, Yulai Gao

2620–2628 **Mechanism of coarsening and deformation behavior of nanoporous Cu with varying relative density**

Lijie He, Muhammad Hadi, Haomin Liu, Niaz Abdolrahim

2629–2642 **Nanoporous metal–polymer composite membranes for organics separations and catalysis**

Michael J. Detisch, Thomas John Balk, Mariah Bezold, Dibakar Bhattacharyya