



Journal of  
MATERIALS RESEARCH

VOLUME 31 • NO 13

JULY 14, 2016

FOCUS ISSUE

**Advances and Challenges  
in Carbon-based Tribomaterials**



# 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 new research that demonstrates a significant impact or advance of scientific understanding of interest to the materials research community. 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 x 11 in. paper, and saved as .doc, .pdf, .rtf, or .ps 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 © 2016**, 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](mailto:info@copyright.com).

---

## Journal of Materials Research Subscription Prices (2016)

[includes on-line web access]

	USA and Poss.	Non-US	Online Only
MRS Regular and Student Members	\$273.00	\$334.00	\$105.00
Institutions	\$1955.00	\$1955.00	\$1764.00

---

*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, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 8RU, 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 the Cambridge Journals Online website. To determine availability, visit the appropriate page for the *JMR* back issue desired ([www.journals.cambridge.org/jmr](http://www.journals.cambridge.org/jmr)).

**Individual member subscriptions are for personal use only.**



# Journal of MATERIALS RESEARCH

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

**Associate Editor,** Adrian Mann, *Biomaterials, Rutgers University, USA*

**Associate Editor,** Jürgen Eckert, *Metallic materials, Montanuniversität Leoben, Austria*

**Associate Editor,** Linda S. Schadler, *Polymeric materials, Rensselaer Polytechnic Institute, USA*

**Guest Editors for Focus Issue: Advances and Challenges in Carbon-based Tribomaterials**

Mohd Fadzli Bin Abdollah, *Universiti Teknikal Malaysia Melaka, Malaysia*

Noritsugu Umehara, *Nagoya University, Japan*

Mariyam Jameelah Binti Ghazali, *Universiti Kebangsaan Malaysia, Malaysia*

Mohamed El Mansori, *Arts et Métiers ParisTech, France*

**2016 Principal Editors:**

Lennart Bergström, *Materials processing, Colloidal science, Stockholm University, Sweden*

Jinju Chen, *Mechanics of soft materials/thin film materials, Nanoindentation Newcastle University, United Kingdom*

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

Yang-T. Cheng, *Mechanical behavior, Electrochemical energy storage, University of Kentucky, USA*

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

Paolo Colombo, *Pre ceramic polymers, Porous ceramics, University of Padova, Italy; The Pennsylvania State University, USA*

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

Mathias Göken, *Superalloys, Nanomaterials, Nanomechanics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany*

Amit Goyal, *Superconductors, Photovoltaics, 2D materials, Self-assembly, State University of New York at Buffalo, USA*

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

Himanshu Jain, *Inorganic glass, Optical, Electrical properties, Lehigh University, USA*

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

Edson Roberto Leite, *Materials chemistry, Nanocrystals, Synthesis, Universidade Federal de São Carlos, Brazil*

Jörg Löffler, *Metallic materials/synthesis and properties, ETH Zurich, Switzerland*

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

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

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

Sarah E. Morgan, *Polymer surfaces and interfaces, The University of Southern Mississippi, USA*

Paul Muralt, *Thin films, Piezoelectric and ferroelectric materials, Ecole Polytechnique Federale de Lausanne, Switzerland*

Akira Nakajima, *Photocatalysis, Surface wettability, Ceramic processing, Tokyo Institute of Technology, Japan*

Cewen Nan, *Ferroelectric, Multiferroic materials, Tsinghua University, China*

George M. Pharr, *Mechanical behavior, Nanoindentation, University of Tennessee, USA*

Ian M. Reaney, *Electroceraamics, TEM, Thin films, The University of Sheffield, United Kingdom*

Edward M. Sabolsky, *Electroceraamics, Electrochemistry, Processing, West Virginia University, USA*

Winston Schoenfeld, *Optical materials, University of Central Florida, USA*

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

Susan B. Sinnott, *Computational materials science, The Pennsylvania State University, USA*

Eric A. Stach, *Materials characterization, Nanostructure growth, Brookhaven National Laboratory, USA*

Mauricio Terrones, *Nanocarbon, Graphene, 2-D metal chalcogenides, The Pennsylvania State University, USA; Shinshu University, Japan*

Terry M. Tritt, *Thermoelectrics, Clemson University, USA*

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

William J. Weber, *Radiation effects, Nuclear ceramics, University of Tennessee; Oak Ridge National Laboratory, USA*

Tao Xie, *Polymers, Functional soft materials, Zhejiang University, China*

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*  
Linda A. Baker, *JMR Editorial Assistant, Materials Research Society, Warrendale, PA*  
Kirby L. Morris, *JMR Production Assistant, Materials Research Society, Warrendale, PA*  
Eileen M. Kiley, *Director of Communications, Materials Research Society, Warrendale, PA*

# Journal of MATERIALS RESEARCH

Volume 31, Number 13, July 14, 2016

## ADVANCES AND CHALLENGES IN CARBON-BASED TRIBOMATERIALS

1813 Introduction

Mohd Fadzli Bin Abdollah,  
Noritsugu Umehara,  
Mariyam Jameelah Binti Ghazali,  
Mohamed El Mansori

## INVITED REVIEW

1814–1836 Influence of intrinsic and extrinsic conditions on the tribological characteristics of diamond-like carbon coatings: A review

Rehan Zahid, Haji Hassan Masjuki,  
Mahendra Varman,  
Muhammad Abul Kalam,  
Riaz Ahmad Mufti,  
Nurin Wahidah Binti Mohd Zulkifli,  
Mubashir Gulzar,  
Siti Safiyah Binti Nor Azman

## INVITED ARTICLES

1837–1847 Effect of change in temperature on the tribological performance of micro surface textured DLC coating

Ahmed Arslan,  
Haji Hasan Masjuki,  
Mahendra Varman,  
Muhammad Abul Kalam,  
Moinuddin Mohammed Quazi,  
Muhammad Hossain Mosarof

1848–1856 Effect of deposition time on wear and corrosion performance of Co–Ni–Fe alloy coated mild steel

Koay Mei Hyie,  
Mohd Zakuan Zabri,  
Nik Roselina Nik Roseley,  
Nik Rozlin Nik Mohd Masdek

## ARTICLES

1857–1864 Friction, nanostructure, and residual stress of single-layer and multi-layer amorphous carbon films deposited by radio-frequency sputtering

Jun Xie, Kyriakos Komvopoulos

1865–1872 Measurement and analysis of friction and wear on electrodeposited coatings against a high carbon chrome steel ball

Kyungmok Kim

## INVITED ARTICLES

1873–1879 Wear mechanism of coated and uncoated carbide cutting tool in machining process

Jaharah A. Ghani,  
Che Hassan Che Haron,  
Mohd Shahir Kasim,  
Mohd Amri Sulaiman,  
Siti Haryani Tomadi

1880–1884 Effect of carbon content in  $\text{TiC}_x\text{N}_{1-x}$  coating on the adhesivity of carbide cutting tools and machining performance

Ping Chuan Siow,  
Jaharah Abdul Ghani,  
Che Hassan Che Haron,  
Mariyam Jameelah Ghazali,  
Talib Ria Jaafar

(Continued)

1885–1892 **Effect of cutting speed on the carbide cutting tool in milling Inconel 718 alloy**

Musfirah Abdul Hadi,  
Jaharah A. Ghani,  
Che Hassan Che Haron,  
Mohd. Shahir Kasim

#### ARTICLE

1893–1899 **Study on wear mechanism of solid carbide cutting tool in milling CFRP**

Nor Khairusshima Muhamad  
Khairussaleh,  
Che Hassan Che Haron,  
Jaharah A. Ghani

#### INVITED ARTICLES

1900–1907 **Effect of recycled carbon fiber reinforcement on the wear behavior of epoxy composite**

Qumrul Ahsan, Law Mei Lin,  
Rose Farahiyah Binti Munawar,  
Noraiham Mohamad

1908–1913 **Correlation of wear characteristics with hardness of recycled carbon fiber prepreg reinforced polypropylene composites**

Anisah Abd Latiff,  
Noraiham Mohamad,  
Abd Razak Jeefferie,  
Mohd Hayatunnufus Md Nasir,  
S. Siti Rahmah,  
Mazlin Aida Mahamood,  
Muhammad Ilman Hakimi Chua  
Abdullah,  
Hairul Effendy Ab Maulod

#### ARTICLES

1914–1923 **Nanoscale tribology of graphene grown by chemical vapor deposition and transferred onto silicon oxide substrates**

Tuna Demirbaş,  
Mehmet Z. Baykara

1924–1931 **Nanotribological properties of few layer graphene surfaces, prepared by bottom-up and top-down methods, in ambient air and liquid environments**

Konstantinos A. Sierros,  
Sai Suvineeth Ramayanam,  
Charter D. Stinespring

#### INVITED ARTICLES

1932–1938 **Study of tribological properties of lubricating oil blend added with graphene nanoplatelets**

Siti Safiyah Nor Azman,  
Nurin Wahidah Mohd Zulkifli,  
Hassan Masjuki, Mubashir Gulzar,  
Rehan Zahid

1939–1946 **Study of graphene nanolubricant using thermogravimetric analysis**

Abdul Khaliq Rasheed,  
Mohammad Khalid,  
Rashmi Walvekar,  
Thummalapalli Chandra Sekhara  
Manikyam Gupta, Andrew Chan

1947–1956 **Structural and optical properties of graphene from green carbon source via thermal chemical vapor deposition**

M.J. Salifairus, S.B. Abd Hamid,  
T. Soga, Salman A.H. Alrokayan,  
Haseeb A. Khan, M. Rusop

1957–1963 **A study on thick coatings of tetrahedral amorphous carbon deposited by filtered cathode vacuum arc plasma**

Young-Jun Jang, Gi Taek Kim,  
Yong-Jin Kang, Dong-Sik Kim,  
Jong-Kuk Kim

#### ARTICLE

1964–1971 **Nanocrystalline diamond films prepared by pulsed electron beam ablation on different substrates**

Redhouane Henda,  
Omar Alshekhli, Matiar Howlader,  
Jamal Deen

(Continued)

**INVITED ARTICLE**

1972–1982 **An extensive study on carbon nanomaterials electrode from electrophoretic deposition technique for energy storage device**

Elyas Talib, Mohd Asyadi Azam

**CORRIGENDA**

1983 **Corrigenda**