Nanotubes and Related Nanostructures–2014

MATERIALS RESEARCH SOCIETY
SYMPOSIUM PROCEEDINGS VOLUME 1700

Nanotubes and Related Nanostructures–2014

Symposium held April 21-25, 2014, San Francisco, California, USA

EDITORS

Don Futaba
National Institute of Advanced Industrial Science and Technology
Ibaraki, Japan

Yoke Khin Yap
Michigan Technological University
Houghton, Michigan, USA

MRS®
Materials Research Society
Warrendale, Pennsylvania

CAMBRIDGE UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Mexico City

Cambridge University Press
32 Avenue of the Americas, New York, NY 10013-2473, USA

www.cambridge.org
Information on this title: www.cambridge.org/9781605116778

Materials Research Society
506 Keystone Drive, Warrendale, PA 15086
http://www.mrs.org

© Materials Research Society 2014

This publication is in copyright. Subject to statutory exception
and to the provisions of relevant collective licensing agreements,
no reproduction of any part may take place without the written
permission of Cambridge University Press.

This book has been registered with Copyright Clearance Center, Inc.
For further information please contact the Copyright Clearance Center,
Salem, Massachusetts.

First published 2014

CODEN: MRSPDH

ISBN: 978-1-60511-677-8 Hardback

Cambridge University Press has no responsibility for the persistence or
accuracy of URLs for external or third-party Internet Web sites referred to
in this publication and does not guarantee that any content on such Web sites is,
or will remain, accurate or appropriate.

CONTENTS

*Invited Paper

MECHANICAL INVESTIGATION

OPTICAL INVESTIGATION

CHEMICAL AND BIOLOGICAL INVESTIGATION

*Invited Paper

PREFACE

Carbon nanotubes and related nanostructures, including nanosheets have attracted tremendous attention for their unique structures and intriguing properties. These nanomaterials have been widely investigated—from theory, synthesis, and characterization to applications in electronic devices, energy generation and storage, biological and chemical sensors, etc. In addition, non-carbon nanostructures such as nanotubes and nanosheets of boron nitride (BN) have gained increasing interest.

To facilitate scientific interaction among students and researchers on the latest advancements in this area, Symposium MM – Nanotubes and Related Nanostructures, was organized and held on Apr. 21–25 at the 2014 MRS Spring Meeting in San Francisco, California. The symposium organizers were Don Futaba (National Institute of Advanced Industrial Science and Technology), Annick Loiseau (Laboratoire d'Etude des Microstructures), Yoke Khin Yap (Michigan Technological University), and Ming Zheng (National Institute of Standards and Technology).

This proceedings volume consists of peer-reviewed papers presented in the symposium, including invited and contributed presentations. These papers represent a snapshot of topics discussed in both theoretical and experimental aspects. We hope this publication will contribute toward productive research in the area of nanotubes and related nanostructures.

Don N. Futaba
Yoke Khin Yap

September 2014

Acknowledgments

The papers published in this volume result from the MRS Spring 2014 symposium MM. We extend our gratitude to all the oral and poster presenters of the symposium who contributed to this volume. We also thank the reviewers of these manuscripts, who provided valuable feedback to the editors and authors. The organizers of Symposium MM thank Hummingbird Scientific, the Multi-Scale Technologies Institute (MuSTI) at Michigan Technological University for their financial support.

Y.K. Yap acknowledges the National Science Foundation (DMR 1261910) for supporting his outreach efforts to promote the interest of the younger generation in science, technology, engineering, and mathematics (STEM) education.

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

Volume 1666E — Film-Silicon Science and Technology, 2014, P. Stradins, R. Collins, F. Finger, N. Wyrsch, A. Terakawa, ISBN 978-1-60511-643-3

Volume 1667E — Organic and Inorganic Materials for Dye-Sensitized Solar Cells, 2014, H. He, J. Kim, K. Zhu, Z. Zhao, ISBN 978-1-60511-644-0

Volume 1668E — Synthesis and Processing of Organic and Polymeric Materials for Semiconductor Applications, 2014, J. Brooks, C. Lee, J. Li, B. Ma, ISBN 978-1-60511-645-7

Volume 1669E — Materials for Photoelectrochemical and Photocatalytic Solar-Energy Harvesting and Storage, 2014, J. Turner, ISBN 978-1-60511-646-4

Volume 1670E — Advances in the Characterization, Performance and Defect Engineering of Earth Abundant and Thin Film Materials for Solar Energy Conversion, 2014, T. Gershon, D.O. Scanlon, K. Thompson, S-H. Wei, Y. Yan, A. Zakutayev, ISBN 978-1-60511-647-1

Volume 1671E — Controlling the Interaction between Light and Semiconductor Nanostructures for Energy Applications, 2014, R. Gearba, M. Beard, J. Cahoon, D. Lee, H. McDaniel, ISBN 978-1-60511-648-8

Volume 1672E — Photoactivated Chemical and Biochemical Processes on Semiconductor Surfaces, 2014, M. Eickhoff, D. Fattakhova-Rohlfing, S. Maldonado, I. Sharp, ISBN 978-1-60511-649-5

Volume 1673E — Materials for Carbon Capture, 2014, S. Kulkarni, J. Bara, D. Jiang, I. Pinnau, K. Walton, ISBN 978-1-60511-650-1

Volume 1674E — Physics of Oxide Thin Films and Heterostructures, 2014, S.H. Baek, C.M. Folkman, Y. Takamura, T. Tybell, ISBN 978-1-60511-651-8

Volume 1675 — Synthesis, Characterization, and Applications of Functional Materials— Thin Films and Nanostructures, 2014, V. Craciun, M. Guilloux-Viry, M. Jain, Q.X. Jia, H. Kozuka, D. Kumar, S. Mathur, X. Obradors, K. Singh, ISBN 978-1-60511-652-5

Volume 1676E — Materials and Interfaces in Solid Oxide Fuel Cells, 2014, D. Fong, B. Yildiz, K. Amezawa, R. De Souza, ISBN 978-1-60511-653-2

Volume 1677E — Fuel Cells, Electrolyzers and Other Electrochemical Energy Systems, 2014, S. Hamrock, N. Brandon, V. Di Noto, T. Zawodzinski, ISBN 978-1-60511-654-9

Volume 1678E — Research Frontiers on Electrochemical Energy Storage Materials—Design, Synthesis, Characterization and Modeling, 2014, C. Wang, ISBN 978-1-60511-655-6

Volume 1679E — Novel Energy-Storage Technologies beyond Li-ion Batteries—From Materials Design to System Integration, 2014, Linda F. Nazar, ISBN 978-1-60511-656-3

Volume 1680E — Mechanics of Energy Storage and Conversion—Batteries, Thermoelectrics and Fuel Cells, 2014, J.Y. Li, J. Christensen, J. Huber, K.Y. Zeng, ISBN 978-1-60511-657-0

Volume 1681E — Materials, Technologies and Sensor Concepts for Advanced Battery Management Systems, 2014, P. Kiesel, M. Klein, V. Srinivasan, ISBN 978-1-60511-658-7

Volume 1682E — Materials Challenges and Integration Strategies for Flexible Energy Devices and Systems, 2014, S. Dunn, ISBN 978-1-60511-659-4

Volume 1683E — Actinides—Basic Science, Applications and Technology, 2014, L. Havela, W. Lukens, A. Migliori, P.S. Riseborough, P. Söderlind, ISBN 978-1-60511-660-0

Volume 1684E — Superconductor Materials—From Basic Science to Novel Technology, 2014, T. Haugan, K. Matsumoto, T. Puig, J. Wu, ISBN 978-1-60511-661-7

Volume 1685E — Soft Nanomaterials, 2014, S. Taioli, ISBN 978-1-60511-662-4

Volume 1686E — Micro- and Nanofluidic Systems for Materials Synthesis, Device Assembly and Bioanalysis, 2014, T. Huang, R. Fan, Y. Huang, Q. Shi, ISBN 978-1-60511-663-1

Volume 1687E — Functional Biomaterials for Regenerative Engineering, 2014, E. Alsberg, G. Camci-Unal, B. Harley, K. Kataoka, ISBN 978-1-60511-664-8

Volume 1688E — Biomaterials for Biomolecule Delivery and Understanding Cell-Niche Interactions, 2014, G.D. Prestwich, ISBN 978-1-60511-665-5

Volume 1689E — Bioelectronics—Materials, Processes and Applications, 2014, J. Rivnay, N. Stingelin, F. Cicoira, P. Meredith, R. Owens, ISBN 978-1-60511-666-2

Volume 1690E — Advanced Multifunctional Biomaterials for Neuroprosthetic Interfaces, 2014, M.R. Abidian, G. Malliaras, D. Tyler, L. Poole-Warren, ISBN 978-1-60511-667-9

Volume 1691E — Materials for End-of-Roadmap Devices in Logic, Power and Memory, 2014, E.M. Vogel, ISBN 978-1-60511-668-6

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

Volume 1692E — New Materials and Processes for Interconnects, Novel Memory and Advanced Display Technologies, 2014, S. Barry, ISBN 978-1-60511-669-3
Volume 1693E — Silicon Carbide–Materials, Processing and Devices, 2014, F. Zhao, F. Iacopi, E. Sanchez, C.-M. Zetterling, ISBN 978-1-60511-670-9
Volume 1694E — Advances in Inorganic Semiconductor Nanoparticles and Their Applications, 2014, B. Korgel, ISBN 978-1-60511-671-6
Volume 1695E — The Grand Challenges in Organic Electronics, 2014, O. Jurchescu, ISBN 978-1-60511-672-3
Volume 1697E — Phase-Change Materials for Memory, Reconfigurable Electronics and Cognitive Applications, 2014, H.-Y. Cheng, D.-H. Ahn, R. Calarco, M. Salinga, ISBN 978-1-60511-674-7
Volume 1698E — Emerging Nanophotonic Materials and Devices, 2014, K. Aydin, J. Caldwell, L. Cao, M.G. Humphrey, S. Larouche, S. Maier, J. Munday, W. Sun, R. Walters, C. Zhang, R. Zia, ISBN 978-1-60511-675-4
Volume 1699E — Transparent Electrodes, 2014, S. Magdassi, R. Abbel, K. Suganuma, M. van Hest, ISBN 978-1-60511-676-1
Volume 1700 — Nanotubes and Related Nanostructures –2014, 2014, Y.K. Yap, D.N. Futaba, ISBN 978-1-60511-677-8
Volume 1701E — 2D Materials and Devices beyond Graphene, 2014, J.A. Robinson, ISBN 978-1-60511-678-5
Volume 1702E — De Novo Graphene, 2014, R. Kaner, H. Gao, Y. Gogotsi, C. Ozkan, ISBN 978-1-60511-679-2
Volume 1703E — Nanodiamonds—Fundamentals and Applications, 2014, V. Mochalin, E. Osawa, O. Shenderova, J. Wrachtrup, ISBN 978-1-60511-680-8
Volume 1704E — Computationally Enabled Discoveries in Synthesis, Structure and Properties of Nanoscale Materials, 2014, J. Wang, H. Huang, F. Liu, ISBN 978-1-60511-681-5
Volume 1705E — Nanocrystal Growth via Oriented Attachment and Mesocrystal Formation, 2014, Z. Lin, Z. Zhuang, ISBN 978-1-60511-682-2
Volume 1706E — Mesoscale Self-Assembly of Nanoparticles—Manufacturing, Functionalization, Assembly and Integration, 2014, C. Cao, ISBN 978-1-60511-683-9
Volume 1707E — Semiconductor Nanowires—Synthesis, Properties and Applications, 2014, Y. Zhu, S. Gradecak, Y. Gu, J. Spanier, ISBN 978-1-60511-684-6
Volume 1708E — Magnetic Nanomaterials and Nanostructures, 2014, P.D. Cozzoli, Arunava Gupta, Y. Hou, J.P. Liu, ISBN 978-1-60511-685-3
Volume 1709E — Materials by Design—Merging Advanced In-Situ Characterization with Predictive Simulation, 2014, I. Takeuchi, E. Campo, J. Warren, F. Alamgir, ISBN 978-1-60511-686-0
Volume 1710E — Shape Programmable Materials, 2014, T. White, M. Dickey, ISBN 978-1-60511-687-7
Volume 1712E — Recent Advances in the Structural Characterization of Materials, 2014, A. Barber, A. Boulle, Y. Kim, S. Wong, ISBN 978-1-60511-689-1
Volume 1713E — In-situ Characterization of Material Synthesis and Properties at the Nanoscale with TEM, 2014, M. Chi, Z. Shan, R. Sharma, J. Winterstein, ISBN 978-1-60511-690-7
Volume 1714E — Atomic-Resolution Analytical Electron Microscopy of Disruptive and Energy-Related Materials, 2014, J.-C. Idrobo, R. Erni, R. Klie, N. Shibata, ISBN 978-1-60511-691-4
Volume 1715E — Materials Behavior under Extreme Irradiation, Stress or Temperature, 2014, A. Horsfield, N. Li, J. Morris, J. Yu, ISBN 978-1-60511-692-1
Volume 1716E — Educating and Mentoring Young Materials Scientists for Career Development, 2014, M. Minus, L. Liu, V. Uskokovi, E. Howard, ISBN 978-1-60511-693-8

Prior Materials Research Symposium Proceedings available by contacting Materials Research Society

AUTHOR INDEX

SUBJECT INDEX