

**Amorphous and Polycrystalline
Thin-Film Silicon Science
and Technology—2011**

MATERIALS RESEARCH SOCIETY
SYMPOSIUM PROCEEDINGS VOLUME 1321

Amorphous and Polycrystalline Thin-Film Silicon Science and Technology—2011

Symposium held April 25–29, 2011, San Francisco, California, U.S.A.

EDITORS

Baojie Yan

United Solar Ovonic LLC
Troy, Michigan, U.S.A.

Qi Wang

National Renewable Energy Laboratory
Golden, Colorado, U.S.A.

Helena Gleskova

University of Strathclyde
Glasgow, United Kingdom

Chuang Chuang Tsai

National Chiao Tung University
Hsinchu, Taiwan

Seiichiro Higashi

Hiroshima University
Higashi-Hiroshima, Japan



Materials Research Society
Warrendale, Pennsylvania



CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS

Cambridge, New York, Melbourne, Madrid, Cape Town,
Singapore, São Paulo, Delhi, Tokyo, 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/9781605112985

Materials Research Society

506 Keystone Drive, Warrendale, PA 15086, USA

<http://www.mrs.org>

© Materials Research Society 2012

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 2012

CODEN: MRSPDH

ISBN: 978-1-60511-298-5 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

Preface xv

Materials Research Society Symposium Proceedings xvii

SOLAR CELLS

High Efficiency, Large Area, Nanocrystalline Silicon Based, Triple-junction Solar Cells3

A. Banerjee, T. Su, D. Beglau,
G. Pietka, F. Liu, B. Yan,
J. Yang, and S. Guha

Thin Film Silicon Solar Cells Under Moderate Concentration.9

L.M. van Dam, W.G.J.H.M. van Sark,
and R.E.I. Schropp

Effect of Bandgap Grading on the Performance of a-Si_{1-x}Ge_x:H Single-junction Thin-film Solar Cells15

H.J. Hsu, C.M. Wang,
C.H. Hsu, and C.C. Tsai

*** High-efficiency Microcrystalline Silicon and Microcrystalline Silicon-germanium Alloy Solar Cells.21**

Takuya Matsui and Michio Kondo

V_{oc} Saturation Effect in High-temperature Hydrogenated Polycrystalline Silicon Thin-film Solar Cells33

Hidayat Hidayat, Per I. Widenborg,
and Armin G. Aberle

Improvement of Single-junction a-Si:H Thin-film Solar Cells Toward 10% Efficiency39

P.H. Cheng, S.W. Liang, Y.P. Lin,
H.J. Hsu, C.H. Hsu, and C.C. Tsai

*Invited Paper

Semiconducting Polymer and Hydrogenated Amorphous Silicon Heterojunction Solar Cells	45
A.R. Middy and Eric A. Schiff	
Impact of a Finite Shunt Resistance on the Dark Spectral Response of a-Si:H/μc-Si Thin-film Multi-junction Photovoltaic Devices	51
Mauro Pravettoni and Alessandro Virtuani	
Investigation of Local Light Scattering Properties of Thin-film Silicon Solar Cells with Subwavelength Resolution	57
K. Bittkau, A. Hoffmann, J. Owen, and R. Carius	
Reflectance Improvement by Thermal Annealing of Sputtered Ag/ZnO Back Reflectors in a-Si:H Thin Film Silicon Solar Cells	63
Karin Söderström, Franz-Josef Haug, Céline Pahud, Rémi Biron, Jordi Escarré, Martial Duchamp, Rafal Dunin-Borkowski, and Christophe Ballif	
11.0% Stable Efficiency on Large Area, Encapsulated a-Si:H and a-SiGe:H Based Multijunction Solar Cells Using HF Technology	69
A. Banerjee, D. Beglau, T. Su, G. Pietka, G. Yue, B. Yan, J. Yang, and S. Guha	
Calibration of Multi-junction (Tandem) Thin Film Photovoltaic Modules Under Natural Sunlight	75
Georgios Tzamalidis and Harald Müllejjans	
* Flexible, Lightweight, Amorphous Silicon Based Solar Cells on Polymer Substrate for Space and Near-space Applications	81
K. Beernink, A. Banerjee, J. Yang, K. Lord, F. Liu, G. DeMaggio, G. Pietka, C. Worrel, and S. Guha	
Properties of Amorphous Silicon Passivation Layers for All Back Contact c-Si Heterojunction Solar Cells	93
Lulu Zhang, Ujjwal Das, Jesse Appel, Steve Hegedus, and Robert Birkmire	

*Invited Paper

Thin Film Si Photovoltaic Devices on Photonic Structures Fabricated on Steel and Polymer Substrates.....	99
S. Pattnaik, N. Chakravarty, J. Bhattacharya, R. Biswas, D. Slafer, and V.L. Dalal	
Performance of Hydrogenated a-Si:H Solar Cells with Downshifting Coating.....	105
Bill Nemeth, Yueqin Xu, Haorong Wang, Ted Sun, Benjamin G. Lee, Anna Duda, and Qi Wang	
Light-induced Open-circuit Voltage Increase in Amorphous Silicon/Microcrystalline Silicon Tandem Solar Cells.....	111
Xiaodan Zhang, Guanghong Wang, Shengzhi Xu, Shaozhen Xiong, Xinhua Geng, and Ying Zhao	
Modulated Surface-textured Substrates with High Haze for Thin-film Silicon Solar Cells.....	117
O. Isabella, P. Liu, B. Bolman, J. Krč, and M. Zeman	
Excitation of Guided-mode Resonances in Thin Film Silicon Solar Cells.....	123
F.-J. Haug, K. Söderström, A. Naqavi, and C. Ballif	
Effect of Buffer Structure on the Performance of a-Si:H/a-Si:H Tandem Solar Cells.....	129
C.H. Hsu, C.Y. Lee, P.H. Cheng, C.K. Chuang, and C.C. Tsai	
Annealing Effects of Microstructure in Thin-film Silicon Solar Cell Materials Measured by Effusion of Implanted Rare Gas Atoms.....	135
W. Beyer, D. Lennartz, P. Prunici, and H. Stiebig	

Room Temperature Fabricated ZnO:Al with Elevated and Unique Light-trapping Performance	141
E.V. Johnson, C. Charpentier, T. Emeraud, J.F. Lerat, C. Boniface, K. Huet, P. Prod'homme, and P. Roca i Cabarrocas	
n-Type Hydrogenated Microcrystalline Silicon Oxide Films and Their Applications in Micromorph Silicon Solar Cells.	147
Amornrat Limmanee, Songkiate Kittisontirak, Channarong Piromjit, Jaran Sritharathikhun, and Kobsak Sriprapha	
Modeling of Advanced Light Trapping Approaches in Thin-film Silicon Solar Cells	153
Miro Zeman, Olindo Isabella, Klaus Jäger, Pavel Babal, Serge Solntsev, and Rudi Santbergen	

POLYCRYSTALLINE FILMS

Flash-lamp-induced Lateral Solidification of Thin Si Films	161
K. Omori, G.S. Ganot, U.J. Chung, A.M. Chitu, A.B. Limanov, and James S. Im	
Poly-Si Thin Film Formation Using a Novel Low Thermal Budget Process.	167
Minghao Zhu, Yue Kuo, Chen-Han Lin, and Qi Wang	
Impact of Rapid Thermal Annealing and Hydrogenation on the Doping Concentration and Carrier Mobility in Solid Phase Crystallized Poly-Si Thin Films	173
A. Kumar, P.I. Widenborg, H. Hidayat, Qiu Zixuan, and A.G. Aberle	
Characterization of Green Laser Crystallized GeSi Thin Films	179
Balaji Rangarajan, Ihor Brunets, Peter Oesterlin, Alexey Y. Kovalgin, and Jurriaan Schmitz	

A Study of the Post-hydrogenation Passivation Mechanism of Crystallized Poly-Si Films.	185
Chong Luo, Juan Li, He Li, Zhiguo Meng, Chunya Wu, Qian Huang, Xu Shengzhi, Hoi Sing Kwok, and Shaozhen Xiong	
The Role of H-plasma in Aluminum Induced Crystallization of Amorphous Silicon.	191
Chong Luo, Juan Li, He Li, Zhiguo Meng, Qian Huang, Shengzhi Xu, Hoi Sing Kwok, and Shaozhen Xiong	
Excimer-laser-induced Melting and Solidification of PECVD a-Si films Under Partial-melting Conditions	197
Q. Hu, Catherine S. Lee, T. Li, Y. Deng, U.J. Chung, A.B. Limanov, A.M. Chitu, M.O. Thompson, and James S. Im	
Growth of Large Grain Polycrystalline Silicon Thin Film on Soda-lime Glass at Low Temperature for Solar Cell Applications.	203
K. Wang and K.H. Wong	
Non-melt Laser Thermal Annealing of Shallow Boron Implantation for Back Surface Passivation of Backside-illuminated CMOS Image Sensors.	209
Zahra Ait Fqir Ali-Guerry, Karim Huet, Didier Dutartre, Rémi Beneyton, Daniel Bensahel, Philippe Normandon, and Guo-Neng Lu	

THIN FILM SILICON ALLOYS

Effect of Substrate Temperature on Hardness and Transparency of SiOC(-H) Thin Films Synthesized by Atmospheric Pressure Plasma Enhanced CVD Method	217
Mayui Noborisaka, So Nagashima, Hidetaka Hayashi, Naoharu Ueda, Kyoko Kumagai, Akira Shirakura, and Tetsuya Suzuki	

Use of a-SiC:H Multilayer Transducers for Detection of Fluorescence Signals from Reactive Cyan and Yellow Fluorophores.223
P. Louro, M. Vieira, M.A. Vieira, J. Costa, M. Fernandes, and A. Karmali	
Properties of a-(Si,Ge) Materials and Devices Grown Using Chemical Annealing229
Ashutosh Shyam, Daniel Congreve, Max Noack, and Vikram Dalal	
Effect of Dynamic Bias Stress (AC) in Short-channel (L=1.5μm) p-Type Polycrystalline Silicon (Poly-Si) Thin Film Transistors (TFTs) on the Glass Substrate235
Sung-Hwan Choi, Yeon-Gon Mo, and Min-Koo Han	
The Suppression of Leakage Current in the Solid Phase Crystallized Silicon (SPC-Si) TFT Employing Off-state Bias Annealing Under Light Illumination.241
Sang-Geun Park, Seung-Hee Kuk, Jong-Seok Woo, and Min-Koo Han	
Investigation of Amorphous IGZO TFT Employing Ti/Cu Source/Drain and SiNx Passivation247
Young Wook Lee, Sung-Hwan Choi, Jeong-Soo Lee, Jang-Yeon Kwon, and Min-Koo Han	
Reliability of Oxide Thin Film Transistors Under the Gate Bias Stress with 400 nm Wavelength Light Illumination253
Soo-Yeon Lee, Sun-Jae Kim, Yongwook Lee, Woo-Geun Lee, Kap-Soo Yoon, Jang-Yeon Kwon, and Min-Koo Han	
DC and AC Gate-bias Stability of Nanocrystalline Silicon Thin-film Transistors Made on Colorless Polyimide Foil Substrates.259
I-Chung Chiu, I-Chun Cheng, Jian Z. Chen, Jung-Jie Huang, and Yung-Pei Chen	

SIMULATION AND CHARACTERIZATION

Wide-spectral-range, Expanded-beam Spectroscopic Ellipsometer and its Application for Imaging/Mapping of Graded Nanocrystalline Si:H Films267
A. Nemeth, D. Attygalle, L.R. Dahal, P. Aryal, Z. Huang, C. Salupo, P. Petrik, G. Juhasz, C. Major, O. Polgar, M. Fried, B. Pecz, and R.W. Collins	
Numerical 3D-simulation of Micromorph Silicon Thin Film Solar Cells273
Stefan Geißendörfer, Karsten von Maydell, and Carsten Agert	
Correlated Photoluminescence Spectroscopy Investigation of Grain Boundaries and Diffusion Processes in Nanocrystalline and Amorphous Silicon (nc-Si:H) Mixtures279
Jeremy D. Fields, K.G. Kiriluk, D.C. Bobela, L. Gedvilas, and P.C. Taylor	
Hopping Transport in Doped Co-deposited Mixed-phase Hydrogenated Amorphous/Nanocrystalline Silicon Thin Films285
L.R. Wienkes, C. Blackwell, and J. Kakalios	
Photocarrier Excitation and Transport in Hyperdoped Planar Silicon Devices291
Peter D. Persans, Nathaniel E. Berry, Daniel Recht, David Hutchinson, Aurore J. Said, Jeffrey M. Warrender, Hannah Peterson, Anthony DiFranzo, Christina McGahan, Jessica Clark, Will Cunningham, and Michael J. Aziz	
* Theoretical Studies of Structure and Doping of Hydrogenated Amorphous Silicon297
Bin Cai and D.A. Drabold	

*Invited Paper

***Ab Initio* Structure Characterization for the Amorphous Assembly of Si Clusters Encapsulating Transition Metal** 307
 Takehide Miyazaki, Noriyuki Uchida, and Toshihiko Kanayama

* **Microscopic Characterizations of Nanostructured Silicon Thin Films for Solar Cells** 313
 Antonín Fejfar, Petr Klapetek, Jakub Zlámal, Aliaksei Vetushka, Martin Ledinský, and Jan Kočka

Band Alignment at Amorphous/Crystalline Silicon Hetero-interfaces 323
 L. Korte, T.F. Schulze, C. Leendertz, M. Schmidt, and B. Rech

Electron Emission from Deep Traps in Hydrogenated Amorphous Silicon and Silicon-germanium: Meyer-Neldel Behavior and Ionization Entropy 329
 Qi Long, Steluta Dinca, Eric A. Schiff, Baojie Yan, Jeff Yang, and Subhendu Guha

NANOSTRUCTURES

* **Opto-electronic Properties of Co-deposited Mixed-phase Hydrogenated Amorphous/Nanocrystalline Silicon Thin Films** 337
 James Kakalios, U. Kortshagen, C. Blackwell, C. Anderson, Y. Adjallah, L.R. Wienkes, K. Bodurtha, and J. Trask

Mixed Phase Silicon Oxide Layers for Thin-film Silicon Solar Cells 349
 Peter Cuony, Duncan T.L. Alexander, Linus Löfgren, Michael Krumrey, Michael Marending, Mathieu Despeisse, and Christophe Ballif

Silicon Thin-films From Nanoparticle Dispersion: Tailoring Morphological, Electrical and Optical Characteristics 355
 Etienne Drahi, Sylvain Blayac, and Patrick Benaben

*Invited Paper

**Electric Field Effect in Amorphous Semiconductor
Films Assembled from Transition-metal-encapsulating
Si Clusters**361
 N. Uchida, T. Miyazaki, Y. Matsushita,
 K. Sameshima, and T. Kanayama

**Optical Characterization Using Ellipsometry of Si
Nanocrystal Thin Layers Embedded in Silicon Oxide**367
 E. Agocs, P. Petrik, M. Fried,
 and A.G. Nassiopoulou

GROWTH MECHANISM

* **Control of Materials and Interfaces in $\mu\text{c-Si:H}$ -Based Solar
Cells Grown at High Rate**375
 Yasushi Sobajima, Chitose Sada,
 Akihisa Matsuda, and Hiroaki Okamoto

**Monitoring the Growth of Microcrystalline Silicon
Deposited by Plasma-enhanced Chemical Vapor
Deposition Using In-situ Raman Spectroscopy**.....387
 S. Muthmann, F. Köhler, M. Hülsbeck,
 M. Meier, A. Mück, R. Schmitz,
 W. Appenzeller, R. Carius, and A. Gordijn

**Deposition of p-Type Nanocrystalline Silicon
Using High Pressure in a VHF-PECVD Single
Chamber System.**393
 Xiaodan Zhang, Guanghong Wang,
 Xinxia Zheng, Shengzhi Xu,
 Changchun Wei, Jian Sun, Xinhua Geng,
 Shaozhen Xiong, and Ying Zhao

**Influence of the Electrode Spacing on the Plasma
Characteristics and Hydrogenated Amorphous
Silicon Film Properties Grown in the DC Saddle
Field PECVD System**399
 Keith R. Leong, Nazir P. Kherani,
 and Stefan Zukotynski

SENSORS AND NOVEL DEVICES

**Development of Si Microliquid Processing
Using Piezo Actuator**407
 Muneki Akazawa, Shunki Koyanagi,
 and Seiichiro Higashi

*Invited Paper

Thin Film Power Harvesting System for Displays	413
Arman Ahnood, Reza Chaji, and Arokia Nathan	
Optical Bias Controlled Amplification in Tandem Si-C Pinpin Devices	417
M. Vieira, M.A Vieira, P. Louro, M. Fernandes, A. Fantoni, and M. Barata	
* Amorphous Silicon Based Particle Detectors	423
N. Wyrsh, A. Franco, Y. Riesen, M. Despeisse, S. Dunand, F. Powolny, P. Jarron, and C. Ballif	
Amorphous Silicon Photosensors for Detection of Intrinsic Cell Fluorophores	435
A. Joskowiak, V. Chu, D.M.F. Prazeres, and J.P. Conde	
Self Optical Gain in Multilayered Silicon-carbon Heterostructures: A Capacitive Active Band-pass Filter Model	441
M.A. Vieira, M. Vieira, P. Louro, M. Fernandes, J. Costa, and A.S. Garção	
Optical Demultiplexer Device: Frequency and Optical Bias Analysis	449
P. Louro, M. Vieira, M.A. Vieira, and T. Silva	
Thin-film Photodiode with an a-Si:H/nc-Si:H Absorption Bilayer	455
Y. Vygranenko, M. Vieira, and A. Sazonov	
Author Index	461
Subject Index	465

*Invited Paper

PREFACE

This volume includes sixty-eight papers presented in the 2011 MRS Spring Meeting Symposium A, “Amorphous and Polycrystalline Thin Film Silicon Science and Technology – 2011”, which took place April 25-29, in San Francisco, California. The symposium covers the science and technology of thin-film silicon based materials and devices. The symposium traditionally started off on April 25 with an extremely well-attended full-day tutorial aimed at young researchers and people new to the field. The tutorial was lectured by Profs. Andrew Flewitt and Arokia Nathan. During the four days of fourteen oral sessions and two evenings of poster presentations, seventeen invited talks reviewed the recent progress and addressed the scientific and technical issues in the field. The oral and poster presentations reported new results in various areas, covering fundamental studies and technology advances.

Among various applications, solar cells for photovoltaic solar energy and thin-film transistors for flat-panel display have been the two major driving forces for research and development of thin-film silicon materials and devices. In the last few years, the thin-film silicon community has mainly focused on thin-film silicon solar cells to address the issues of efficiency, manufacturing capability and manufacturing cost. This year Symposium A held focused sessions on the topic of solar cell efficiency. Microcrystalline ($\mu\text{c-Si:H}$) or nanocrystalline silicon (nc-Si:H) offers the potential for improving the cell efficiencies. Dr. Friedhelm Finger (Forschungszentrum Jülich, Germany) reviewed the recent efficiency improvement in $\mu\text{c-Si:H}$ solar cells with an emphasis on $\mu\text{c-SiC:H}$ and $\mu\text{c-SiO:H}$ doped layers and effective light management. Dr. Finger expected that over 14% efficiency with a-Si:H/ $\mu\text{c-Si:H}$ tandem solar cells will be attained soon. Prof. Miro Zeman (Delft University of Technology, The Netherlands) showed that 23% efficiency is achievable using a-SiC:H/a-SiGe:H/nc-Si:H triple-junction structure with advanced light trapping to enhance the photon harvesting of the sun light. Along this line, many new light trapping and light management approaches have been investigated, including plasmonic light scattering using metal and dielectric nano-particles and photonic structures. Theoretical and simulation studies show that the classical limit of $4n^2$ can be exceeded using advanced light trapping techniques. Dr. Takuya Matsui (AIST, Japan) presented their recent progress in developing $\mu\text{c-SiGe:H}$ materials as low bandgap materials to absorb long wavelength light, which provides a new material for high efficiency solar cells. Significant progress in advancing the nc-Si:H technology for mass production has been made. Dr. Arindam Banerjee of United Solar Ovonic LLC (Michigan, USA) reported achieving initial 12% and stable 11.2% encapsulated module (400 cm^2) efficiencies with an a-Si:H/nc-Si:H/nc-Si:H triple-junction structure. The high module efficiencies are new world records for thin film silicon solar modules measured by the National Renewable Energy Laboratory. In addition, Symposium A had three sessions on thin film transistors, sensors and other novel devices reporting advances in these areas. To improve the device quality significant fundamental studies have been presented, especially advanced microscopic characterization (Dr. A. Fejfar, Academy of Sciences, Czech Republic) and simulations (Prof. D. Drabold, Ohio University, USA). The presentations covered the thin-film silicon materials ranging from amorphous to nano- and micro-structured materials, and polycrystalline thin films. The unique optical

properties of black silicon attracted significant attention for its potential application in solar cells as an effective light trapping material.

We had a very successful and enjoyable symposium. The number of presentations and attendees reflect the great need for development of thin-film silicon materials and devices. Unique and advanced results ensured the high quality of the symposium. As the organizers of Symposium A, we greatly acknowledge the invaluable contributions of the authors of oral and poster presentations, especially those who made written contributions to this volume

The symposium organizers thank all the people evolved in the Symposium before, during, and after the conference. The organizers greatly appreciate the program committee members of V. Chu (INESC, Portugal), A. Fejfar (Academy of Sciences of the Czech Republic, Czech Republic), F. Finger (Forschungszentrum Jülich, Germany), A. Flewitt (University of Cambridge, United Kingdom), T. Matsui (AIST, Japan), E.A. Schiff (Syracuse University, USA), P. Stradins (NREL, USA), J. Robertson (University of Cambridge, United Kingdom), and M. Zeman (Delft University of Technology, The Netherlands). They kindly reviewed all of the abstracts, which helped the organizers to prepare an interesting program. Special appreciation goes to all of the referees for their careful review of papers in the proceedings and valuable feedback given to the authors. We sincerely thank Mary Ann Woolf, who supervised and managed the abstract and manuscript reviewing process. Her experience and hard work allowed for smooth and timely production of this volume. The MRS staff provided friendly and professional support throughout the organization of the Symposium and Proceedings

On behalf of all the participants, we thank the generous financial support of our corporate sponsors: ITRI, NREL, ULVAC Inc., and United Solar Ovonic LLC.

Baojie Yan
Qi Wang
Helena Gleskova
Chuang-Chuang Tsai
Seiichiro Higashi

September 2011

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

- Volume 1321 — Amorphous and Polycrystalline Thin-Film Silicon Science and Technology—2011, B. Yan, Q. Wang, H. Gleskova, C.C. Tsai, S. Higashi, 2011, ISBN 978-1-60511-298-5
- Volume 1322 — Third-Generation and Emerging Solar-Cell Technologies, Y. Lu, J.M. Merrill, M.T. Lusk, S. Bailey, A. Franceschetti, 2011, ISBN 978-1-60511-299-2
- Volume 1323 — Advanced Materials Processing for Scalable Solar-Cell Manufacturing, H. Ji, B. Ren, L. Tsakalakos, 2011, ISBN 978-1-60511-300-5
- Volume 1324 — Compound Semiconductors for Energy Applications and Environmental Sustainability—2011, F. Shahedipour-Sandvik, L.D. Bell, K. Jones, B. Simpkins, D. Schaadt, M. Contreras, 2011, ISBN 978-1-60511-301-2
- Volume 1325 — Energy Harvesting—Recent Advances in Materials, Devices and Applications, R. Venkatasubramanian, H. Liang, H. Radousky, J. Poon, 2011, ISBN 978-1-60511-302-9
- Volume 1326E — Renewable Fuels and Nanotechnology, H. Idriss, 2011, ISBN 978-1-60511-303-6
- Volume 1327 — Complex Oxide Materials for Emerging Energy Technologies, J.D. Perkins, A. Ohtomo, H.N. Lee, G. Herranz, 2011, ISBN 978-1-60511-304-3
- Volume 1328E — Electrochromic Materials and Devices, M. Bendikov, D. Gillaspie, T. Richardson, 2011, ISBN 978-1-60511-305-0
- Volume 1329E — Nanoscale Heat Transfer—Thermoelectrics, Thermophotovoltaics and Emerging Thermal Devices, K. Nielsch, S.F. Fischer, B.J.H. Stadler, T. Kamins, 2011, ISBN 978-1-60511-306-7
- Volume 1330E — Protons in Solids, V. Peterson, 2011, ISBN 978-1-60511-307-4
- Volume 1331E — Frontiers of Solid-State Ionics, K. Kita, 2011, ISBN 978-1-60511-308-1
- Volume 1332E — Interfacial Phenomena and *In-Situ* Techniques for Electrochemical Energy Storage and Conversion, H. Li, 2011, ISBN 978-1-60511-309-8
- Volume 1333E — Nanostructured Materials for Energy Storage, J. Lemmon, 2011, ISBN 978-1-60511-310-4
- Volume 1334E — Recent Developments in Materials for Hydrogen Storage and Carbon-Capture Technologies, R. Zidan, 2011, ISBN 978-1-60511-311-1
- Volume 1335 — Materials, Processes, and Reliability for Advanced Interconnects for Micro- and Nanoelectronics—2011, M. Baklanov, G. Dubois, C. Dussarrat, T. Kokubo, S. Ogawa, 2011, ISBN 978-1-60511-312-8
- Volume 1336E — Interface Engineering for Post-CMOS Emerging Channel Materials, Y. Kamata, 2011, ISBN 978-1-60511-313-5
- Volume 1337 — New Functional Materials and Emerging Device Architectures for Nonvolatile Memories, D. Wouters, O. Auciello, P. Dimitrakis, Y. Fujisaki, E. Tokumitsu, 2011, ISBN 978-1-60511-314-2
- Volume 1338E — Phase-Change Materials for Memory and Reconfigurable Electronics Applications, B.-K. Cheong, P. Fons, B.J. Kooi, B.-S. Lee, R. Zhao, 2011, ISBN 978-1-60511-315-9
- Volume 1339E — Plasma-Assisted Materials Processing and Synthesis, J.L. Endrino, A. Anders, J. Andersson, D. Horwat, M. Vinnichenko, 2011, ISBN 978-1-60511-316-6
- Volume 1340E — High-Speed and Large-Area Printing of Micro/Nanostructures and Devices, T. Sekitani, 2011, ISBN 978-1-60511-317-3
- Volume 1341 — Nuclear Radiation Detection Materials—2011, A. Burger, M. Fiederle, L. Franks, K. Lynn, D.L. Perry, K. Yasuda, 2011, ISBN 978-1-60511-318-0
- Volume 1342 — Rare-Earth Doping of Advanced Materials for Photonic Applications—2011, V. Dierolf, Y. Fujiwara, T. Gregorkiewicz, W.M. Jadwisieniczak, 2011, ISBN 978-1-60511-319-7
- Volume 1343E — Recent Progress in Metamaterials and Plasmonics, G.J. Brown, J. Pendry, D. Smith, Y. Lu, N.X. Fang, 2011, ISBN 978-1-60511-320-3
- Volume 1344 — Functional Two-Dimensional Layered Materials—From Graphene to Topological Insulators, A.A. Balandin, A. Geim, J. Huang, D. Li, 2011, ISBN 978-1-60511-321-0
- Volume 1345E — Nanoscale Electromechanics of Inorganic, Macromolecular and Biological Systems, J. Li, S.V. Kalinin, M.-F. Yu, P.S. Weiss, 2011, ISBN 978-1-60511-322-7
- Volume 1346 — Micro- and Nanofluidic Systems for Materials Synthesis, Device Assembly and Bioanalysis—2011, R. Fan, J. Fu, J. Qin, A. Radenovic, 2011, ISBN 978-1-60511-323-4
- Volume 1347E — Nanoscale Heat Transport—From Fundamentals to Devices, A. McGaughey, M. Su, S. Putnam, J. Shiomi, 2011, ISBN 978-1-60511-324-1

MATERIALS RESEARCH SOCIETY SYMPOSIUM PROCEEDINGS

- Volume 1348E — Hybrid Interfaces and Devices, D.S. Ginley, N.R. Armstrong, G. Frey, R.T. Collins, 2011, ISBN 978-1-60511-325-8
- Volume 1349E — Quantitative Characterization of Nanostructured Materials, A. Kirkland, 2011, ISBN 978-1-60511-326-5
- Volume 1350E — Semiconductor Nanowires—From Fundamentals to Applications, V. Schmidt, L.J. Lauhon, T. Fukui, G.T. Wang, M. Björk, 2011, ISBN 978-1-60511-327-2
- Volume 1351 — Surfaces and Nanomaterials for Catalysis through *In-Situ* or *Ex-Situ* Studies, F. Tao, M. Salmeron, J.A. Rodriguez, J. Hu, 2011, ISBN 978-1-60511-328-9
- Volume 1352 — Titanium Dioxide Nanomaterials, X. Chen, M. Graetzel, C. Li, P.D. Cozzoli, 2011, ISBN 978-1-60511-329-6
- Volume 1353E — The Business of Nanotechnology III, L. Merhari, M. Biberger, D. Cruikshank, M. Theelen, 2011, ISBN 978-1-60511-330-2
- Volume 1354 — Ion Beams—New Applications from Mesoscale to Nanoscale, J. Baglin, D. Ila, G. Marletta, A. Öztarhan, 2011, ISBN 978-1-60511-331-9
- Volume 1355E — Biological Hybrid Materials for Life Sciences, L. Stanciu, S. Andreescu, T. Noguier, B. Liu, 2011, ISBN 978-1-60511-332-6
- Volume 1356E — Microbial Life on Surfaces—Biofilm-Material Interactions, N. Abu-Lail, W. Goodson, B.H. Lower, M. Fornalik, R. Lins, 2011, ISBN 978-1-60511-333-3
- Volume 1357E — Biomimetic Engineering of Micro- and Nanoparticles, D. Discher, 2011, ISBN 978-1-60511-334-0
- Volume 1358E — Organic Bioelectronics and Photonics for Sensing and Regulation, L. Torsi, 2011, ISBN 978-1-60511-335-7
- Volume 1359 — Electronic Organic and Inorganic Hybrid Nanomaterials—Synthesis, Device Physics and Their Applications, Z.-L. Zhou, C. Sanchez, M. Popall, J. Pei, 2011, ISBN 978-1-60511-336-4
- Volume 1360 — Synthesis and Processing of Organic and Polymeric Materials for Semiconductor Applications, A.B. Padmaperuma, J. Li, C.-C. Wu, J.-B. Xu, N.S. Radu, 2011, ISBN 978-1-60511-337-1
- Volume 1361E — Engineering Polymers for Stem-Cell-Fate Regulation and Regenerative Medicine, S. Heilshorn, J.C. Liu, S. Lyu, W. Shen, 2011, ISBN 978-1-60511-338-8
- Volume 1362 — Carbon Functional Interfaces, J.A. Garrido, K. Haenen, D. Ho, K.P. Loh, 2011, ISBN 978-1-60511-339-5
- Volume 1363 — Fundamental Science of Defects and Microstructure in Advanced Materials for Energy, B.P. Uberuaga, A. El-Azab, G.M. Stocks, 2011, ISBN 978-1-60511-340-1
- Volume 1364E — Forum on Materials Education and Evaluation—K-12, Undergraduate, Graduate and Informal, B.M. Olds, D. Steinberg, A. Risbud, 2011, ISBN 978-1-60511-341-8
- Volume 1365 — Laser-Material Interactions at Micro/Nanoscales, Y. Lu, C.B. Arnold, C.P. Grigoropoulos, M. Stuke, S.M. Yalisove, 2011, ISBN 978-1-60511-342-5
- Volume 1366E — Crystalline Nanoporous Framework Materials—Applications and Technological Feasibility, M.D. Allendorf, K. McCoy, A.A. Talin, S. Kaskel, 2011, ISBN 978-1-60511-343-2
- Volume 1367E — Future Directions in High-Temperature Superconductivity—New Materials and Applications, C. Cantoni, A. Ballarino, K. Matsumoto, V. Solovyov, H. Wang, 2011, ISBN 978-1-60511-344-9
- Volume 1368 — Multiferroic, Ferroelectric, and Functional Materials, Interfaces and Heterostructures, P. Paruch, E. Tsybal, M. Rzchowski, T. Tybell, 2011, ISBN 978-1-60511-345-6
- Volume 1369E — Computational Studies of Phase Stability and Microstructure Evolution, Z.-K. Liu, 2011, ISBN 978-1-60511-346-3
- Volume 1370 — Computational Semiconductor Materials Science, L. Liu, S.-H. Wei, A. Rubio, H. Guo, 2011, ISBN 978-1-60511-347-0

Prior Materials Research Society Symposium Proceedings available by contacting Materials Research Society