

PROCEEDINGS OF SPIE

Photonics for Solar Energy Systems VII

**Ralf B. Wehrspohn
Alexander N. Sprafke**

Editors

**23–25 April 2018
Strasbourg, France**

Sponsored by
SPIE

Cosponsored by
Strasbourg the Eurooptimist (France)
CNRS (France)
Investissements d'Avenir (France)
iCube (France)
Université de Strasbourg (France)

Cooperating Organisations
Photonics 21 (Germany)
EOS—European Optical Society (Germany)
Photonics Public Private Partnership (Belgium)
Comité National d'Optique et de Photonique (France)

Published by
SPIE

Volume 10688

Proceedings of SPIE 0277-786X, V. 10688

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

Photonics for Solar Energy Systems VII, edited by Ralf B. Wehrspohn,
Alexander N. Sprafke, Proc. of SPIE Vol. 10688, 1068801 · © 2018
SPIE · CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2502804

Proc. of SPIE Vol. 10688 1068801-1

The papers in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIEDigitalLibrary.org.

The papers reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from these proceedings:

Author(s), "Title of Paper," in *Photonics for Solar Energy Systems VII*, edited by Ralf B. Wehrspohn, Alexander N. Sprafke, Proceedings of SPIE Vol. 10688 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

ISSN: 0277-786X
ISSN: 1996-756X (electronic)

ISBN: 9781510619029
ISBN: 9781510619036 (electronic)

Published by
SPIE
P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445
SPIE.org
Copyright © 2018, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/18/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.

**SPIE. DIGITAL
LIBRARY**
SPIEDigitalLibrary.org

Paper Numbering: *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc. The CID Number appears on each page of the manuscript.

Contents

v	<i>Authors</i>
vii	<i>Conference Committee</i>

NANOPHOTONICS FOR PHOTOVOLTAICS

10688 03	Photonic structures for III-V//Si multi-junction solar cells with efficiency >33% (Invited Paper) [10688-2]
----------	--

NANOPHOTONICS FOR SOLAR MODULES

10688 05	Advanced module optics of textured perovskite silicon tandem solar cells [10688-4]
----------	---

NANOSTRUCTURED ANTIREFLECTION COATINGS AND ENERGY SAVING IN BUILDINGS

10688 0A	Antireflective nanotextures for monolithic perovskite-silicon tandem solar cells [10688-9]
10688 0B	Nanoimprinted sol-gel materials for antireflective structures on silicon solar cells [10688-10]
10688 0D	A combined experimental and theoretical study into the performance of multilayer vanadium dioxide nanocomposites for energy saving applications [10688-12]

SPECTRAL CONVERSION AND LIGHT TRAPPING

10688 0K	Modified PV structures with a nanostructured top electrode [10688-20]
----------	--

DISORDERED PHOTONIC NANOSTRUCTURES III

10688 0V	A slab waveguide source for discontinuous Galerkin time-domain methods [10688-31]
----------	--

POSTER SESSION

- 10688 0Y **Algorithm for precise positioning of the sun position in solar energy system using the GPS/GLONASS system** [10688-34]
- 10688 13 **Stochastic modelling of hopping charge carrier transport mechanism in organic photovoltaic structures** [10688-41]
- 10688 14 **Formation of nanostructures on the surface of CIGS films by picosecond laser with different beam patterns** [10688-43]
- 10688 15 **Plasmonic nanoscale antireflective coating for efficient CZTS solar cells** [10688-44]
- 10688 16 **Design methodology for selecting optimum plasmonic scattering nanostructures inside CZTS solar cells** [10688-45]
- 10688 17 **Design of optimum back contact plasmonic nanostructures for enhancing light coupling in CZTS solar cells** [10688-46]
- 10688 18 **Angle-selective reflection surface for energy efficiency** [10688-47]
- 10688 19 **Linear and nonlinear light sensors in SCC based maximum power point search algorithms** [10688-48]
- 10688 1A **The multi-input photovoltaic maximum power point tracker with integrated linear light sensor** [10688-49]
- 10688 1C **Wafer scale FeCl₃ intercalated graphene electrodes for photovoltaic applications** [10688-52]
- 10688 1D **Potassium-alumina-boron glass doped with copper ions for solar cell down-converters** [10688-51]
- 10688 1F **Conversion characteristics of silicon photovoltaic cells for optical beaming** [10688-42]
- 10688 1H **Analysis of mirrors geometry of V-trough solar concentrator in photovoltaic system** [10688-36]

Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Abdelraouf, Omar A. M., 15, 16, 17	Murphy, Conor, 1C
Albrecht, Steve, 0A	Nagata, Kohki, 18
Allam, Nageh K., 15, 16, 17	Ostrowski, Mariusz, 19, 1A
Bărar, Ana, 13	Otani, Yukitoshi, 18
Barnes, Matthew, 1C	Ozga, Monika, 0K
Becker, Christiane, 0A	Papakonstantinou, Ioannis, 0D
Benick, Jan, 03	Parkin, Ivan P., 0D
Bett, Andreas W., 03	Pietruszka, Rafał, 0K
Beutel, Paul, 03	Plachta, Kamil, 0Y, 1H
Blank, A. V., 1F	Romanov, Alexey E., 1D
Bläsi, Benedikt, 03, 05, 0B	Russo, Saverio, 1C
Bougrov, Vladislav E., 1D	Şchiopu, Paul, 13
Burger, Sven, 0A	Shaker, Ahmed, 15, 16, 17
Busch, Kurt, 0V	Shin, Dong-Wook, 1C
Cariou, Romain, 03	Shirshnev, Pavel S., 1D
Chebotareva, A. B., 1F	Shirshneva-Vaschenko, Elena V., 1D
Chen, Duote, 0A	Siefer, Gerald, 03
Craciun, Monica, 1C	Snezhnaia, Zheneveva G., 1D
Dănilă, Octavian, 13	Sol, Christian, 0D
De Sanctis, Adolfo, 1C	Stevens, L., 0B
Dimroth, Frank, 03	Suhareva, N. A., 1F
Ebisawa, Mizue, 18	Tockhorn, Philipp, 0A
Eisenhauer, David, 0A	Tucher, Nico, 03, 05, 0B
Feldmann, Frank, 03	Tugaenko, V. Yu., 1F
Glaubitt, W., 0B	Untila, G. G., 1F
Glunz, Stefan W., 03	Varytis, Paris, 0V
Godlewski, Marek, 0K	Viădescu, Marian, 13
Goldschmidt, Jan Christoph, 05	Walsh, Kieran K., 1C
Guldin, Stefan, 0D	Wang, Wenjun, 14
Hammerschmidt, Martin, 0A	Wellens, C., 0B
Hauser, Hubert, 03, 0B	Wiłkowski, Bartłomiej S., 0K
Hermle, Martin, 03	Yang, Huizhu, 14
Höhn, Oliver, 03, 05, 0B	
Huynh, Dan-Nha, 0V	
Isoda, Kazutaka, 18	
Jäger, Klaus, 0A	
Jahn, R., 0B	
Jiang, Gedong, 14	
Jones, Gareth, 1C	
Köppel, Grit, 0A	
Kost, T. N., 1F	
Lackner, David, 03	
Li, Ming, 14	
Li, Tao, 0D	
Łukasiewicz, Małgorzata, 0K	
Mănăilă-Maximean, Doina, 13	
Manley, Phillip, 0A	
Mei, Xuesong, 14	
Müller, C., 0B	

Conference Committee

Symposium Chairs

Francis Berghmans, Vrije Universiteit Brussel (Belgium)
Thierry Georges, Oxxius SA (France)
Harald Giessen, Universität Stuttgart (Germany)
Paul Montgomery, Université de Strasbourg (France)

Conference Chair

Ralf B. Wehrspohn, Fraunhofer-Institut für Werkstoffmechanik
(Germany)

Conference Co-chair

Alexander N. Sprafke, Martin-Luther Universität Halle-Wittenberg
(Germany)

Conference Programme Committee

Benedikt Bläsi, Fraunhofer-Institut für Solare Energiesysteme
(Germany)
Christoph J. Brabec, Friedrich-Alexander-Universität Erlangen-
Nürnberg (Germany)
Mark Brongersma, Geballe Laboratory for Advanced Materials
(GLAM) (United States)
Ning Dai, Shanghai Institute of Technical Physics (China)
Jung-Ho Lee, Hanyang University (Korea, Republic of)
Martin P. Pfeiffer, Heliatek GmbH (Germany)

Session Chairs

- 1 Nanophotonics for Photovoltaics
Ralf B. Wehrspohn, Fraunhofer-Institut für Mikrostruktur von Werkstoffen
und Systemen (Germany)
- 2 Nanophotonics for Solar Modules
Alexander N. Sprafke, Martin-Luther-Universität Halle-Wittenberg
(Germany)
- 3 Nanostructured Antireflection Coatings and Energy Saving in
Buildings
Benedikt Bläsi, Fraunhofer-Institut für Solare Energiesysteme
(Germany)

- 4 Thin-film and Tandem Solar Cells
Lucio C. Andreani, Università degli Studi di Pavia (Italy)
- 5 Spectral Conversion and Light Trapping
Thomas White, The Australian National University (Australia)
- 6 Nanowire Solar Cells and Disordered Photonic Nanostructures I
Marko Topic, University of Ljubljana (Slovenia)
- 7 Disordered Photonic Nanostructures II
Aimi Abass, Karlsruher Institut für Technologie (Germany)
- 8 Disordered Photonic Nanostructures III
Alexander N. Sprafke, Martin-Luther Universität Halle-Wittenberg (Germany)