

PROCEEDINGS OF SPIE

Thin Films for Solar and Energy Technology VII

**Louay A. Eldada
Michael J. Heben**
Editors

**9–10 August 2015
San Diego, California, United States**

Sponsored and Published by
SPIE

Volume 9561

Proceedings of SPIE 0277-786X, V. 9561

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

Thin Films for Solar and Energy Technology VII, edited by Louay A. Eldada, Michael J. Heben, Proc. of SPIE Vol. 9561,
956101 · © 2015 SPIE · CCC code: 0277-786X/15/\$18 · doi: 10.1117/12.2218488

Proc. of SPIE Vol. 9561 956101-1

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 SPIDigitalLibrary.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 *Thin Films for Solar and Energy Technology VII*, edited by Louay A. Eldada, Michael J. Heben, Proceedings of SPIE Vol. 9561 (SPIE, Bellingham, WA, 2015) Six-digit Article CID Number.

ISSN: 0277-786X

ISSN: 1996-756X (electronic)

ISBN: 9781628417272

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 © 2015, 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/15/\$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**

SPIDigitalLibrary.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 six-digit CID article numbering system structured as follows:

- The first four 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 *Authors*
- vii *Conference Committee*
- ix *Photochemical upconversion of light for renewable energy and more (Plenary Paper)*
[9562-202]

SESSION 1 SIMULATION, MODELLING, TESTING, AND METROLOGY

- 9561 02 **Combined optical-electrical finite-element simulations of thin-film solar cells: preliminary results** [9561-1]
- 9561 03 **Theoretical limits of the multistacked 1D and 2D microstructured inorganic solar cells**
[9561-2]

SESSION 2 PEROVSKITES

- 9561 07 **Investigation of degradation mechanisms of perovskite-based photovoltaic devices using laser beam induced current mapping** [9561-8]

SESSION 3 MATERIALS AND PROCESSES

- 9561 08 **Robust measurement of thin-film photovoltaic modules exhibiting light-induced transients**
[9561-5]
- 9561 09 **Sol-gel deposition and plasma treatment of intrinsic, aluminum-doped, and gallium-doped zinc oxide thin films as transparent conductive electrodes** [9561-9]

SESSION 4 LIGHT MANAGEMENT

- 9561 0E **Light absorption enhancement in elliptical nanohole array for photovoltaic application**
[9561-14]

POSTER SESSION

- 9561 0J **Simple one step spray process for CuInS_2 / In_2S_3 heterojunctions on flexible substrates for photovoltaic applications** [9561-19]
- 9561 0L **Characterization of $\text{Cu}_2\text{ZnSnS}_4$ thin films prepared by the sulfurization of co-sputtered metal precursors** [9561-21]

- 9561 0M **Device characteristics of antenna-coupled metal-insulator-metal diodes (rectenna) using Al_2O_3 , TiO_2 , and Cr_2O_3 as insulator layer for energy harvesting applications** [9561-24]
- 9561 0N **The electrodeposition of multilayers on a polymeric substrate in flexible organic photovoltaic solar cells** [9561-25]

Authors

Numbers in the index correspond to the last two digits of the six-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first four 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.

Abusnina, Mohamed, 0L	Xia, Zihuan, 0E
Al-Jassim, Mowafak, 0L	Yengel, Emre, 03
Anderson, Tom H., 02	Zhang, Zongyi, 0E
Balakrishnan, Kaushik, 09	Zhou, Jian, 0E
Benammar, Mohieddine A., 09	Zhu, Zhaozhao, 09
Cunha, Idaulo Jose, 0N	
Deceglie, Michael G., 08	
Ellingson, Randy J., 07	
Falco, Charles M., 09	
Faryad, Muhammad, 02	
Guedes, Andre F. S., 0N	
Guedes, Vilmar P., 0N	
Gurbuz, Yasar, 0M	
Heben, Michael J., 07	
Inac, Mesut, 0M	
Islam, M. Saif, 03	
Karaagac, Hakan, 03	
Kartha, C. Sudha, 0J	
Khanal, Rajendra R., 07	
Kumar, K. Rajeev, 0J	
Kurtz, Sarah R., 08	
Lakhtakia, Akhlesh, 02	
Liyanage, Geethika K., 07	
Mackay, Tom G., 02	
MacQueen, Rowan W., ix	
Mankowski, Trent, 09	
Mansuripur, Masud, 09	
Marion, Bill, 08	
Matin, Mohammad, 0L	
Moutinho, Helio, 0L	
Ozcan, Meric, 0M	
Pan, Yongdong, 0E	
Phillips, Adam B., 07	
Qin, Xuefei, 0E	
Schmidt, Timothy W., ix	
Shafique, Atia, 0M	
Shikoh, Ali Sehpar, 09	
Silverman, Timothy J., 08	
Singh, Rajendra, 02	
Song, Zhaoning, 07	
Souza, Monica L., 0N	
Tartari, Simone, 0N	
Thomas, Tifu, 0J	
Tompkins, Brandon L., 07	
Touati, Farid, 09	
Vijayakumar, K. P., 0J	
VJ, Logeeswaran, 03	
Watthage, Suneth C., 07	
Wu, Yonggang, 0E	

Conference Committee

Symposium Chair

Oleg V. Sulima, GE Global Research (United States)

Conference Chairs

Louay A. Eldada, Quanergy Systems, Inc. (United States)

Michael J. Heben, The University of Toledo (United States)

Conference Program Committee

Bulent Basol, EncoreSolar, Inc. (United States)

Howard M. Branz, National Renewable Energy Laboratory
(United States)

Paola Delli Veneri, ENEA (Italy)

David S. Ginley, National Renewable Energy Laboratory
(United States)

Ivan Gordon, imec (Belgium)

William N. Shafarman, University of Delaware (United States)

Ayodhya N. Tiwari, EMPA (Switzerland)

Session Chairs

- 1 Simulation, Modelling, Testing, and Metrology
Zhaoning Song, The University of Toledo (United States)
- 2 Perovskites
Carina Bronnbauer, imeet (Germany)
- 3 Materials and Processes
Zhaoning Song, The University of Toledo (United States)
- 4 Light Management
Michael G. Deceglie, National Renewable Energy Laboratory
(United States)

