

---

# Photovoltaics for the 21st Century 8

---

## Editors:

### **M. K. Sunkara**

University of Louisville  
Louisville, Kentucky, USA

### **T. Druffel**

University of Louisville  
Louisville, Kentucky, USA

## Sponsoring Divisions:



**Dielectric Science & Technology**



**Electrodeposition**



**Electronics and Photonics**



**Energy Technology**



**Industrial Electrochemistry and Electrochemical Engineering**



Published by

**The Electrochemical Society**

65 South Main Street, Building D  
Pennington, NJ 08534-2839, USA

tel 609 737 1902

fax 609 737 2743

[www.electrochem.org](http://www.electrochem.org)

**ecs**transactions™

**Vol. 50, No. 51**

---

Copyright 2013 by The Electrochemical Society.  
All rights reserved.

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

Published by:

The Electrochemical Society  
65 South Main Street  
Pennington, New Jersey 08534-2839, USA

Telephone 609.737.1902  
Fax 609.737.2743  
e-mail: [ecs@electrochem.org](mailto:ecs@electrochem.org)  
Web: [www.electrochem.org](http://www.electrochem.org)

ISSN 1938-6737 (online)  
ISSN 1938-5862 (print)  
ISSN 2151-2051 (cd-rom)

ISBN 978-1-62332-087-4 (Softcover)  
ISBN 978-1-60768-439-8 (PDF)

Printed in the United States of America.

---

**Table of Contents**

*Preface* *iii*

**Chapter 1  
Dye Sensitized Solar Cells**

Microstructural Controls of a Titania Electrode for Dye-Sensitized Solar Cells 3  
*A. Nakamura, T. Hyodo, Y. Shimizu*

Electrochemical Analysis for the Realization of Low Temperature Processed 11  
ZnO Dye-Sensitized Solar Cells  
*D. T. J. Bryant, M. Carnie, T. M. Watson, D. A. Worsley*

**Chapter 2  
Poster Session**

Effects of Annealing Pressure for Electrodeposited CuInSe<sub>2</sub> Solar Cell 25  
*T. W. Chang, W. H. Lee, Y. H. Su*

The Effect of TiO<sub>2</sub> Microstructure and Introduction of Silver Nanoparticles on 33  
Conversion Efficiency of Sb<sub>2</sub>S<sub>3</sub> Sensitized Semiconductor Solar Cells  
*S. Yoshioka, T. Mishima, M. Ihara*

ZnS Films Deposited by ALD for Solar Cell Applications 45  
*Y. Erkaya, D. Nminibapiel, K. Aryal, N. Hegde, G. Rajan, P. Boland,  
K. Zhang, H. Baumgart, S. Marsillac*

Application of Electrochemical Impedance Spectroscopy in Characterization of 49  
Mass- and Charge Transfer Processes in Dye-Sensitized Solar Cells  
*T. H. Nguyen, H. M. Tran, T. P. T. Nguyen*

Photovoltaic Properties in Al-doped ZnO/non-doped Zn <sub>1-x</sub> Mg <sub>x</sub> O/Cu <sub>2</sub> O Heterojunction Solar Cells <i>T. Minami, Y. Nishi, T. Miyata, S. Abe</i>	59
Improving the Efficiency of Polymer:Fullerene Bulk Heterojunction Solar Cells by Varying the Material Concentration in the Photoactive Layer <i>M. Samson, K. Latimer, P. Boland, K. Foe, G. Namkoong, H. Baumgart, T. M. Abdel-Fattah, M. S. Jeong</i>	69
Optical Management by Localized Surface Plasmon of Metal Nanoparticles and Application to a Solar Cell <i>K. Nam, H. Hachimura, M. Ihara</i>	77

### Chapter 3 CIGS

Electrodeposition of In-S based Buffer Layers for High Efficiency Cu(In,Ga)Se <sub>2</sub> based Solar Cells <i>E. Chassaing, N. Naghavi, S. Galanti, G. Renou, M. Soro, M. Bouttemy, A. Etcheberry, D. Lincot</i>	93
The Effect of a Heating Rate on the Properties of Cu <sub>2</sub> ZnSnS <sub>4</sub> Thin Films Solar Cells <i>K. D. Lee, S. W. Seo, D. K. Lee, H. Kim, M. J. Ko, B. Kim, D. H. Kim, J. Y. Kim</i>	101

### Chapter 4 Novel Photovoltaics

Optical Property of Random Inverted-Pyramid Textures on Si Surface by Etching with <i>N</i> -Fluoropyridinium Salts <i>M. Otani, J. Uchikoshi, K. Tsukamoto, T. Hirano, T. Nagai, K. Adachi, K. Kawai, K. Arima, M. Morita</i>	109
Author Index	115