

THE THIRD NANOSCIENCE AND
NANOTECHNOLOGY SYMPOSIUM 2010
(NNSB2010)

AN INTERNATIONAL SYMPOSIUM

Bandung, Indonesia June 16, 2010

EDITORS

Mikrajuddin Abdullah
Khairurrijal

CP 1284. *The Third Nanoscience and Nanotechnology Symposium 2010*
Edited by M. Abdullah and Khairurrijal
©2010 American Institute of Physics 978-0-7354-0838-8/10/S30.00

AIP
American Institute
of Physics

154

AIP CONFERENCE PROCEEDINGS ■ 1284

THE THIRD NANOSCIENCE AND NANOTECHNOLOGY SYMPOSIUM 2010 (NNSB2010)

Bandung, Indonesia June 16, 2010

EDITORS

Mikrajuddin Abdullah
Khairurrijal

*Department of Physics
Bandung Institute of Technology, Indonesia*

SPONSORING ORGANIZATIONS

Bandung Institute of Technology
Materials Research Society of Indonesia

All papers have been peer reviewed.

AIP

American Institute
of Physics



Melville, New York, 2010

AIP CONFERENCE PROCEEDINGS ■ 1284

CP 1284. *The Third Nanoscience and Nanotechnology Symposium 2010*

Edited by M. Abdullah and Khairurrijal

©2010 American Institute of Physics 978-0-7354-0838-8/10/S30.00

Editors

Mikrajuddin Abdullah
Khairurrijal
Department of Physics
Bandung Institute of Technology
Jalan Ganeca 10 Bandung 40132
Indonesia

Email: din@fi.itb.ac.id
krijal@fi.itb.ac.id

Authorization to photocopy items for internal or personal use, beyond the free copying permitted under the 1978 U.S. Copyright Law (see statement below), is granted by the American Institute of Physics for users registered with the Copyright Clearance Center (CCC) Transactional Reporting Service, provided that the base fee of \$30.00 per copy is paid directly to CCC, 222 Rosewood Drive, Danvers, MA 01923, USA. For those organizations that have been granted a photocopy license by CCC, a separate system of payment has been arranged. The fee code for users of the Transactional Reporting Services is: 978-0-7354-0838-8/10/\$30.00

© 2010 American Institute of Physics

Permission is granted to quote from the AIP Conference Proceedings with the customary acknowledgment of the source. Reproduction of an article or portions thereof (e.g., extensive excerpts, figures, tables, etc.) in original form or in translation, as well as other types of reuse (e.g., in course packs) require formal permission from AIP and may be subject to fees. As a courtesy, the author of the original proceedings article should be informed of any request for republication/reuse. Permission may be obtained online using Rightslink. Locate the article online at <http://proceedings.aip.org>, then simply click on the Rightslink icon/"Permission for Reuse" link found in the article abstract. You may also address requests to: AIP Office of Rights and Permissions, Suite 1N01, 2 Huntington Quadrangle, Melville, NY 11747-4502, USA; Fax: 516-576-2450; Tel.: 516-576-2268; E-mail: rights@aip.org.

L.C. Catalog Card No. 2010914426

CP 1284. *The Third Nanoscience and Nanotechnology Symposium 2010*
Edited by M. Abdullah and Khairurrijal

ISBN 978-0-7354-0838-8

©2010 American Institute of Physics 978-0-7354-0838-8/10/S30.00

ISSN 0094-243X

154

Printed in the United States of America

Nanocomposite Solar Cells from “Dirty” TiO₂ Nanoparticles

Sahrul Saehana, Rita Prasetyowati, Marina I. Hidayat, Fatimah A. Noor,
Mikrajuddin Abdullah^a, and Khairurrijal

*Physics of Electronics Materials Research Division,
Faculty of Mathematics and Natural Sciences
Institut Teknologi Bandung
^ae-mail address: din@fi.itb.ac.id*

Abstract. TiO₂ solar cells were fabricated consisting TiO₂ layer, TiO₂ nanocomposite layers, electrolyte polymer and counter electrode layer. It was found that TiO₂ nanocomposite layer that contains metal (Zn) contact could be conductive and make better charge transfer than pure TiO₂. Conversion efficiency 1.0% was achieved using TiO₂ nanocomposite. It indicates that using of TiO₂ nanocomposite is an effective technique for improvement of conversion efficiency.

Keywords: solar cells, TiO₂, Zn, nanocomposite, efficiency.

PACS: 81.07.-b, 62.23.Pq, 81.16.Rf

INTRODUCTION

TiO₂ SOLAR CELLS IS ONE OF ORGANIC SOLAR CELLS THAT HAVE ATTRACTED MUCH ATTENTION BECAUSE HIGH EFFICIENCY [1], EASY FABRICATION [2], LOW COST [3,4], NON-TOXIC MATERIALS [4], AND LONG TERM STABILITY [5].

TiO₂ SOLAR CELLS AND CONVENTIONAL SOLAR CELLS WORK IN DIFFERENT MECHANISM. IT CONSIST OF TiO₂ WORKING ELECTRODE ON TRANSPARENT CONDUCTING GLASS SUBSTRATE, COUNTER ELECTRODE, AND ELECTROLYTE [6].

THERE ARE MANY EFFORT TO MAKE HIGH EFFICIENCY SOLAR CELLS, SUCH AS: OPTIMIZE TiO₂ SIZE AND THICKNESS NANOPARTICLE LAYER [7,8], DOPED SOME METAL IN TiO₂ LAYER[9], USING NANOCOMPOSITE MATERIAL [10], USING POLYMER ELECTROLYTE [11], AND OPTIMIZE COUNTER ELECTRODE[4,12,13].

IN PREVIOUS STUDY, WE HAVE DEVELOPED TiO₂ SOLAR CELLS WITHOUT NANOCOMPOSITE LAYER, BUT ITS PERFORMANCE STILL LOWER [14]. IN THIS STUDY, WE USE TiO₂ NANOCOMPOSITE LAYER WHICH CONTAIN METAL (ZN) CONTACT IN SOLAR CELLS BECAUSE IT IS PROMISING FOR HIGH-PERFORMANCE SOLAR CELLS AND OFFERS POSSIBLE ELECTRON TRANSFER PATHS WITHOUT LOSING HIGH SURFACE AREA [15].

IN THIS PAPER, WE ATTEMPTED TO IMPROVE THE EFFICIENCY BY USING NANOCOMPOSITE MATERIAL TO INCREASE ELECTRON TRANSPORT AND PREVENT RECOMBINATION ELECTRON-HOLE. TiO₂ ELECTRODE WAS SYNTHESIZED BY SPRAY METHODS BECAUSE FAST AND CHEAP [16]. IN OTHER HAND, NANOCOMPOSITE LAYERS WERE USED TiO₂, ZN, LIOH AND PEG AND DEPOSITED BY DOCTOR BLADE METHODS.

EXPERIMENTAL

WE MADE A SIMPLE DESIGN OF SOLAR CELL, CONSISTING OF FIVE LAYERS: FIRST ELECTRODE (INDIUM TIN OXIDE, ITO), TiO₂ LAYER, TiO₂ NANOCOMPOSITE LAYER, POLYMER ELECTROLYTE LAYER, AND SECOND ELECTRODE (CARBON). INITIALLY,

ITO SUBSTRATE (1 CM² IN AREA) WAS WASHED WITH AQUADES FOR 15 MIN, FOLLOWED BY WASHING WITH ALCOHOL 70% FOR 30 MIN, BOTH IN AN ULTRASONIC BATH, AND THEN DRYING. SUSPENSION WAS MADE BY DISPERSING 10 G TiO₂ IN 10 ML AQUADES AND MIXED WITH A MAGNETIC STIRRER FOR 45 MIN. COATING OF ITO SUBSTRATE WITH THE TiO₂ WAS PERFORMED BY SPRAY METHOD AT TEMPERATURE OF 150°C. THE SPRAY PROCESS WAS REPEATED FOR 100 TIMES. FINALLY, THE THICK FILM OF TiO₂ ON THE ITO SUBSTRATE WAS HEATED ON A HOT PLATE AT 200°C FOR 30 MIN TO EVAPORATE WATER AND THE SINTERED AT 450°C FOR 30 MIN TO CREATE ELECTRIC CONTACTS BETWEEN TiO₂ PARTICLES. NANOCOMPOSITE WAS MADE BY DISSOLVING 1 GR TiO₂ IN 10 ML ALCOHOL 70% FOR 1 MIN, AND THEN 1 GR ZN WAS ADDED. AFTER THAT, 0.02 GR LIOH WAS ADDED AND 0.4 GR POLYETHYLENE GLYCOL (PEG), RESPECTIVELY.

POLYMER ELECTROLYTE WAS MADE BY DISSOLVING 0.5 G LIOH (BRATACHEM, INDONESIA) IN 10 ML AQUADES, INTO WHICH 0.8 G POLYETHYLENE GLYCOL (PEG, N = 20.000, MERCK) WAS THEN ADDED AND HEATED WITH STIRRING AT 110°C FOR 1 HOUR TO PRODUCE A GEL-LIKE ELECTROLYTE.

THE NANOCOMPOSITE DEPOSITED ON TiO₂ LAYER BY DOCTOR BLADE METHODS AND WAS HEATED ON A HOT PLATE AT 80°C FOR 5 MIN. THEN, ELECTROLYTE WAS ADDED MANUALLY INTO THE NANOCOMPOSITE LAYER. FINALLY, THE SOLAR CELL WAS SUCCESSFULLY MADE BY ADDED AL COUNTER ELECTRODE.

SCANNING ELECTRON MICROSCOPY (SEM) WAS USED TO MICROSTRUCTURAL CHARACTERIZATION OF TiO₂. ABSORBANCE OF TiO₂ ELECTRODE IN THE VISIBLE REGION WAS MEASURED USING UV-VIS SPECTROMETER. I-V CHARACTERIZATION OF SOLAR CELLS HAS BEEN MEASURED FOR SIMULATED FULL SUN ILLUMINATION (25.600 LUX). SHORT-CIRCUIT CURRENT (I_{sc}) AND OPEN-CIRCUIT VOLTAGE (V_{oc}) WERE MEASURED USING ELECTROMETER.

THE SANDWICHED STRUCTURE OF THIS SOLAR CELL IS SHOWN IN FIG. 1.

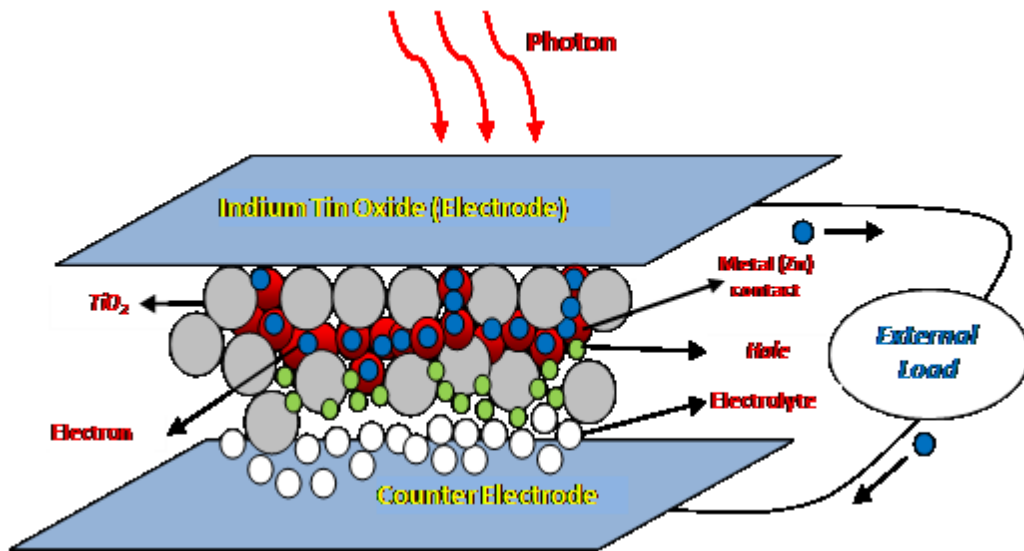


FIGURE 1. THE CROSS-SECTION VIEW OF TiO₂ NANOCOMPOSITE SOLAR CELL.

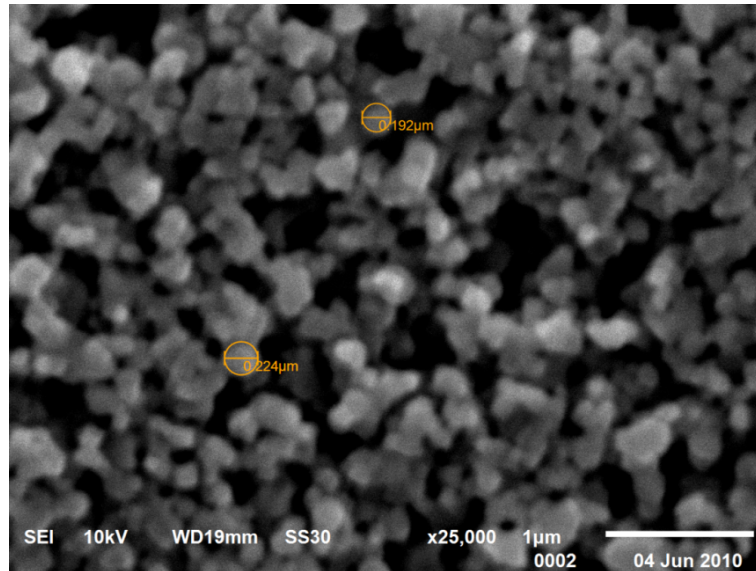


FIGURE 2. SCANNING ELECTRON MICROGRAPHS OF A TiO_2 NANOPARTICLE FILM SPRAY DEPOSITED FROM AQUEOUS SOLUTION ON ITO SUBSTRATE.

RESULT AND DISCUSSION

SURFACE MORPHOLOGY

FIG. 2 SHOWS THE SURFACE MORPHOLOGY OF TiO_2 FILMS DEPOSITED ON ITO GLASS USED IN THIS STUDY. IT ALSO SHOWED THAT THE MINIMUM SIZE OF TiO_2 PARTICLES WAS APPROXIMATELY 192 NM. ACCORDING TO RYAN O'HAYRE, ET. AL [7] THAT THIS SIZE LEAD TO SOLAR CELLS BETTER PERFORMANCE. EFFECT OF TiO_2 NANOPARTICLE SIZE TO SOLAR CELLS DISCUSSED MORE DETAILED IN [7]. THE PORE OF TiO_2 FILM WAS BETTER ENOUGH TO ELECTRON AND HOLES DIFFUSING. [17]

FIGURE 2 ALSO CLEARLY SHOWED THAT THE FILM TiO_2 WAS HOMOGENOUS, SO IT IS BETTER ENOUGH TO ABSORB PHOTON AND TO PRODUCE EXCITED ELECTRON. THE THICKNESS OF THE FILM WAS PREDICTED THE SEVERAL MICROMETER. IT MEANS THE SPRAY METHODS BETTER ENOUGH TO PREPARE THE WORKING ELECTRODE. THIS RESULT IS SIMILAR WITH JANNE HALME, ET. AL REPORT [16]. THIS TiO_2 LAYER ALSO WAS EXPECTED TO REDUCE THE RECOMBINATION OF CHARGES. [18]

ABSORBANCE OF TiO_2 WORKING ELECTRODE

IN THIS EXPERIMENT, WE USED LESS PURE TiO_2 POWDER FROM BRATACHEM (INDONESIA) IN MARKETS AND ITS ABSORPTION SPECTRA SHOWN FIGURE 3. ACCORDING TO MIKRAJUDDIN, ET. AL. REPORT THAT OUR TiO_2 'S WAS DOPED CARBON. [14]

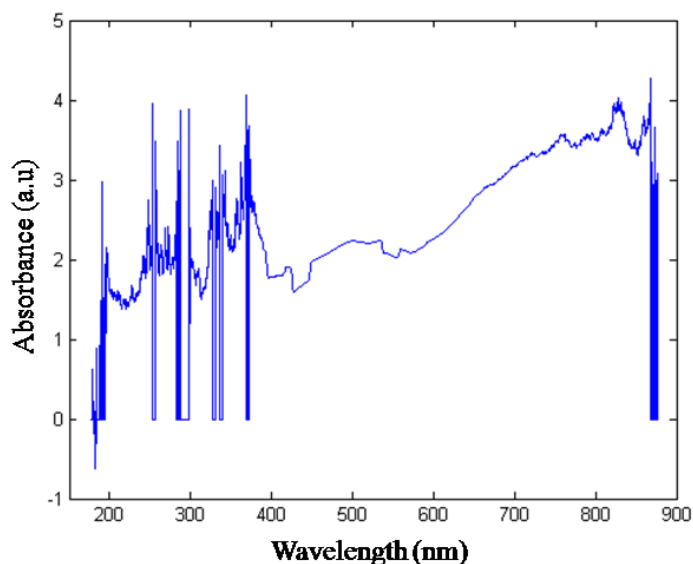


FIGURE 3. ABSORBANCE OF TiO_2 ELECTRODE.

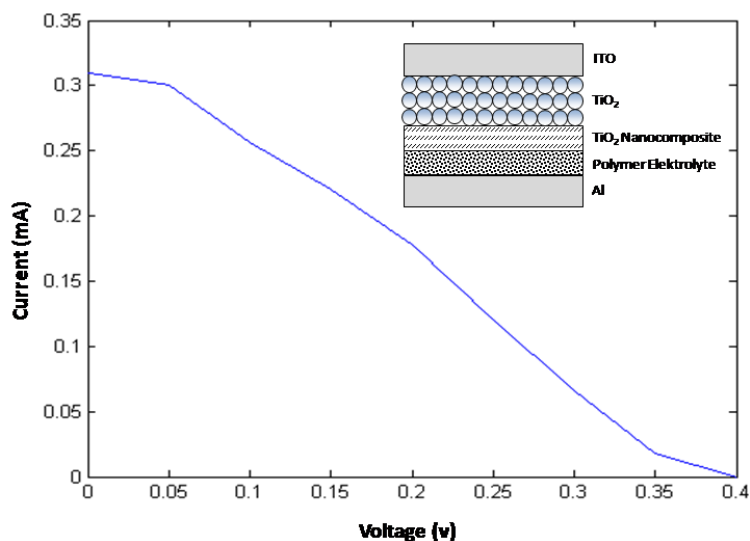


FIGURE 4. PHOTOCURRENT-VOLTAGE CHARACTERISTICS OF TiO_2 NANOCOMPOSITE SOLAR CELLS.

FIG. 3 SHOWS THAT THE TiO_2 ELECTRODES ARE ABLE TO ABSORB BROAD WAVELENGTH, RANGING FROM LESS THAN 200 NM TO LONGER THAN 800 NM. IT INDICATES THAT THIS ELECTRODE IS BETTER ENOUGH TO USE AS SOLAR CELLS. FIGURE 3 ALSO SHOWS THAT MAXIMUM WAVELENGTH AROUND 876 NM. THIS RESULT IS HIGHER THAN DA CHEN, ET. AL. REPORT [10] AND MIKRAJUDDIN, ET. AL [14]. THE DOPING LEVEL IN OUR SAMPLE IS HIGHER SO FURTHER REDUCTION IN THE EFFECTIVE BAND GAP IS EXPECTED.

PHOTOVOLTAIC PERFORMANCE OF NANOCOMPOSITE TiO_2 SOLAR CELL

FIG. 4 SHOWS I-V CHARACTERISTICS OF THESE SOLAR CELLS FOR ONE SUN ILLUMINATION (25.600 LUX). THE BETTER PERFORMANCE MAY CAUSED BY GOOD METAL CONTACT IN NANOCOMPOSITE LAYER. IN THE FIGURE 1, IT WAS APPEAR

THAT WHEN SOLAR CELL IS IRRADIATED BY SUNLIGHT, THE ELECTRON-HOLE PAIR FORMED. THE ELECTRONS OF TiO_2 ARE EXCITED FROM GROUND STATE TO EXCITED STATE BY ADSORBING PHOTONS AND THEN TRANSFER TO THE CONDUCTING GLASS THROUGH THE METAL (ZN) CONTACT LAYER. IN OTHER HAND, THE HOLE DIFUSE TO ELECTROLYTE. MEANWHILE, UPON REACHING THE TCO ELECTRODE, THE ELECTRONS ARE CONDUCTED TO THE COUNTER ELECTRODE VIA THE EXTERNAL CIRCUIT. THROUGH COUNTER ELECTRODE, THE ELECTRONS ARE ACCEPTED BY THE ELECTROLYTE. THIS MEANS, THAT THE HOLES IN THE ELECTROLYTE RECOMBINE WITH ELECTRONS TO FORM THE NEGATIVE CHARGE CARRIERS. [19]

HOWEVER, THE INCREASING PHOTOVOLTAIC PERFORMANCES ARE ATTRIBUTED TO SEVERAL REASONS. FIRST, ZN CONTACT LAYER SEEMS TO HAVE GOOD ELECTRON TRANSFER ABILITY (AS IN FIG 1). SECOND, IT IS THOUGHT THAT PACKING DENSITY CAN BE INCREASED BY MIXING TWO NANOMATERIALS WITH DIFFERENT SIZE AND MORPHOLOGY. THIRD, ENHANCEMENT OF LIGHT SCATTERING INDUCED BY THE NANOCOMPOSITES MAY BE IMPORTANT FACTOR [15]. IN THIS EXPERIMENT, ZN CONTACT LAYER ACTS AS ELECTRON PATH AND LEAD TO RAPID ELECTRON TRANSFER. FARTHER STUDY INCLUDING QUANTITATIVE ELECTRON DIFFUSION MEASUREMENT IS REQUIRED TO DETERMINE THE CONTRIBUTION OF THESE FACTORS.

TABLE 1 SHOWS THAT OUR SOLAR CELLS HAVE SHORT CIRCUIT CURRENT (I_{sc}) 0,31 MA, OPEN CIRCUIT VOLTAGE (V_{oc}) 0.4 VOLT, FILL FACTOR (FF) 0.29 AND EFFICIENCY 1.00%. THE LACK OF THESE SOLAR CELLS IS FILL FACTOR STILL LOWER. IT MAY BE CAUSED BY DIRECT CONTACT OF TiO_2 NANOCOMPOSITE TO THE ITO SURFACE AND LARGE OHMIC LOSS IN TiO_2 NANOCOMPOSITE LAYER [20,21].

TABLE 1. TiO_2 SOLAR CELLS PERFORMANCES.

MATERIAL OF TiO_2 NANOCOMPOSITE	SHORT CIRCUIT CURRENT I_{sc} (MA)	OPEN CIRCUIT VOLTAGE V_{oc} (V)	FILL FACTOR (FF)	EFFICIENCY (%)
TiO_2 +ZN+LIOH+PEG	0.31	0.40	0.29	1.00

FROM TABLE 1 WE OBTAINED THE EFFICIENCY OF THE SOLAR CELL IS HIGHER THAN OUR PREVIOUS STUDY [14]. OPTIMIZING THE PARAMETERS OF SYNTHESIS SUCH AS THE SIZE OF THE TiO_2 FILM, THE HOMOGENEITY OF NANOCOMPOSITE LAYER, THE HIGHER CONDUCTIVITY OF ELECTROLYTE LAYER, ETC, ARE REQUIRED.

CONCLUSION

WE HAVE SUCCESSFULLY DEVELOPED LOW COST SOLAR CELLS WITH A SOLAR TO ELECTRIC ENERGY CONVERSION EFFICIENCY ABOUT 1.00%. OUR SOLAR CELLS CONSIST OF TiO_2 ELECTRODE WAS MADE USING SPRAY TECHNIQUE, TiO_2 NANOCOMPOSITE, ELECTROLYTES AND AL COUNTER ELECTRODE. THESE SOLAR CELLS HAVE SHOWN BETTER PERFORMANCE IN TERMS OF SHORT CIRCUIT CURRENT (I_{sc}), OPEN CIRCUIT VOLTAGE (V_{oc}), AND ENERGY CONVERSION EFFICIENCY. HOWEVER, THE FILL FACTOR (FF) IS STILL LOWER. ZN CONTACT ACTS AS ELECTRON PATH AND LEAD TO RAPID ELECTRON TRANSFER. THEREFORE, THE NANOCOMPOSITE SOLAR CELLS SHOWED SIGNIFICANT POTENTIAL AS A LOW COST ALTERNATIVE TO CURRENTLY WIDELY-USED.

ACKNOWLEDGEMENTS

THIS WORK WAS SUPPORTED BY RESEARCH GRANTS FROM ASAHI GLASS FOUNDATION 2010 AND HIBAH STRATEGIS NASIONAL DIPA-ITB (BANDUNG INSTITUTE OF TECHNOLOGY) 2010.

REFERENCES

- CP 1284. *The Third Nanoscience and Nanotechnology Symposium 2010*
 Edited by. M. Abdullah and Khairurrijal
 ©2010 American Institute of Physics 978-0-7354-0838-8/10/S30.00

1. Y. CHIBA, A. ISLAM, Y. WATANABE, R. KOMIYA, N. KOIDE, AND L. HAN, *J. APPL. PHYS. JPN.* **45**, L638-L640 (2006).
2. Z. HUANG, X. LIU, K. LI, D. LI, Y. LUO, H. LI, W. SONG, L.Q. CHEN, AND Q. MENG, *ELECTROCHEM. COM.* **9**, 596-598 (2007).
3. B. O'REGAN AND M. GRÄTZEL, *NATURE* **353**, 737-740 (1991).
4. P. JOSHI, Y. XIE, M. ROPP, D. GALIPEAU, S. BAILEYB AND Q. QIAO, *EN. ENVIRON. SCI.* **2**, 426-429.(2009).
5. P.M. SOMMELING, M. SPÄTH, H.J.P. SMIT, N.J. BAKKER AND J.M. KROON, *J. PHOTOCHEM. PHOTOBIOLOG. A: CHEM.* **164**, 137-144 (2004).
6. M. GRÄTZEL, *J. PHOTOCHEM. PHOTOBIOLOG. C: PHOTOCHEM. REV.* **4**, 145-153 (2003).
7. B.R. O'HAYRE, M. NANU, J. SCHOONMAN, A. GOOSSENS, Q. WANG AND M. GRÄTZEL, *ADV. FUNCT. MATER.* **16**, 1566-1576 (2006).
8. S. ITO, M.K. NAZEERUDDIN, S.M. ZAKEERUDDIN, P. P'ECHY, P. COMTE, M. GRATZEL AND T. MIZUNO, A. TANAKA, AND T. KOYANAGI, *INT. J. PHOTOEN.* **V2009**, 1-8 (2009).
9. Y. WANG, Y. HAO, H. CHENG, J. MA, B. XU, W. LI AND S. CAI, *J. MATER. SCI.* **34**, 2773-2779 (1999).
10. D. CHEN, H. ZHANG, S. HU AND J. LI, *J. PHYS. CHEM. C* **112**, 117-122 (2008).
11. A.F. NOGUEIRA, J.R. DURRANT AND M.A. DE PAOLI, *ADV. MATER* **13**, 11, 826-830 (2001).
12. Q.W. JIANG, G.R. LI AND X.P. GAO, *SUPPLEM. MAT. (ESI) CHEM. COM.*, (2009).
13. Z. HUANG, X. LIU, K. LI, D. LI, Y. LUO, H. LI, W. SONG, L.Q. CHEN AND Q. MENG, *ELECTROCHEM. COM.* **9**, 596-598 (2007).
14. M. ABDULLAH, I. NURMAWARTI, H. SUBIANTO, KHAIRURRIJAL AND H. MAHFUDZ, *J. NANO SAINTEK.* **3**, (2010).
15. K. ASAGOE, Y. SUZUKI, S. NGAMSINLAPASATHIAN AND S. YOSHIKAWA, *J. PHYS.: CONF. SER.* **61**, 1112-1116 (2007).
16. J. HALME, J. SAARINEN AND P. LUND, *SOL. ENERGY MATER. SOL. CELLS.* **90**, 887-899 (2006).
17. H.J. SNAITH, R.H. BAKER, P. CHEN, I. CESAR, S.M. ZAKEERUDDIN AND M. GRÄTZEL, *J. NANOTECHNOL.* **19**, (2008)
18. M. WU, Z.H. YANG, Y.H. JIANG, J.J. ZHANG, S.Q. LIU AND Y.M. SUN, *J SOLID. STATE ELECTROCHEM.*, DOI 10.1007/S10008-009-0866-6 (2009).
19. R. SASTRAWAN, PH.D THESIS, UNIVERSITÄT FREIBURG (2006).
20. J.H. AHN, R.S. MANE, V.V. TODKAR AND S.H. HAN, *INT. J. ELECTROCHEM. SCI.* **2**, 517-522 (2007).
21. K.J. JIANG, Y.L. SUN, K.F. SHAO, J.F. WANG, AND L.M. YANG, *CHINESE CHEM. LETT.* **14**, 1093-1096 (2003).

CP 1284. *The Third Nanoscience and Nanotechnology Symposium 2010*
Edited by, M. Abdullah and Khairurrijal
©2010 American Institute of Physics 978-0-7354-0838-8/10/S30.00



ISBN 978-0-7354-0838-8
ISSN 0094-243X

