CURRICULAM VITAE

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Education & Experiences:

Post Doctoral Position: Post Doctoral Researcher at CNR-IMM, Catania, Italy (15th June 2018 to 14th June 2019) - Supervisor: *Prof. Salvatore A. Lombardo (CNR-IMM, Italy)*

PhD (Chemical Sciences): Course work score: **9.02/10** (CSIR-CMERI & AcSIR, India, 2013-2017) - Supervisors: *Dr. Biswanath Mondal (CSIR-CMERI, India) and Dr. Kalisadhan Mukherjee (Pandit Deendayal Petroleum University, India)*

M.Sc in Physical Chemistry: 69.00 % (828/1200) (The University of Burdwan, 2009-2011)

B.Sc in Chemistry: 55.00 % (440/800) (Presidency College, University of Calcutta, 2006-2009)

10+2 standard: 91.10 % (911/1000) (Pandua SBS High School, WBCHSE, 2006)

10th standard: 86.25 % (690/800) (Pandua SBS High School, WBBSE, 2004)

Research:

Research Experience (Including PhD tenure - Jan 2013 to Nov 2017) 2011-2017 (CSIR-Central Mechanical Engineering Research Institute, India) (~ 66 months): Experience in the synthesis of nanostructural as well as aggregate semiconductiong oxide (e.g. ZnO) and its application in Dye Sensitized Solar Cell (DSSC). Additionally experience in handling some essential sophisticated lab instruments like dip coater, spin coater, UV-visible spectrophometer, FTIR spectrophometer, thermal analyser (TGA, DTA, DSC), surface analyser (BET), quantum efficiency measurement system, cyclic voltametry and impedance, zetasizer, ultrasonic cleaner, furnaces etc.

Post-PhD Experience (15th June 2018 - 14th June 2019): Post Doctoral Researcher at Consiglio Nazionale delle Ricerche-Istituto per la microelettronica e microsistemi (CNR-IMM), Catania, Italy (June 2018-June 2019-12 months tenure). Experience in solar water splitting based on alkaline electrolyzers and fabrication of electrodes for HER & OER phenomena. During the research work, additional scope to learn the operation of the Kiethley power sources for electrochemical experiments and working with three electrode system. Ability to design and construct electrolyzers and operate it with solar cell panel to generate the required voltage for solar water splitting.

Research Interests:

· Nanomaterials: Synthesis and characterizations
· Photovoltaics & Energy storage application
· Photo-electrochemistry & materials chemistry
· Electrodes & Wet chemical methods
· Dye Sensitized Solar Cell (DSSC) & solar water splitting
· Renewable Energy

PhD awarded (in Chemical Sciences): November 15, 2017 (*Academy of Scientific & Innovative Research (AcSIR), India and CSIR-Central Mechanical Engineering Research Institute (CSIR-CMERI), Durgapur, India*

Thesis title: *Synthesis of chemically modified zinc oxide and investigation on their performances as photo-anodes for dye sensitized solar cell application*

Funding agency:
Council of Scientific & Industrial Research (CSIR), India (2011-2013 & 2015-2017)

Research Experience: As **JRF (GATE)** (Salary: Rs 16000 per month consolidated) from **Oct 2011 to Oct 2013** & as **Project Assistant Level III** (Salary: Rs 28000 per month consolidated) from **Mar 2015 to Mar 2017** at **CSIR-CMERI, Durgapur, India**

Course work syllabus during PhD:

1. Research Methodology
2. Analytical Tools and Instrumentation
3. Advanced Physical Chemistry
4. Advanced Coordination Chemistry
5. Advanced Catalysis
6. Advanced Inorganic Chemistry
7. Porous Structure

Journal Publications:

1. **D. Sengupta**, P. Das, U. Kasinadhuni, B. Mondal, *K. Mukherjee*. Morphology induced light scattering by zinc oxide polydisperse particles: Promising for dye sensitized solar cell application. *Journal of Renewable and Sustainable Energy 2014, 6, 063114*. (AIP Publishing)
2. **D. Sengupta**, B. Mondal, *K. Mukherjee*. Visible light absorption and photo-sensitizing properties of spinach leaves and beetroot extracted natural dyes. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 2015, 148, 85-92*. (Elsevier)
3. **D. Sengupta**, P. Das, B. Mondal, *K. Mukherjee*. Study on the dye sensitized solar cell characteristics of zinc oxide photo-anode Prepared on two different transparent conducting substrates. *Material Focus 2015, 4, 379-384*. (American Scientific Publishers)

4. **D. Sengupta**, P. Das, B. Mondal, *K. Mukherjee*. Effects of doping, morphology and film-thickness of photo-anode materials for dye sensitized solar cell application-A review. *Renewable and Sustainable Energy Reviews 2016, 60, 356-376*. (Elsevier)
5. **D. Sengupta**, B. Mondal, *K. Mukherjee*. Genesis of flake like morphology and dye sensitized solar cell performance of Al doped ZnO particles: A study. *Journal of Nanoparticle Research 2017, 19, 100*. (Springer)
6. **D. Sengupta**, B. Mondal, *K. Mukherjee*. Structural features and dye sensitized solar cell performance of chemically synthesized F doped ZnO particles. *Journal of Solid State Electrochemistry 2018, 22, 227-235*. (Springer)
7. P. Das, **D. Sengupta**, B. Mondal, *K. Mukherjee*. A review on metallic ion and nonmetal doped titania and zinc oxide photo-anodes for dye sensitized solar cells. *Reviews in Advanced Sciences and Engineering 2015, 4, 271-290*. (American Scientific Publishers)
8. P. Das, **D. Sengupta**, U. Kasinadhuni, B. Mondal, *K. Mukherjee*. Nano-crystalline thin and nano-particulate thick TiO_2 layer: Cost effective sequential deposition and study on dye sensitized solar cell characteristics. *Materials Research Bulletin 2015, 66, 32-38*. (Elsevier)
9. K. Usha, *B. Mondal*, **D. Sengupta**, P. Das, K. Mukherjee, P. Kumbhakar. Development of multilayered nanocrystalline TiO_2 thin films for photovoltaic application. *Optical Materials 2014, 36, 1070-1075*. (Elsevier)
10. K. Usha, *B. Mondal*, **D. Sengupta**, P. Das, K. Mukherjee, P. Kumbhakar. Fabrication of dye sensitized solar cell using nanocrystalline TiO_2 and optical characterization of photoanode. *Nanoscience and Nanoengineering 2014, 2, 29-35*. (HRPUB)
11. K. Usha, *B. Mondal*, **D. Sengupta**, P. Kumbhakar. Photo-conversion efficiency measurement of dye-sensitized solar cell using nanocrystalline TiO_2 thin film as photo-anodes. *Measurement 2015, 61, 21-26*. (Elsevier)

International/National conference proceedings:

(1) **D. Sengupta**, P. Das, U. Kasinadhuni, B. Mondal, *K. Mukherjee*. Zinc oxide photo-anode based chlorophyll sensitized solar cell. ISBN 978-81-928552-1-9; pp 298-302. *International Conference on Emerging Materials and Processes (ICEMP-2014)*, CSIR-Institute of Minerals & Materials Technology (IMMT) Bhubaneswar; 26-28 Feb, 2014.

International/National conference presentations/posters:

(1) **D. Sengupta**, B. Mondal, *K. Mukherjee*. Aluminum-doping in zinc oxide: Effect on the morphology, electrical properties and dye sensitized solar cell characteristics. *The First International Conference on Emerging Materials: Characterization and Applications (EMCA 2014)*. CSIR-Central Glass & Ceramic Research Institute, December 4-6, 2014.

(2) **D. Sengupta**, K. Usha, *K. Mukherjee*, *B. Mondal*. Addressing the photovoltaic and ethanol sensing applications of auto-combustion route derived zinc oxide powder. *National Seminar on Advanced Functional Materials (NSAFM-2013)*, CSIR- Central Mechanical Engineering Research Institute (CMERI), Durgapur, Jan, 2013.

(3) K. Usha, *B. Mondal*, **D. Sengupta**, P. Kumbhakar. Electrodes with modified n-TiO_2 particles for use in dye sensitized solar cells. *Nanosolar-2012*, Kochi, 24th Feb, 2012.

International/National conference participation:

(1) *Royal Society of Chemistry (RSC) India Roadshow* at Indian Association for the Cultivation of Science (IACS), Kolkata, India on February, 2013

(2) National Conference on Advanced Functional Materials Processing & Manufacturing (NCAFMPM-2017), CSIR- Central Mechanical Engineering Research Institute (CMERI), Durgapur, February 2-3, 2017.

International/National conference abstract acception:

(1) **Dipanjan Sengupta**, Stefania Maria Serena Privitera, Rachela Gabriella Milazzo, Corrado Bongiorno, Silvia Scalese, Salvatore Lombardo. Ni-Fe Electrodes by impregnation for efficient oxygen evolution reaction in water splitting systems. *FisMat-2019*, CNISM, CNR, and University of Catania, Catania, September 30 - October 04, 2019, Italy.

Projects accomplished:

(1) Nurturing social consciousness on renewable energy sources and development of a laboratory based LED solar indicator/lamp (CSIR-800 topic; Presented on 05.01.2016)

Scholarships / Awards:

(1) Rural Scholarship in 2002 (Standard VIII)
(2) All India GATE 2010 in CHEMISTRY: All India Rank 294 (Percentile: 96.35)
(3) All India GATE 2012 in CHEMISTRY: All India Rank 555 (Percentile: 93.78)
(4) CSIR-JRF (GATE) Fellowship (2011-2013)
(5) CSIR-Project Fellowship (2015-2017)
(6) Abdus Salam International Centre for Theoretical Physics (ICTP), Training and Research in Italian Laboratories (TRIL) fellowship (2018-2019)

References:

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Declaration:

I hereby declare that the above written particulars are true to the best of my knowledge and belief.

Dipanjan Sengupta

AIP | Journal of Renewable and Sustainable Energy

Morphology induced light scattering by zinc oxide polydisperse particles: Promising for dye sensitized solar cell application

D. Sengupta, P. Das, U. Kasinadhuni, B. Mondal, and K. Mukherjee

Citation: Journal of Renewable and Sustainable Energy **6**, 063114 (2014); doi: 10.1063/1.4904435
View online: http://dx.doi.org/10.1063/1.4904435
View Table of Contents: http://scitation.aip.org/content/aip/journal/jrse/6/6?ver=pdfcov
Published by the AIP Publishing

JOURNAL OF RENEWABLE AND SUSTAINABLE ENERGY **6**, 063114 (2014)

Morphology induced light scattering by zinc oxide polydisperse particles: Promising for dye sensitized solar cell application

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(Received 25 July 2014; accepted 5 December 2014; published online 17 December 2014)

In the present work, polydisperse zinc oxide composed of nano and submicron size particles is used to prepare photo-anode for dye sensitized solar cell. The particles are synthesized through auto-combustion route and characterized in terms of their phase formation behavior as well as morphological properties. UV-vis diffused reflectance spectra of the prepared photo-anode show its promising dye uptake and incident light scattering behavior. The prepared cells reveal ~3.2% solar to electric conversion efficiency. The fairly acceptable efficiencies of the cells are attributed due to the efficient scattering of incident light and reasonable dye uptake within polydisperse particulate photo-anode. © *2014 AIP Publishing LLC*.
[http://dx.doi.org/10.1063/1.4904435]

I. INTRODUCTION

Dye sensitized solar cells (DSSCs) are attractive as simple and low-cost renewable energy source. A typical DSSC is usually composed of photo-anode, counter electrode, electrolyte, and photo-sensitized dye. The operating principle of the DSSC has been discussed well in various literatures.[1,2] Briefly, under the exposure of sunlight, the dye molecules become photo excited and inject electrons into the photo-anode. The original configuration of the dye is then subsequently regenerated by electron donation from the electrolyte. The quick regeneration of the dye by the electrolyte intercepts recombination of the electrons injected into the photo-anode. The electrolyte is regenerated at the counter electrode when the circuit is completed by an external load. Among the components, photo-anode significantly contributes in collection and transportation of photo-excited electron from dye to external electric circuit. Usually, wide band gap semiconducting metal oxides (e.g., ZnO, TiO_2, etc.) are deposited over transparent conducting substrate to prepare the photo-anodes.

After the discovery of DSSC by Professor Gratzel in 1991, the traditional titania based photo-anodes have been studied extensively by the researchers.[2–8] In contrast, zinc oxide (ZnO) received less attention in spite of having comparable band gap and chemical properties like titania.[9,10] Among all the wide band gap semiconducting metal oxides explored for DSSC application, ZnO presents superior bulk electron mobility (more than 1 order of magnitude higher than anatase TiO_2) which enable it for faster transport of photo injected electrons.[11,12] Additionally, ZnO can be tailored into various morphologies from nano to micron scale using simple and cost effective wet chemical route.[13,14] The irreversible electron injection from dye molecules to the conduction band of ZnO has also been verified experimentally.[12] Such combined distinctive

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Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 148 (2015) 85–92

Contents lists available at ScienceDirect

Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy

journal homepage: www.elsevier.com/locate/saa

Visible light absorption and photo-sensitizing properties of spinach leaves and beetroot extracted natural dyes

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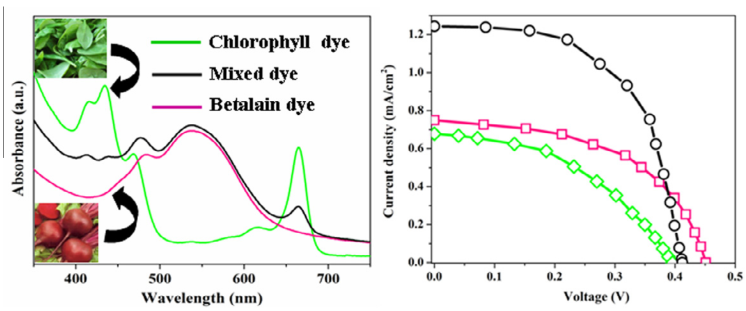
HIGHLIGHTS

- Chlorophyll and betalain dyes are extracted from spinach leaves and beet roots.
- Temperature and pH dependent UV characteristics of these dyes are investigated.
- Zinc oxide (ZnO) particles are synthesized and characterized using XRD, FTIR, SEM.
- Dye sensitized solar cells are fabricated using extracted dyes and ZnO particles.
- Mixture of aforesaid dyes shows better efficiency than individual dyes.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 20 June 2014
Received in revised form 10 March 2015
Accepted 27 March 2015
Available online 4 April 2015

Keywords:
Natural dye
Zinc oxide
UV–vis spectroscopy
Dye sensitized solar cell

ABSTRACT

Herein, chlorophyll and betalain dyes are extracted from fresh spinach leaves and beetroots. Fourier transform infrared spectra are used to identify the characteristic peaks of the extracted dyes. UV–vis light absorption characteristics of the dyes and their mixed counterpart are investigated by varying their pH and temperature. These dyes are used as photo sensitizer for fabrication of zinc oxide photo-anode based dye sensitized solar cells (DSSCs). The photo-voltaic characteristics of the developed DSSCs are measured under simulated solar light (power of incident light 100 mW cm^{-2} from Air Mass 1.5G). The solar to electric conversion efficiencies for the chlorophyll, betalain and mixed dye based solar cells are estimated as 0.148%, 0.197% and 0.294% respectively. The highest conversion efficiency for mixed dye based solar cell is attributed due to the absorption of wider range of solar spectrum.

Introduction

The most abundant source of renewable energy on earth is sun light. The proper use of solar energy in a well organized, economical manner is a challenging research issue. Various kinds of solar cells (e.g., inorganic, polymer based p–n junction photovoltaic cells, quantum dot and dye sensitized solar cell, etc.) are developed till date for harvesting of solar light into electrical energy [1–4]. In this regard, dye sensitized solar cells (DSSCs) have attracted significant academic and technological attention due to their simple and cost-effective fabrication [5]. A typical DSSC is usually composed of photo-anode (semiconducting metal oxides coated on transparent conducting glass substrate), photo-sensitizer (dye), counter electrode and electrolyte [6]. The operating principle of DSSC is described well in various literatures [7]. As reviewed, for DSSCs, dye and metal oxide play significant role in the generation, injection and transportation of photo-excited electrons. The choice of photo-sensitizers in solar cells is directed mostly based on their visible light absorption characteristics, stability and cost. Several

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http://dx.doi.org/10.1016/j.saa.2015.03.120
1386-1425/

Renewable and Sustainable Energy Reviews 60 (2016) 356–376

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Effects of doping, morphology and film-thickness of photo-anode materials for dye sensitized solar cell application – A review

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A R T I C L E I N F O

Article history:
Received 16 November 2015
Received in revised form
12 January 2016
Accepted 20 January 2016

Keywords:
Titania
Zinc oxide
Photo-anode
Dye sensitized solar cell

A B S T R A C T

Dye sensitized solar cells are attractive as simple and low cost renewable energy source. In dye sensitized solar cells, photo-anode plays significant role for collection and transportation of photo-excited electrons from dye to external electric circuit. Usually, wide band gap semiconducting metal oxides like titania, zinc oxide etc are deposited over transparent conducting substrate to prepare the photo-anodes. The performances of the photo-anodes depend on the band gap, morphology, composition of metal oxides and thickness of metal oxide layers. Enormous research efforts have been accomplished for studying the photo-voltaic characteristics of the dye sensitized solar cells by varying the aforementioned influencing parameters. However, the research activities executed towards the modification of photo-anode for dye sensitized solar cell application are quite scattered. It seems therefore important to summarize the research efforts executed towards the development of photo-anode for dye sensitized solar cell. In the present review, the effect of influencing parameters on the photo-voltaic characteristics of photo-anode for dye sensitized solar cell application is discussed. The descriptions have been made by summarizing the relevant literature reports.

Contents

Abbreviations: DSSC, Dye sensitized solar cell; J_{SC}, Short circuit current density; V_{OC}, Open circuit voltage; FF, Fill factor; FTO, Fluorinated tin oxide; ITO, Indium tin oxide; nm, Nanometer; μm, Micrometer; η, Efficiency; AM, Air Mass; NS, Nanospindles; NF, Nanofibers; NW, Nanowires; NeHS, Nano-embossed hollow spherical; PC, Photonic crystals; SEM, Scanning electron microscopy; FESEM, Field emission scanning electron microscopy; TEM, Transmission electron microscopy; EIS, Electrochemical impedance spectroscopy; 1/2/3D, One/Two/Three dimensional

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http://dx.doi.org/10.1016/j.rser.2016.01.104
1364-0321/

J Nanopart Res (2017) 19:100
DOI 10.1007/s11051-017-3802-1

RESEARCH PAPER

Genesis of flake-like morphology and dye-sensitized solar cell performance of Al-doped ZnO particles: a study

D. Sengupta · B. Mondal · K. Mukherjee

Received: 28 October 2016 / Accepted: 21 February 2017

Abstract In dye-sensitized solar cell (DSSC) application, the particulate morphologies of photo-anode facilitate efficient dye loading and thus lead to better photoconversion efficiency than their thin film counterpart. However, till date, the electronic and optical properties as well as the DSSC application of Al-doped ZnO (AZO) particles as photo-anode material is studied less than thin films. Herein, phase formation behavior, morphology evolution, optical properties, and dye-sensitized solar cell performance of wet chemically prepared ZnO and AZO (dopant level: 1–4 mol%) particles are studied. It is found that Al doping modulates significantly the ZnO morphology which in turn results the maximum dye adsorption as well as best photoconversion efficiency at optimum dopant concentration. Specifically, the nanoparticle of ZnO turns predominantly to flake-like morphology with a higher surface area when 2 mol% Al is doped. Such morphology modulation is expected, since the crystallinity, lattice parameters, and lattice strain of ZnO changes appreciably with Al doping. The variations of optical properties (absorbance, diffused reflectance, and band gap) of AZO materials as compared to primitive ZnO are also identified through UV-vis studies. An attempt is made here to correlate the structural features with the photovoltaic performances of ZnO and AZO.

Keywords Zinc oxide · Doping · X-ray diffraction · Electron microscopy · Dye-sensitized solar cell · Energy conversion

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Introduction

Zinc oxide (ZnO) is an important *n* type II-VI semiconducting material which has widespread applications in piezoelectric transducers, optical waveguides, surface acoustic wave filters, chemical/gas sensors, catalysts, light-emitting diodes, and solar cells (Punnoose et al. 2014; Aeugle et al. 1991; Manekkathodi et al. 2013; Kadota and Kando 2003; Zhao et al. 2015b; Das et al. 2016b; Tian et al. 2012; Lim et al. 2006; Kathalingam et al. 2014). In traditional Si-based p-n junction solar cells, the use of ZnO is not studied very frequent. However, in sensitizer-based solar cells (e.g., dye-sensitized solar cells (DSSCs)) ZnO has been paid considerable attention as photo-anode material (Anta et al. 2012; Lin et al. 2011; Tan et al. 2013; Martinson et al. 2007). Photo-anode, an essential component of a DSSC, is composed of a wide-band gap semiconducting material having fast electron transport ability. In this context, ZnO, a wide-band-gap (~3.2 eV) semiconductor with reasonably high electron mobility (205 $cm^2\ V^{-1}\ s^{-1}$ at room temperature) has become an attractive choice to

J Solid State Electrochem
DOI 10.1007/s10008-017-3743-8

CrossMark

ORIGINAL PAPER

Structural features and dye-sensitized solar cell performance of chemically synthesized F doped ZnO particles

D. Sengupta [1,2] · B. Mondal [1,2] · K. Mukherjee [1,2]

Received: 14 May 2017 / Revised: 18 August 2017 / Accepted: 20 August 2017

Abstract In dye-sensitized solar cell (DSSC) application, the particulate morphologies of photo-anode facilitate efficient dye loading and thus lead to better photo-conversion efficiency than their thin film counterpart. However, till date, the electronic and optical properties as well as the DSSC application of F doped ZnO (FZO) particles as photo-anode material is hardly found in the open literature. Herein, crystalline nature, morphology evolution, optical properties and dye-sensitized solar cell performance of wet chemically prepared ZnO and FZO (dopant level 1–4 mol%) particles are studied. It is found that F doping modulates significantly the ZnO morphology which in turn results the maximum dye adsorption as well as best photo-conversion efficiency at optimum dopant concentration. In particular, when 3 mol% F is doped in ZnO, the photo-conversion efficiency for DSSC application reaches maximum. An attempt is made here to correlate the structural features with the photo-voltaic performances of ZnO and FZO.

Keywords Zinc oxide · F doped ZnO · X-ray diffraction · Electron microscopy · Dye-sensitized solar cell

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s10008-017-3743-8) contains supplementary material, which is available to authorized users.

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Introduction

Zinc oxide (ZnO), an important "n"-type semiconducting material has wide range of applications which include but not limited to photocatalysts, varistors, optical waveguides, surface acoustic wave filters, chemical/ gas sensors, catalysts, light-emitting diodes, solar cells, etc. [1–9]. To improve further the performance of ZnO in aforementioned applications, various dopants are introduced into the ZnO lattice. Cation (e.g., Al^{3+}, Mg^{2+}) doping in ZnO is very much popular and substantial research activities are reported in the related area [10–14]. On contrary to cation doping, the doping of anions in ZnO lattice is studied less. However, similar to the cations, anionic dopants may also change the structural and morphological features as well as optical and electrical properties of ZnO [15–17]. Fluoride (F) as anionic dopant can be promising for replacing oxygen ion of ZnO since its ionic radius (F^-, 1.17 Å) is in close proximity with oxygen (O^{2-}, 1.24 Å) [18]. Additionally, the substitution of oxygen by fluorine introduces excess charge within the ZnO lattice resulting higher electron density [19]. In the present work, structural features (crystallinity, morphology), optical properties and dye-sensitized solar cell (DSSC) performance of pure and fluoride (F) doped ZnO particles are studied. Similar studies are not frequent in literature, and the existing reports deal mostly with the fluorine doped ZnO thin film. As photo-anode material, ZnO mainly anchors the dye molecules on its surface, collects the photo-excited electrons, and ultimately transports the charge to the external circuitry of the cell. The anchoring of the dye molecules on thin film surface is not effective, and thus, particulate morphology (instead of thin film) of the photo-anode materials is advantageous for DSSC application. Herein, ZnO particles and the F doped counterparts (with F doping concentration in the range of 1–4 mol%) are prepared through co-precipitation technique. The effect of F doping in

Published online: 30 August 2017