

**SYNTHESIS AND CHARACTERIZATION OF METAL
OXIDE NANOPARTICLES AND NANOSTRUCTURED
FILMS FOR DYE-SENSITIZED SOLAR CELL
APPLICATIONS**

by

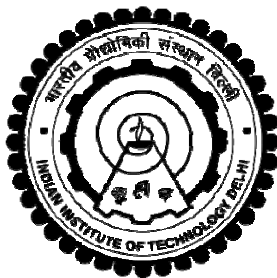
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Submitted

in fulfillment of the requirements of the degree of Doctor of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

DECEMBER - 2012

Dedicated to

My Parents....

Certificate

This is to certify that the thesis entitled “**Synthesis & characterization of metal oxide nanoparticles and nanostructured films for dye-sensitized solar cell applications**” being submitted by **Ms. Charu Dwivedi** to the Indian Institute of Technology Delhi, for the award of the degree of ‘*Doctor of Philosophy*’ in Centre for Energy Studies, is a record of bonafide research work carried out by her. **Ms. Charu Dwivedi** has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard. The results contained in this work have not been submitted in part or full, to any other University or Institute for the award of any degree.

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Acknowledgement

This is a wonderful opportunity for me to acknowledge the people without whom it would not have been possible to complete my doctoral degree. Truly, words are not enough to express my gratitude to all of them.

First of all, I would like to express my deepest appreciation to my supervisor Prof. Viresh Dutta. I was very fortunate to have such a wonderful person as my Ph.D supervisor. Many thanks for his support, encouragement and having confidence in me. This thesis would not have been possible without his help, support and patience. Your guidance and advices have been invaluable to me. I wish to express my sincere thanks to the Heads of the Centre (during last five years) Prof. S.C. Kaushik and Prof. R.P. Sharma, for their help at various levels. I would like to thank all faculty members of CES, especially Dr. A.K. Mukerjee and Dr. Vamsi Krishna for their valuable suggestions, advices and approval of my thesis work.

My heartfelt thanks to my seniors Dr. Deepak Verma and Dr. A. Rangarao for their time and knowledge to introduce me to the world of “Nano” and teach experimental techniques. Many thanks to Mr. Naresh Kumar for the friendly environment. Thanks to my group members Atif Khan, Sanjay Kumar Swami, Neha Chaturvedi, Eshwar, Nikhil, Sanjay Sardana who created friendly and productive atmosphere in our

Photovoltaic Lab. And a special mention to Neetesh Kumar and Firoz Alam for a constant encouragement and co-operation. I would like to take the opportunity to especially thank Dr. Anuj Kumar and Mr. Nagendra Chaudhary for many assistances during my Ph.D. and being an emotional support too.

Many thanks to my friends Maneesha, Anamika, Geetanjali and Geeta to share all of my sadness and laughter during my stay in I.I.T. hostel. I am fortunate to have Sangita as my true friend. I would like to acknowledge the love of all my family members including my sister-in-laws Upma, Sanyogita and Pushpa.

I also thank Mr. D.C. Sharma for SEM measurements at IIT. It has been his kind support that I could learn the SEM facility so quickly and could scan my samples with such an ease.

To my parents and my husband Dr. Sachin, all I can say is, this small space is not enough to acknowledge your contributions up to this stage of my life. Many thanks to Sachin for encouraging and criticizing me throughout my Ph.D, and for being my great support. And to my parents I just want to say, it was your dream which made my journey up to this possible. Thanks for supporting me and showing faith in me. Last but not the least I thank God almighty for the blessing he has showed on me.

Charu Dwivedi

December- 2012

Abstract

The growth of various nanostructures of ZnO (nanorods, nanoflowers, etc.) and hollow microspheres of TiO₂ by continuous spray pyrolysis (CoSP) reactor has been studied. The ZnO nanostructured films are used as a photoelectrode in dye-sensitized solar cells (DSSCs) and their performance is investigated. The thesis begins with an introductory chapter on various photovoltaic technologies and the integration of nanotechnology in PV especially in dye-sensitized solar cells. The operating principle of DSSC is presented. The current status of this technology in India has also been discussed. Second chapter introduces the various experimental and characterization techniques that have been used for the synthesis of metal oxide nanoparticles and nanostructures. The main thesis work involves five distinct studies. Firstly, the conditions to synthesize ZnO nanoparticles via CoSP reactor and the effect of high DC voltage (1kV) applied during synthesis are studied. The as-synthesized nanoparticles are then utilized to prepare thin films on glass substrate or Indium Tin Oxide (ITO) coated glass substrates via spin coating. The films grown by spin coating have issues with the adhesion property. So, it is thought of growing films directly by keeping the substrates inside the CoSP reactor, which saves time and helps in the collection of both nanoparticles and nanostructured films altogether. Thus secondly, the optimum conditions to grow nanorod and various other nanostructures on various

substrates (glass, ITO, Si, Cu, etc.) using a seed layer are studied. In this, the effect of substrate pre-treatment, deposition time, seed layer, annealing temperature, applied voltage have been studied. A comparative study of the PL properties of as collected nanoparticles and nanostructured films deposited at the same time is also done. Thirdly, the conditions to synthesis of aluminium doped ZnO (AZO) nanoparticles and nanostructured films are investigated. Further, the effect of seed layer and annealing temperature is studied on the morphology of nanostructured films. The current–voltage curves of the thin film with ZnO and AZO nanorod arrays are measured. Fourthly, the growth of hollow microspheres of TiO₂ and the effect of precursor concentration, applied voltage and annealing is also studied. The precursor concentration and applied voltage are found to have a direct impact on the size of the microspheres, which is also evident in the absorption spectrum. Finally, these as-synthesized nanostructures of ZnO are incorporated as a photoelectrode and the hollow microspheres of TiO₂ are incorporated as a scattering layer on top of a TiO₂ (~ 20 nm) transparent layer in DSSCs and their performance have been investigated. Effect of deposition time of ZnO nanorod array films as photoelectrode on cell efficiency is presented. The thesis concludes with a summary of the work done, some general conclusions and comments on possible future directions.

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