DOI : 10.31357/fapsphd.2009.00618

# SUPPRESSION OF RECOMBINATION CHANNELS OF DYE–SENSITIZED SOLAR CELLS BY INCORPORATING NANO-PARTICLES OF METALS AND INSULATORS TO THE SEMICONDUCTOR FILM

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Ph. D. 2009

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Thesis submitted to the University of Sri Jayewardenepura for the award of the Degree of Doctor of Philosophy in chemistry on 2009.

# DECLARATION

"The work described in this thesis was carried out by me under the supervision of Prof. K. Tennakone, Director (former), Institute of Fundamental Studies, Hanthana Road, Kandy and Prof. Pradeep Jayaweera, Professor in Chemistry, Department of Chemistry, University of Sri Jayewardenepura, Nugegoda and a report on this has not been submitted in whole or in part to any university or any other institute for another Degree/Diploma".

..........................

Signature of the candidate

"We certify that the above statement made by the candidate is true and that thesis is suitable for submission to the University for the purpose of evaluation".

.......................

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21 JUN 2010

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# ACKNOWLEDGEMENTS

I deeply express my appreciations to my external supervisor Prof. K. Tennakoon, Director (former), Institute of Fundamental Studies, Kandy, for his continuous supervision, valuable guidance and keen interest in my work through the research period. And I am grateful to him for his advice given to achieve the Doctor of Philosophy degree successfully.

I also thank sincerely to my internal supervisor Prof. Pradeep Jayaweera, Professor, Department of Chemistry, Faculty of Applied Science, University of Sri Jayewardenepura, Nugegoda for his generous support and continuous attention paid on me in the period of study.

Great thanks are due to my colleagues Y. P. Y. P. Ariyasinghe, T. R. C. K. Wijayarathna, E. V. A. Premalal, P. K. D. D. P. Pitigala and M. K. Indika Senevirathna for their encouragement and moral supports extended to me to accomplish this task.

I cannot forget my wife Menik and my parents for their devotional sacrifices in this task.

I am indeed grateful to the staff members of institute of fundamental studies who help me in various ways during the period of my stay at I. F. S.

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## ABSTRACT

In the conversion of solar energy into electricity, devices made of high band gap semiconductor materials are more stable comparable to those made of low band gap semiconductor materials. However, under these circumstances, an efficient absorber material is very essential. In this work, particular dye (Indoline) as a sensitizer and high band gap semiconductors such as $TiO_2$ and $SnO_2$ were utilized in the construction of dye–sensitized solar cells.

The performance of dye–sensitized solar cells based on $SnO_2$ film is inferior due to existing of shallow trap levels belong to it. On the other hand, the existing of these defects on $TiO_2$ film is minimum and hence, improvement of cell performance based on composite systems becomes marginal for $TiO_2$ semiconductor. However, the efficiency of indoline–149 sensitized photoelectrochemical solar cells increases significantly when the nanocrystalline $TiO_2$ is doped with Cu to a concentration similar to the dye concentration. Indoline–149 possesses sulfur in rhodanine rings in addition to carboxylate ligand. Therefore, sulfur in rhodanine rings of indoline–149 too could coordinate with copper in $TiO_2$ in addition to the anchoring of this dye to $TiO_2$ surface via the carboxylate ligand. And hence it suppresses the aggregation of the dye molecules. The firm bonding of the indoline–149 molecule to the $TiO_2$ surface at two points

covers $TiO_2$ surface without leaving any voids. Therefore, suppression of recombination through these voids may increase both photovoltage as well as photocurrent.

Depositing nano–particles of gold on $SnO_2$ particles showed enhancement of both photovoltage as well as photocurrent. As many articles in literature claims, the surface plasmon resonance of the gold nano–particles deposited on semiconductors enhances the performance of the dye–sensitized solar cells accompanied by an increment of photocurrent. Since the above device improves photovoltage as well, it is realized that in addition to the surface plasmon resonance effect, there may be several factors which dominates the mechanism of this device. The Fermi level of $SnO_2$ particles rises when it is in contact with a metal having lower work function. Since the particles are in nano–range, to achieve the equalization of Fermi levels of gold and $SnO_2$ particles, the potential of the conduction band edge of $SnO_2$ rises up together with the shallow traps. This will result to suppress the recombination of germinated electrons with acceptors in electrolyte which increases the photocurrent. The shift of the conduction band edge to a higher level attributes to higher photovoltage as well.

$ZrO_2$ is an insulating material with its energy gap in between 5–7 eV. Suppression of recombination processes through the incorporation of the insulating material, $ZrO_2$ improved cell performance significantly. Many articles in literature revealed that the enhancement of the photocurrent is impossible in coupled type heterostructures formed between insulator and semiconductor. And therefore, the formation of $ZrO_2$ shell around the $SnO_2$ crystallites in the [$SnO_2$] $ZrO_2$ (capped type heterostructures) can not be ruled out in this regard. This $ZrO_2$ shell around $SnO_2$ prevents the recombination of germinated electrons with acceptors in electrolyte. And accumulation of these electrons in $SnO_2$ particles rises up quasi–Fermi level (QFL) of the [$SnO_2$] $ZrO_2$ composite. This will attributes to higher photovoltage and photocurrent of the cell.