PERFORMANCE OF NATURAL DYE SENSITIZED SOLAR CELLS FOR LOW POWER APPLICATIONS

Commodore C.I.F. Attanayake

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Department of Chemical & Process Engineering

University of Moratuwa

Sri Lanka

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TERMS OF REFERENCE

This Report is made to fulfill the practical and academic requirements of the Doctor of Philosophy Research Degree in Electrochemical Engineering pertaining to the 3rd generation Solar Photovoltaic Cell Technology of Dye – Sensitized Solar Cells (DSSC's) of Renewable Energy Systems.

DECLARATION

This is a report of research work carried out at the Department of Chemical and Process Engineering and it's Laboratories of the University of Moratuwa, Katubedda, and Laboratories of the Solid State Chemistry Division of the Institute of Fundamental Studies (IFS), Hantana, Sri Lanka between November 2008 and November 2014. Except where the references are made to other work, the contents of this research work are original. This work has not been submitted in part or in whole to any other University.

Commodore C.I.F. Attanayake
Department of Chemical & Process Engineering,
University of Moratuwa, Katubedda,
Sri Lanka.

Professor B. A.J.K. Premachandra
Professor
Department of Chemical &
Process Engineering
University of Moratuwa,
Katubedda,
Sri Lanka

Professor G.K.R.Senadheera
Institute of Fundamental Studies
Hantana, and Open University of
Sri Lanka, Polgolla,
Sri Lanka.

Professor A.A.P. De Alwis
Professor
Department of Chemical & Process Engineering,
University of Moratuwa,
Katubedda,
Sri Lanka

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ABSTRACT

The need for renewable energy sources in Sri Lanka is assessed and solar photovoltaics (PVs) is identified to be the most technically suitable and economically viable power source for the conversion of solar energy to electricity in future. Three generations of solar PVs comprising 1^{st}, 2^{nd} and 3^{rd} generations are dentified, and Dye – Sensitized Solar Cells (DSSCs) comprising the 3^{rd} generation cutting – edge solar cell technology is identified being the low-cost easy to manufacture, durable, stable, long life time with reasonably high solar energy to power conversion efficiency (11% max with expensive , scarce, synthetic dyes like Ruthenium bipiridyl complex technology), or of about 1% with cheap, low-cost, abundant, non-toxic, environmentally friendly natural dyes of photosynthetic green plants. Natural dyes were selected to carry out further research and development work for practical applications.

Research done on DSSC's since inception in Sri Lanka were scrutinized and assessed at the Institute of Fundamental Studies (IFS), Hantana, Sri Lanka, and other Institutions in Sri Lanka. It has been observed that most of the research at the IFS has been done using very expensive synthetic Ruthenium metallic dyes and have achieved a high conversion efficiency of 10% in May 2001.

DSSCs sensitized with 145 natural dyes of plants growing in Sri Lanka were electrically and electronically tested and the ethanolic dye extracts of natural Mangoostein fruit rind (deep purple colour) exhibited the best conversion efficiency (of about 1%.) . It was also observed that other natural dyes such as Ekkiriya wood, Egg plant fruit peel, Karawalla kabilla fruit, Banana flower inflorescence, Beetroot tuber, Turmeric root and Fire fern leaf (not endemic to Sri Lanka) yield relatively good conversion efficiencies.

Natural dye-based DSSCs even though possess conversion efficiencies usually below 1%, may be improved by finding different additives. Such DSSCs are cost effective , easy to manufacture, environmentally friendly and stable . They are potential solar energy to electricity conversion devices for low power applications if further research is done to boost their conversion efficiencies to about 2% - 3%, and to increase their long term stability. The reasons why DSSC's have not been developed for commercial use in Sri Lanka have been identified, assessed and remedial measures proposed.

Research and development work were also initiated to develop practical DSSCs sensitized with low-cost abundant and environmentally friendly natural dyes of plants for low power applications such as battery charging of mobile telephones, iPod's, portable radio communications equipment, LED operated multi – coloured garden - night lights of hotels etc., construction of Building Integrated Photovoltaic (BIPV) systems to provide diffused lighting with multicoloured LED operated lighting systems, provision of propulsion power to small boats etc, in order to assist solve the impending energy crisis when all known sources of fossil fuel will be exhausted in a few decades.

CONTENTS

Chapter 4 - Results and Discussion

Bibliography

Appendices

Appendix A : All Research Papers on DSSC's Published by the IFS, Hantana, Sri Lanka

Appendix B : Research Papers on DSSC's published by Institutions / Universities in Sri Lanka other than the IFS

Appendix C : Construction of DSSC's

Appendix D : Natural Dyes from Plants grown in Sri Lanka

Appendix E : Best Research - Cell Efficiencies Table at IFS, Kandy (since inception to –date)

Appendix F : Best Research – Cell Efficiencies at IFS and University of Moratuwa, Sri Lanka

Appendix G : Best Research – Cell Efficiencies (from NREL – Colorado , U.S.A)..

Appendix H : Band Gaps of various Solar Cell Materials and Conversion Efficiencies

Appendix I : PV Power Costs as a Function of Cell Efficiency and Module Cost

Appendix J : Efficiency vs. Cost for I,II,and III Generations of Solar Cells

Appendix K : List of major Solar PV Cell Manufacturuing Companies

Appendix L : Main Research Organisatios and Established Companies in the world carrying out R&D on DSSC'

Appendix M : Basin Trials of Organic / DSSC Powered Catamaran Boat

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTOGRAPHS

LIST OF ACRONYMS (ABBREVIATIONS)

Abbreviation	**Description**
AM	Air Mass Density
PV	Photovoltaic
DSSC’s	Dye –Sensitized Solar Cells
CB	Conduction Band
VB	Valance Band
WE	Working Electrode
FTO	Fluorine doped Tin oxide
CE	Counter Electrode
Pt	Platinum
IL	Ionic liquid
AN	Acetonitrile
I – V	Current – Voltage
Jsc	Short Circuit Current Density
Voc	Open Circuit Voltage
Io	Light intensity
ff	Fill Factor
η	Overall light to –electricity conversion efficiency
P_{in}	Intensity of incident light
P_{max}	Maximum Power
HOMO	Highest occupied Molecular Orbital
LUMO	Lowest Unoccupied Molecular Orbital
HTM	Hole Transporting Material
LHE	Light Harvesting Efficiency
IPCE	Incident Photon to Current Converse
OPV	Organic Photovoltaic
N	Electron concentration
P	Hole concentration
R_S	Series Resistance
R_t	Electron Transport resistance
P	Power Density
K	Kinetic Constant
K_B	Boltzmann Constant
L	Length
L_D	Electron Diffusion Length
T	Temperature
W	Watt
eV	Electron Volts

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