ANALYSIS OF LA-DOPED SNO2 AS ELECTRON TRANSPORT LAYER IN PEROVSKITE SOLAR CELL

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ANALYSIS OF LA-DOPED SNO2 AS ELECTRON TRANSPORT LAYER IN PEROVSKITE SOLAR CELL

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DEDICATION

In the hopes that this work may in some way contribute to others, this is dedicated to my supportive supervisor, Ts. Mohd Shahril Izuan Bin Mohd Zin and my co-supervisor, Ts. Dr. Faiz Bin Arith. I also presenting this work to my beloved parents, Mr. Mohd Arip Bin Osman and Mrs. Nawar Hanim Binti Ismail and my beloved friends that have been a source of motivation and strength during moments of despair and discouragement.

ABSTRACT

A solar cell is a device that uses the photovoltaic effect to convert light energy into electricity, producing an electrical charge that can move freely in a semiconductor. High -performance solar cells nowadays are first generation solar cells that are mostly based on silicon wafers. Silicon has several advantages over other competitive materials, but ultra -pure semiconductor wafers are indeed expensive in terms of finance and energy. However, the third-generation solar cell, perovskite solar cell (PSC) has come a long way and has produced a lot of high-quality work, in contrast to silicon solar cells, perovskite solar cells (PSCs) are inexpensive. The electron transport layer (ETL) plays an important role in the photovoltaic performance and overall stability of perovskite solar cells. This project proposes the potential of SnO_2 as an ETL in perovskite solar cell (PSC) applications. Lanthanum is doped together with SnO_2 as an electron transport layer (ETL) to obtain solar cell parameter results in terms of efficiency and fill factor (FF), designed and simulated in wxAMPS software. Thus, this project is expected to demonstrate the suitability of doping as a promising approach that promises efficient, stable and reproducible perovskite solar cells.

ABSTRAK

Sel suria ialah peranti yang menggunakan kesan fotovoltaik untuk menukar tenaga cahaya kepada elektrik, menghasilkan cas elektrik yang boleh bergerak bebas dalam semikonduktor. Sel suria berprestasi tinggi pada masa kini ialah sel suria generasi pertama yang kebanyakannya berasaskan wafer silikon. Silikon mempunyai beberapa kelebihan berbanding bahan saing yang lain, tetapi wafer semikonduktor ultra tulen sememangnya mahal dari segi kewangan dan tenaga. Walau bagaimanapun, sel solar generasi ketiga, sel solar perovskit (PSC) telah melangkah ke hadapan dan telah menghasilkan banyak kerja berkualiti tinggi, berbeza dengan sel suria silikon, sel solar perovskit (PSC) adalah murah. Lapisan pengangkutan elektron (ETL) memainkan peranan penting dalam prestasi fotovoltaik dan kestabilan keseluruhan sel solar perovskit. Projek ini mencadangkan potensi SnO_2 *sebagai ETL dalam aplikasi sel solar perovskite (PSC). Lanthanum di-doping bersama dengan* SnO_2 *sebagai lapisan pengangkutan elektron (ETL) untuk mendapatkan hasil parameter sel suria dari segi kecekapan dan faktor isian (FF), direka dan disimulasikan dalam perisian wxAMPS. Jadi, projek ini dijangka menunjukkan kesesuaian doping sebagai pendekatan yang menjanjikan planar yang cekap, stabil dan boleh dihasilkan semula sel solar perovskit.*

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LIST OF SYMBOLS AND ABBREVIATIONS

A	:	Ampere
Ag	:	Argentums (Silver)
AMPS	:	Analysis of Microelectronic and Photonic Structures
$CH_3NH_3PbI_3$	:	Methylammonium lead iodide
CuSCN	:	Copper (I) thiocyanate
Ec	:	Conduction band energy level
Ef	:	Fermi energy level
ETL	:	Electron Transport Layer
ETM	:	Electron Transport Material
FF	:	Fill Factor
HTL	:	Hole Transport Layer
Isc	:	Short-circuit current
ITO	:	Indium tin oxide
J	:	Current density
Jsc	:	Short-circuit current density
La	:	Lanthanum
mA	:	milliampere
NiO_x	:	Nickel oxide
PCE	:	Power Conversion Efficiency

PSC	:	Perovskite Solar Cell
PV	:	Photovoltaic
SEM	:	Scanning Electron Microscope
SnO_2	:	Tin (IV) oxide
TCO	:	Transparent Conducting Oxide
TiO_2	:	Titanium dioxide
UV	:	Ultraviolet
Voc	:	Open-circuit voltage
XRD	:	X-Ray Diffraction
ZnO	:	Zinc oxide

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CHAPTER 1

INTRODUCTION

This chapter describes the overview of this thesis that includes project background, problem statement, objectives and the scope of work. The summary of the thesis outline also will be included by the end of the chapter.

1.1 Project background

The sun is an amazingly renewable resource that can power life on earth and provide clean and sustainable energy to all its inhabitants. Solar energy can be converted into electricity using photovoltaic (PV) solar modules [15]. PV modules absorb sunlight and convert energy into usable form of electricity. Photovoltaics is a combination of groups of solar cell arrays made up of semiconductors. The semiconductor has a p-n junction, and it is mostly composed to achieve high efficiency of solar cells. The P-junction is called the hole transfer layer (HTL), which has a high concentration of holes, and the N-junction is called the ETL because of the high concentration of electrons [9].

High-performance perovskite solar cells (PSC) have attracted significant attention from researchers in the green energy and renewable energy field [theoretical]. Highly efficient conventional planar perovskite solar cells are usually composed of a transparent conducting oxide (TCO) layer and an electron transport layer (ETL), which usually is a wide bandgap n-type semiconductors, perovskite absorber layers, a hole transport layer (HTL) of p-type semiconductors and proper back contact [8].

The ETL, which is the layer of a perovskite solar cell, is sometimes called an electron extraction layer or an electron collection layer, in which electrons are injected from the absorber layer, transported via an electron transport material (ETM), and finally collected by electrodes [3]. The efficiency of conventional ETL materials like SnO_2, is still lacking due to several factors. Therefore, the choice of ETL material is very important for achieving high efficiency of solar cells, and band gap energy, electron affinity, and carrier concentration of electron transport layer (ETL) are investigated. The features of lanthanum doping have the potential to improve the SnO_2 properties as an ETL in perovskite solar cells.

1.2 Problem statement

The solar cell has been nominated as one of the most important inventions of the twentieth century. The highest efficiency that has been achieved is 47.1% by the team of researchers at the National Renewable Energy Laboratory (NREL) in 2019 [5]. However, the development of silicon solar cells has been a matured technology despite it is also required an intensive fabrication process. Under those circumferences, the third generation of solar cells which include the has been experimented for the past 2 decades. PSC have the potential to replace silicon-based solar cells in the future.

Past research uses aluminium and lanthanum trivalent metals are co-doping with SnO_2 as the ETL layer in PSC [14]. As the ETL material selection is a very critical to achieve the high efficiency of solar cells, the existing conventional ETL of SnO_2 still needs more improvement in efficiency. To overcome this problem, SnO_2 is doped with lanthanum that may allow it to improve the photovoltaic performance. However, lanthanum doping is newly introduced, and the parameter is still under investigation.

1.3 Objectives

This project has three objectives which are :

1. To simulate the perovskite solar cell utilizing La-doped SnO_2 as ETL using wxAMPS solar cell simulator software.
2. To fabricate the SnO_2 layer with lanthanum doping as and ETL for PSC application.
3. To analyse the characteristics of La-Doped SnO_2 as ETL in perovskite solar cell.

1.4 Scope of work

The main objective of this project is to analyse the doping of lanthanum with SnO_2 as an ETL layer in PSC. The analysis is conducted by simulation using solar cell simulation program which is wxAMPS. It will provide the parameters of solar cell such as efficiency, fill factor (FF) and few other parameters. The structure of the solar cell is designed with layer of ITO/La-doped SnO_2/$CH_3NH_3PbI_3$/NiO_x/Ag. The efficiency of the solar cells will be optimized by controlling several parameters of the ETL included the thickness, doping density, working temperature, and defect density etc. To achieve maximum efficiency, the parameters of ETL layer were researched thoroughly.

The SnO_2 layer is then fabricated by using spin coat method. This method has been received high attention due to its modest deposition procedure and low-cost preparation while obtaining a high quality of thin films. It is also a conventional method to deposit a thin layer on substrate. There will be also equipment required to test the solar cell such as Scanning Electron Microscope (SEM), UV–Visible spectrometer, Keithley 2401 source meter, Raman spectroscopy and X-Ray Diffraction (XRD).

CHAPTER 2

BACKGROUND STUDY

This chapter describes a literature review of the theoretical concepts of this project. This chapter also included information gathered from various sources such as journals, articles and books to gain insights and ideas for completing the project. Research-based methods and approaches will serve as reference and guide as well as the completion of the project.

2.1 Photovoltaic

A solar cell is a device that converts light into electricity by the "photovoltaic effect". The photovoltaic effect is a process that occurs in some semiconductor materials such as silicon. At the most basic level, semiconductors absorb photons and excite electrons [15]. The electrons are extracted into the electrical circuit by built-in and applied electric fields. They are also commonly referred as photovoltaic cells to