INVESTIGATION OF LEAD-FREE MATERIAL FOR PEROVSKITE SOLAR CELLS

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronic Engineering with Honours

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I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

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DEDICATION

This thesis is dedicated to the people who have supported me throughout my education. Thanks for making me see this adventure through the end.

ABSTRACT

Due to the development of photovoltaic technology, it is now possible to convert sunlight into electrical energy. With high power conversion efficiency and low cost, perovskite solar cells have advanced for the generation of power in the fields of photovoltaic research. The main issues with lead-based perovskite solar cells are their poor stability and high toxicity. Investigation of environmentally safe lead-free perovskite solar cells have been studied from variety of non-toxic materials, some of which have good optoelectronic properties and can improved device performance. Simulation of tin-based perovskite solar cell is where the lead (Pb) material is substitute with tin (Sn) material, where the tin-based perovskite layer was optimized to achieve the highest efficiency. To analyse the parameters of solar cells configurations such as Power Conversion Efficiency (PCE), Fill Factor (FF), short circuit current density (Jsc) and an open circuit voltage (Voc). Finally, it is expected for the lead-free perovskite solar cells to achieve the PCE of more than 20%.

ABSTRAK

Disebabkan oleh perkembangan teknologi fotovoltaik, kini boleh menukar cahaya matahari kepada tenaga elektrik. Dengan kecekapan penukaran kuasa tinggi dan kos rendah, sel solar perovskite telah maju untuk penjanaan kuasa dalam bidang penyelidikan fotovoltaik. Isu utama dengan sel solar perovskite berasaskan plumbum adalah kestabilan yang lemah dan ketoksikan yang tinggi. Penyiasatan sel suria perovskite bebas plumbum yang selamat dari segi alam sekitar telah dikaji daripada pelbagai bahan bukan toksik, sesetengah daripadanya mempunyai sifat optoelektronik yang baik dan boleh meningkatkan prestasi peranti. Simulasi sel suria perovskit berasaskan timah adalah di mana bahan plumbum (Pb) digantikan dengan bahan timah (Sn), di mana lapisan perovskite berasaskan timah telah dioptimumkan untuk mencapai kecekapan tertinggi. Untuk menganalisis parameter konfigurasi sel suria seperti Kecekapan Penukaran Kuasa (PCE), Faktor Isi (FF), ketumpatan arus litar pintas (Jsc) dan voltan litar terbuka (Voc). Akhirnya, sel suria perovskite bebas plumbum dijangka mencapai PCE lebih daripada 20%.

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LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	:	Analysis of Variance
ETL	:	Electron Transport Layer
FF	:	Field Factor
HTL	:	Hole Transport Layer
ITO	:	Indium Tin Oxide
Jsc	:	Short Circuit Current
$MASnBr_3$	:	Methylammonium Tin Bromide
$MASnBr_3$	:	Methylammonium Tin Iodide
NiO	:	Nickel Oxide
OA	:	Orthogonal Array
PCE	:	Power Conversion Efficiency
PSCs	:	Perovskite Solar Cells
SCAPS 1D	:	Solar Cell Capacitance Simulator
SEM	:	Scanning Electron Microscope
SNR	:	Signal Noise Ratio
UV- Vis	:	Ultraviolet Visible Spectroscopy
Voc	:	Open Circuit Voltage

XRD	:	X-ray Diffraction
ZnO	::	Zinc Oxide

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CHAPTER 1

INTRODUCTION

1.1 Project Introduction

Solar cell also known as photovoltaic cell is a type of device that can converts light energy into electrical energy through photovoltaic effect. Most commonly use type of solar cells are fabricated from silicon material with the efficiency of 21%-22%. Perovskite solar cells (PSCs) is new technology that can provides simple manufacturing, highly efficient photovoltaics, and low-cost solar cell application. A new class of lead-free perovskites material is developed to solved problems regarding the issue of toxicity lead based halide perovskite. An alternative to produce a lead-free perovskite solar cell devices from variety choices of nontoxic perovskite materials for development of environmentally friendly solar cells with excellent performance and properties. The substitution metals for lead (Pb) use in perovskite solar cells with the use of tin (Sn) material to achieve the targets of this

project, others material that can be used to replace the use of lead that have similar semiconducting characteristics is germanium (Ge), bismuth (Bi), and antimony (Sb). Sn- based perovskites have high optical absorption coefficients and low optical band gaps that are similar to Pb- based perovskites [1]. Metal halide perovskite general from formula ABX_3, where A is organic cation usually organic methylammonium, B is a metal cation and X is a halogen anion. Sn-based perovskites able to exhibit higher charge carrier, the highest efficiency reported for Sn-based perovskite solar cells reached up to 27.43% [2].

The simulation process was done by using device simulator, OghmaNano software where in the simulation process the experimental and theoretical data were used for simulating thin film devices. The fundamentals of photovoltaic devices will be discussed and examined. There are several important parameters that can manipulate the performance of a device such as thickness of material, bandgap energy, electron affinity etc. Therefore, an analysis needs to be done before identifying the parameters that would impact most on device characteristics. One of the most significant methods that are being used widely nowadays are known as Taguchi Method. Simulation can help in terms of more understanding on factors that can be controlled and identify appropriate process before actual implementation.

Fabricating devices can be done after investigation process by simulation, spin coating is one of the low-cost preparation methods of perovskite thin film by using depositing techniques. After fabricating, the sample need to be characterized, X-ray diffraction pattern (XRD) of the material confirms the formation of perovskite structure whereas, UV–vis absorption spectroscopy shows the absorption range of these material. Crystal formation of the perovskite is confirmed from the scanning

electron microscope (SEM). Comparison of perovskite material is discussed in depth in terms of structural, optical, and electrical properties.

1.2 Problem Statement

Lead perovskites are considered for next generation photovoltaic technology, but perovskites are generally to be assume as toxic because of the lead (Pb), the exposure to perovskite can cause serious hazard on health and toxic to the environment [3]. Therefore, alternative to do a simulation of lead-free solar cells that focus on compound that have similarity in the perovskite structure and improves the performances that suitable for optoelectronic applications such as solar cell. Besides, the traditional solar cell such as silicon required higher cost for manufacturing compared to perovskite material. Other than that, the efficiency of the tin-based solar cells still needs an improvement due to instability.

1.3 Objectives

The objectives of this project are:

i. To simulate a methylammonium tin bromide and methylammonium tin iodide, lead-free material for perovskite layer using OghmaNano software simulator.

ii. To analyze the output parameters such as power conversion efficiency (PCE), fill factor (FF), short circuit current (Isc), open circuit voltage (Voc) in perovskite layer.

iii. To optimize the input parameters, thickness of material used and temperature in lead-free perovskite solar cells using Taguchi Method.

1.4 Project Scope

This project aims to construct a lead-free perovskite solar cells model by simulation and optimization process.

1.4.1 Simulation using OghmaNano Software

To design and simulate a lead-free perovskite solar cell models that can achieve the maximum efficiency using OghmaNano simulator, a computer-based software tool for simulating and to analyzing the photovoltaic (PV) devices. This software can be used to design several types of devices using different input parameters. This simulation study will provide useful information to make perovskite solar cells and appropriately choose parameters and attain the high efficiency. The design of lead-free perovskite solar cell model configuration contains of metal oxide material: zinc oxide (ZnO) as the Electron Transport Layer (ETL) and nickel oxide (NiO) as the Hole Transport Layer (HTL).

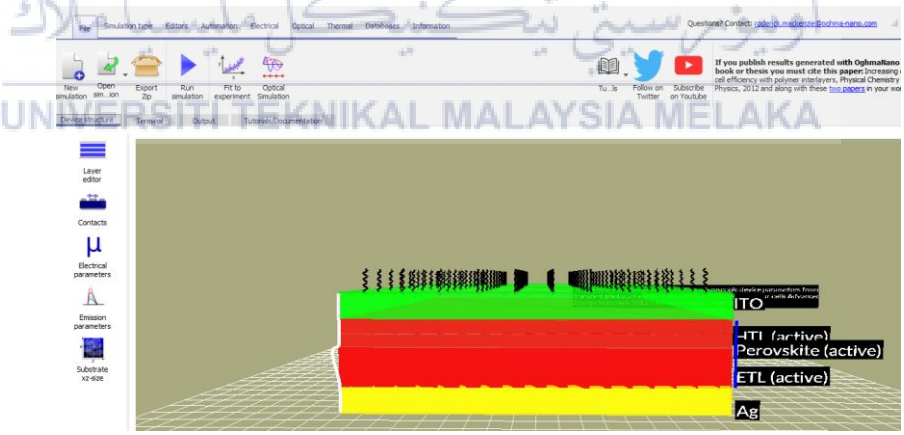

Figure 1.1: Simulation of solar cell using OghmaNano

1.4.2 Analyze and Comparison of Lead-free Perovskite Solar Cells

From collected data, optimization of various input parameters such as the thickness of layer, temperature and electrical parameters of material will be implemented by using appropriate analysis techniques. To make comparison in between two types of tin halides material used at perovskite layer and observe the devices performance after optimization and analyze the output parameters.

1.5 Significant and Importance

The importance of this project is to improve the performance of solar devices, to develop a low cost and easy to fabricate solar cell devices that meet the market's demand for greater functionality and performance. Furthermore, to manufactured perovskite with thinner layer compared to the traditional solar cell. Therefore, this project can help to achieved Sustainable Development Goals 7 which is to ensure access to affordable, reliable, sustainable, and modern energy for all.

It is also essential to conduct a statistical analysis such as Taguchi Method that can identify the parameters affecting the most on devices performances. Taguchi method is being used to ensure the devices produced are in the acceptable quality range [4].

1.6 Summary of Work

In the first chapter, explanation about the problem statement, objectives, and scope of work that will be done to complete the project. For the next part in the project, it will focus on the gathering information to understand the concept and process of the project. Most of the information is obtained from articles and journals. The research was continued with running several experiments of simulation with different parameters after the initial design of device structure was done by using