STUDY OF LA-DOPED BaSnO3 LAYER AS TRANSPARENT CONDUCTIVE OXIDE (TCO) FOR SOLAR CELL

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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

I want like to dedicated to my supervisor, and Dr Siti Aisah and Dr Faiz , for guiding me throughout this PSM journey. Next is my mother Revathi and my siblings, who encouraged me to believe in myself and provide financial support. Lastly, my seniors and friends for supporting me in hard times.

ABSTRACT

Transparent conducting oxides (TCOs) have become essential materials for a wide range of applications, including photovoltaics. Due to its high electron mobility, good heat stability, optical transparency, structural versatility, and adaptable doping stability at room temperature, perovskite lanthanum doped barium stannate ($La - BaSnO_3$), a new TCO system, is an education and outreach for realizing optoelectronic devices and monitoring based on electronic quantum states. This project researched the physical characteristics, electron-scattering process, and development of lanthanum doped barium stannate at transparent conducting oxides layer (TCO) and zinc oxide at electron transport layer (ETL) systems. Mainly, this project aimed to simulate the ZnO_2 as an electron transport layer and $La - BaSnO_3$ as transparent conductive oxide using perovskite solar cells. Moreover, to experiment with the various parameters of ($La - BaSnO_3$) such as working temperature, the effect of the defect on total density at ETL/TCO, doping density and thickness. To accomplish and optimize the parameter's value is employed to determine the maximum efficiency of PSC with $La - BaSnO_3$ at the TCO layer. This project targets synthesizing $La - BaSnO_3$ and analyzes the characteristics.

ABSTRAK

Oksida pengalir telus (TCO) telah menjadi bahan penting untuk pelbagai aplikasi, termasuk fotovoltaik. Oleh kerana mobiliti elektronnya yang tinggi, kestabilan haba yang baik, ketelusan optik, kepelbagaian struktur dan kestabilan doping yang boleh disesuaikan pada suhu bilik, perovskite lanthanum doped barium stannate ($La-BaSnO_3$*), sistem TCO baharu, merupakan pendidikan dan jangkauan untuk merealisasikan peranti optoelektronik dan pemantauan berdasarkan keadaan kuantum elektronik. Projek ini menyelidik ciri fizikal, proses penyerakan elektron, dan pembangunan stannat barium doped lantanum pada lapisan oksida pengalir telus (TCO) dan zink oksida pada sistem lapisan pengangkutan elektron (ETL). Terutamanya, projek ini bertujuan untuk mensimulasikan *ZnO_2* sebagai lapisan pengangkutan elektron dan *$La-BaSnO_3$* sebagai oksida konduktif telus menggunakan sel suria perovskite. Selain itu, untuk bereksperimen dengan pelbagai parameter (*$La-BaSnO_3$*) seperti suhu kerja, kesan kecacatan pada jumlah ketumpatan pada ETL/TCO, ketumpatan dan ketebalan doping. Untuk mencapai dan mengoptimumkan nilai parameter digunakan untuk menentukan kecekapan maksimum PSC dengan *$La-BaSnO_3$* pada lapisan TCO. Projek ini mensasarkan mensintesis *$La-BaSnO_3$* dan menganalisis ciri-ciri.*

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All the blessings are from Him. Thank the Lord for Everything. Next, I want to thank my supervisor, Dr Faiz, for his genuineness and support, which I appreciate the most. This thesis would not be feasible without Dr Faiz's direction from the beginning of the research process, which allowed me to understand the subject thoroughly. I am grateful for the beautiful chances he has provided for me to progress professionally and the extraordinary experiences he has planned for me. Dr Aisah has motivated me as I struggled to complete this degree. It is a privilege to study with Dr Aisah and Faiz. I am thankful for my parents' unwavering care and encouragement, which keeps me driven and self-assured. They helped me achieve my goals and success because they believed in me. My siblings, who keep me focused, remind me of what matters in life, and are always appreciative of my endeavours, deserve my gratitude. Finally, my senior ,Omsri , is the epitome of a leader and the ideal role model.

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LIST OF ABBREVIATIONS

$BaCl_2$ Barium Chloride.

$BaSnO_3$ Barium Stannate.

$NaOH$ Sodium Hydroxide.

$SnCl2$ Tin Chloride.

V_{oc} Voltage Open Circuit.

ZnO_2 Zinc Oxide.

CIGS Copper Indium Gallium Selenide Solar Cell.

FF Fill-Factor.

HTL Hole Transport Layer.

JSC Short-Circuit Current.

LA(NO3)3.6H2O Lanthanum Nitrate Hexahydrate.

PCE Power Conversion Efficiency.

PSC Perovskite Solar Cell.

PV Photovoltaic.

SDG Sustainable Development Goals.

TCO Transparent Conductive Oxide.

XRD Xray Diffraction.

CHAPTER 1

INTRODUCTION

1.1 Background study

According to solar energy estimates, large surface regions of low-cost, high-efficiency solar cells could be created in places with intense sunlight, such as deserts. The total primary mass and low cost enable effective thin film manufacture, with thermal evaporation as a viable production technology. [1] Malaysia, an Asian country just north of the equator, has an equatorial climate, which means it is hot, humid, and wet all year. When highs are about 32/33 °C, and lows are around 23/25 °C, temperatures are high and consistent. As a result of being located in an equatorial zone, Malaysia has an advantage in generating solar energy. Renewable energy is provided through solar panel systems. No harmful compounds or toxins are released into the atmosphere that could harm the ecosystem or humankind. This is one of the most significant advantages. The solar energy can use in any area of Malaysia, and it is always available. Solar energy, unlike other forms of energy, is limitless. Solar energy can be used at any time. A natural tropical climate exists in Malaysia, which receives about 4500 kWh of solar radiation per square meter per day and about 12 hours of sunshine daily.

As one of the solar energy applications, electricity has gained much traction in recent years. Heating with solar energy, there is solar-powered lighting available, and it is possible to transport solar-powered and more.Many wonder about how to trap sunlight and convert it into electricity as shown in Figure 1.1 . This is possible with the help of solar cell. A solar cell is an semiconductor-based electronic device that converts light energy into electrical energy through the photovoltaic effect (PV). Its consists of electrical characteristics such as current, voltage, and resistance. It is also known as a photoelectric cell. There are 16 types of solar cells, such as mono crystalline solar panels (Mono-Si), poly crystalline solar panels, thin-film and more. A solar cell is structured in layer form such as hole transport layer(p-type), electron transport layer(n-type), transparent conductivity oxide etc.

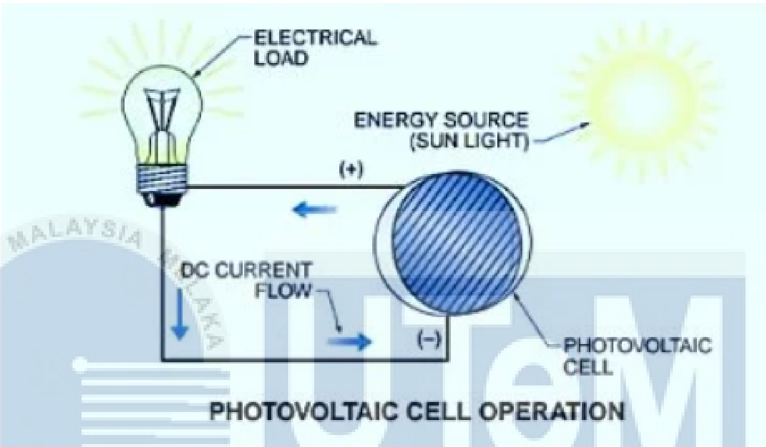

Figure 1.1: The concept of solar cell

One commonly used solar cell is perovskite solar cells (PSC). The Perovskite Solar Cell (PSC) has unique features such as high efficiency, lightweight, low cost, and thin, suitable for solar cell applications. The mineral structure of perovskite has built the capacity to absorb sunlight with less material but a similar quantity of sunlight compared to other solar cells. The perovskite solar cell structure is shown in Figure 1.2. This project is mainly about the transparent conducting oxide layer (TCO), the top layer that absorbs the sunlight. Usually, the Transparent Conductive Oxide (TCO) layer is transparent and electrically conductive, often implemented in liquid crystal display (LCD) and touchscreens. The function of TCO layers is to transport the photo generated electrons to the external device terminals and allow photons into the solar cell by an optically transparent electrode.

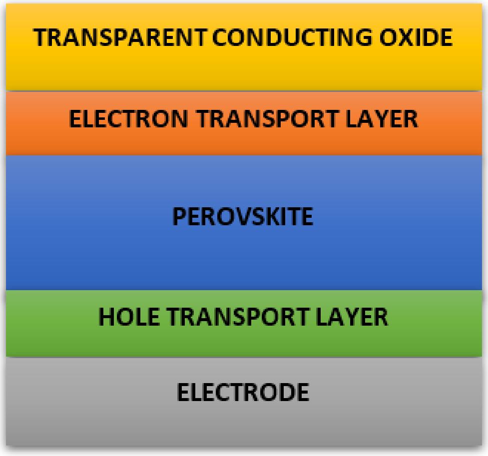

Figure 1.2: The perovskite solar cell layers

1.2 Problem Statement

One of the world's most important research fields is renewable energy. Due to their capability and sustainability, solar cells are often the most efficient source of green energy. But with a question, why are there no solar panels on every roof in the world? A few reasons have been listed down, such as endangered element, costing, and toxicity stage.

1.2.1 The endangered element

Previously, material such as indium tin oxide was extensively used for industrial purposes and interested the researcher community. The electronic properties were a continuous enhancement, making it more favourable for the developer. Unfortunately, indium is considered an endangered element. Based on the Figure 1.3, this element is predicted to be at the range of extinct elements from 2025 to 100 years. Initially, there is no evidence of this happening over the past decade. Indium is a widely requested element, but the resource on earth is not enough to fulfil the request.

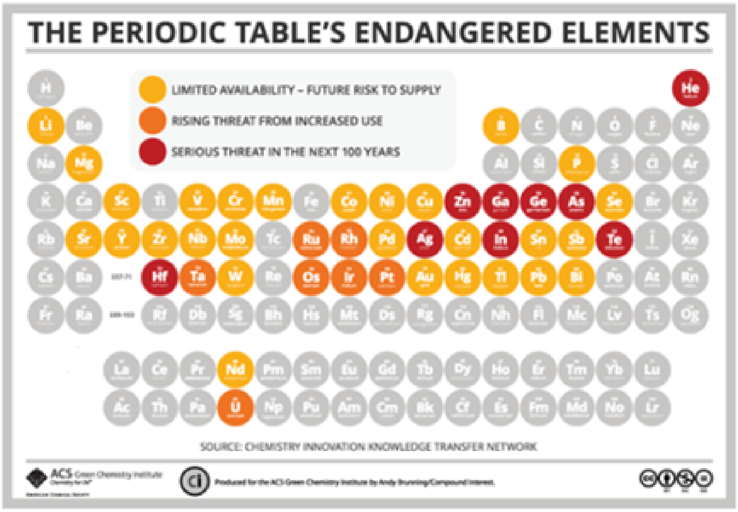

Figure 1.3: The periodic table's endangered element based on the data 2021

1.2.2 Expensive costing

Although Malaysia is blessed with 4-6 hours of sunlight, solar power is not widely used. The sunlight energy is zero costing, yet the solar panel system cannot reduce the price due to the element applied to be expensive. Since the component is running out, the manufacturers have limited the availability and increased the uses, including indium and fluorine, which gives a spike in the price. Moreover, the techniques and equipment are very costly.The main challenge is a TCO in thin-film solar cells to sustain its features at a lower cost. The element that needs to consider is: [2]

- Improving the material uniformity in large areas
- Reducing the total processing time
- Reducing the raw material consumption
- Improving the basic understanding of the material and the processes
- Assuring the long term stability under operating conditions

1.2.3 Toxicity stage

Solar panel waste can include heavy metals such as silver, lead, arsenic and cadmium that at certain levels may be classified as hazardous waste. The indium tin oxide and fluorine tin oxide contain lead substances, harmful to humankind and the environment. The photovoltaic industry uses toxic and flammable substances, although small, which can involve environmental and occupational risks. The main environmental impacts of solar panels are associated with the use of land, water, natural resources, hazardous materials, life-cycle global warming emissions etc .

1.3 Objectives

The objectives of this project are:

- To simulate zinc oxide as electron transporting layer (ETL) on La-doped Barium Stannate ($BaSnO_3$) BaSnO3 as transparent Conductive Oxide layer (TCO) layer using SCAPS simulation software.
- To synthesis La-doped BaSnO3 layer as Transparent Conductive Oxide(TCO) Layer
- To characterise the crystallography of the synthesized La-doped BaSnO3 layer using XRD.

1.4 Scope of Project

This project consists of three significant scopes: the software, hardware, and characterize. Moreover, it is based on the solar cell layers and concepts. The structure of the layer requires many limitations, and range needs to be considered throughout the development term.

Firstly, to identify the parameters of the solar cell layers, the simulation plays a significant role. Several parameters include electron mobility, bandgap, hole mobility, and more. SCAPS software is used to simulate the design based on the researched data and calculations. These data and analyses are helpful in obtaining balanced solar cell layers. Moreover, this software helps to execute the structure in 2d images where it is easier to figure out the data specification and limitations.

Next is the powder synthesis process. This project aims to synthesize the $La-BaSnO_3$ powder by using three main elements: barium chloride, tin chloride, and lanthanum nitrate. Sodium hydroxide is used as a stabilizer. The compound is blended using a magnetic stirrer using a balanced chemical equation. The substance was blended equally, and the doping amount was decided based on the project requirement. Lastly, the powder is sent to characterize the $La-BaSnO_3$ raw material. Based on the data analysis given by the XRD result, the value of the element is compared to obtain the optimized state—the characteristic of the combination of the Barium Chloride ($BaCl_2$), Tin Chloride ($SnCl2$) and Sodium Hydroxide ($NaOH$) as TCO layer element.

CHAPTER 2

LITERATURE REVIEW

This chapter will explain the background study on perovskite solar cell theories and some of the related research done. Many sources were collected showing improved solar cell parameters over five years. The latest researcher has discussed on method and technical approach based on the efficiency of the solar cell, which was used for a reference purpose.

2.1 Introduction

Every day, the sun emits a massive quantity of energy in heat and radiation, which is referred to as solar energy. Solar energy is an infinite energy source that is free to use. Solar energy has a significant benefit over other standard power generators in that sunlight can be directly converted to solar energy using small and tiny photovoltaic solar cells. Although solar energy is available freely everywhere, there is still an initial cost for developing solar cells, panels and modules that capture this radiant energy. Due to the diminishing supply of renewable energy resources, the per-watt cost of solar energy devices has grown essential in recent years. It will become more affordable in the coming years and better technology in terms of cost and application.