

# ANALYSIS OF ELECTROCHEMICALLY DEPOSITED METAL OXIDE AS COUNTER ELECTRODE FOR SOLAR CELLS

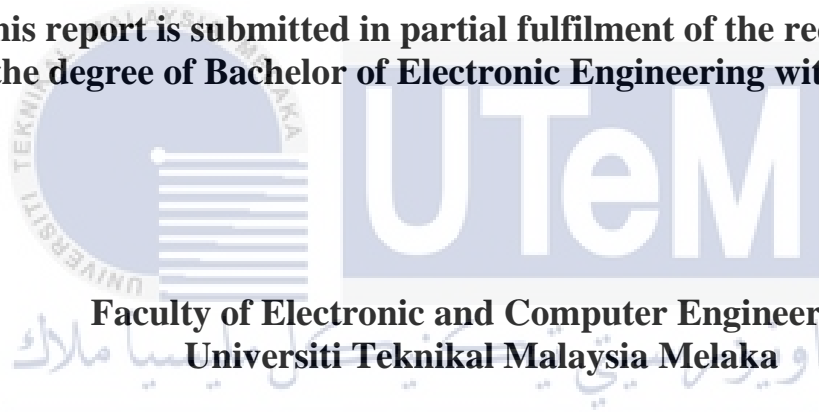
AHMAD SAUFUDIN BIN KARIM



**ANALYSIS OF ELECTROCHEMICALLY DEPOSITED METAL  
OXIDE AS COUNTER ELECTRODE FOR SOLAR CELLS**

**AHMAD SAUFUDIN BIN KARIM**

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



**Faculty of Electronic and Computer Engineering  
Universiti Teknikal Malaysia Melaka**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

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Alamat Tetap: 12 KAMPUNG SUNGAI RENEK 22020, JERTEH TERENGGANU

Tarikh : 01 JUN 2022



(COP DAN TANDATANGAN PENYELIA)

**DR. ZUL ATFY FAUZAN BIN MOHAMMED NAPIAH**  
Senior Lecturer  
Faculty of Electronics and Computer Engineering  
Universiti Teknikal Malaysia Melaka (UTeM)  
Hang Tuah Jaya, 76100  
Duriang Tunggal, Melaka, Malaysia

Tarikh : 21 JUN 2022

## DECLARATION

I declare that this report entitled “Analysis of Electrochemically Deposited Metal Oxide as Counter Electrode for Solar Cells” is the result of my own work except for quotes as cited in the references.



اونيورسيتي تيكنيكل مليسيا ملاك

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Signature : .....  .....

Author : AHMAD SAUFUDIN BIN KARIM  
.....

Date : 21 JUNE 2022  
.....

## APPROVAL

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.



اونيور ستي تنيكل مليسيا ملاك

Signature :  .....

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Supervisor Name : DR. ZUL ATFYI FAUZAN BIN MOHAMMED NAPIAH .....

Date : 21 JUNE 2022 .....

## DEDICATION

I dedicate the thesis to my parents for their endless love, support, and encouragement throughout my pursuit for education. I hope this achievement will fulfill the dream they envisioned for me.



## ABSTRACT

Electrochemical deposition is one of the low-cost techniques to deposit copper oxide thin films onto ITO glass. The method involves using three electrodes system with ITO glass as a working electrode, a silver chloride electrode (Ag/AgCl) as a reference electrode, and a platinum (Pt) plate as a counter electrode for electrochemical deposition. The copper oxide has been electrochemically deposited on the ITO glass in two electrolytes: 0.2M  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  with 3M lactic acid and 0.2M  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$  with 0.1M of sulfuric acid. The copper oxide was electrochemical deposition by varying deposition potentials and deposition times. The copper oxide deposited was characterized by Scanning Electron Microscopy (SEM), Ultraviolet-Visible Spectroscopy (UV-Vis) and a four-point probe. From visual inspection, it was found that copper oxide was dark brown on ITO glass. The SEM study reveals that the deposited layer becomes uniform when the deposition potential and time increase. It was found that the deposited layer becomes thicker with the increase of deposition time. UV-Vis shows that the deposited layer with increased deposition time has high absorbance. Finally, the copper oxide deposited was applied to solar cells where the Dye-Sensitized Solar Cells and Perovskite Solar Cell were fabricated.

## ABSTRAK

*Pemendapan elektrokimia adalah salah satu teknik kos rendah untuk menyalutkan oksida kuprum pada konduktif kaca. Kaedah ini melibatkan penggunaan tiga elektrod dengan konduktif kaca sebagai elektrod berfungsi, elektrod perak klorida sebagai elektrod rujukan dan platinum sebagai elektrod tambahan digunakan untuk pemendapan elektrokimia. Oksida kuprum dimendapkan secara elektrokimia pada konduktif kaca dalam dua elektrolit: 0.2M CuSO<sub>4</sub>.5H<sub>2</sub>O dengan 3M asid laktik dan 0.2M CuSO<sub>4</sub>.5H<sub>2</sub>O dengan 0.1M asid sulfurik. Oksida kuprum adalah pemendapan elektrokimia dengan pemendapan voltan dan masa pemendapan yang berbeza-beza. Oksida kuprum yang dimendapkan dicirikan oleh Scanning Electron Microscopy (SEM), Ultraviolet-Visible Spectroscopy (UV-Vis) dan four-point probe. Daripada pemeriksaan, didapati kuprum oksida berwarna perang gelap pada konduktif kaca. Kajian SEM mendedahkan bahawa lapisan termendap menjadi lebih sekata apabila pemendapan voltan dan masa meningkat. Didapati lapisan termendap menjadi lebih tebal dengan peningkatan masa mendapan. UV-Vis menunjukkan bahawa lapisan termendap dengan peningkatan masa pemendapan mempunyai penyerapan yang tinggi. Akhirnya, oksida kuprum yang didepositkan telah digunakan pada sel suria iaitu "Dye-Sensitized Solar Cells" dan "Perovskite Solar Cell" telah dibuat.*



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In the name of Allah S.W.T, the Most Gracious, the Ever Merciful. Praise is to Allah, Lord of the Universe and Prayers be upon His final Prophet and Messenger Muhammad S.A.W.

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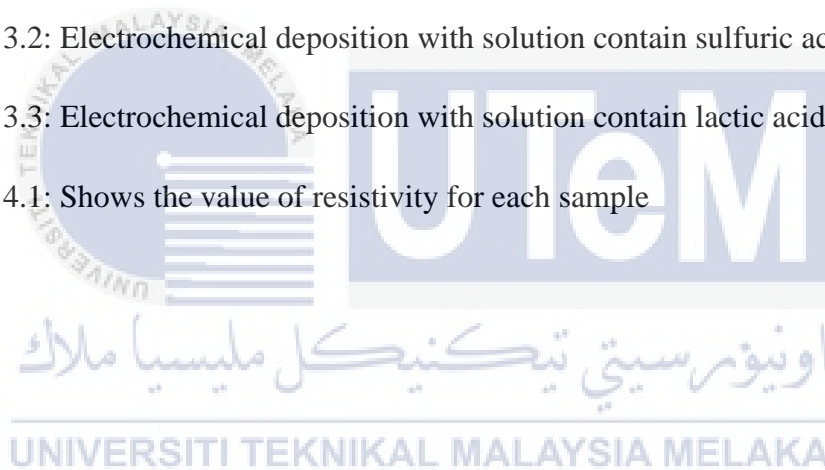
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## LIST OF SYMBOLS AND ABBREVIATIONS

PV	:	Photovoltaic
DSSC	:	Dye Sensitized Solar Cell
TCO	:	Transparent Conducting Oxide
Pt	:	Platinum
CuO	:	Copper Oxide
SEM	:	Scanning Electron Microscopes
UV-Vis	:	Ultraviolet-Visible Spectroscopy
PSC	:	Perovskite Solar Cell
ITO	:	Indium Tin Oxide
Ag/AgCl	:	Silver/Silver Chloride
IEA	:	International Energy Agency
DC	:	Direct Current
AC	:	Alternating Current
GaAs	:	Gallium Arsenide
CdTe	:	Cadmium Telluride
CIS	:	Copper Indium Diselenide
CIGS	:	Copper Indium Gallium Selenide
c-Si	:	Crystalline Silicon
a-Si	:	Amorphous Silicon

OPV	: Organic/Semi-organic PV panels
QD	: Quantum Dot
TiO <sub>2</sub>	: Titanium Dioxide
FTO	: Fluorine-Doped Tin Oxide
HOMO	: Highest Occupied Molecular Orbital
LUMO	: Lowest Unoccupied Molecular Orbital
ZnO	: Zinc Oxide
NiO	: Nickel Oxide
MoS <sub>2</sub>	: Molybdenum Disulfide
PET	: Flexible Polyethene Terephthalate
CV	: Cyclic Voltammetry
XRD	: X-Ray Diffraction
PCE	: Power Conversion Efficiency
FF	: Fill Factor
V <sub>oc</sub>	: Open-Circuit Voltage
I <sub>sc</sub>	: Short-Current Photocurrent
NaOH	: Sodium hydroxide
I-V	: Current-Voltage
HTL	: Hole Transport Layer
ETL	: Electron Transport Layer

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# CHAPTER 1

## INTRODUCTION



### 1.1 Project introduction

Solar energy is a common renewable energy source used worldwide because it can benefit humans and the environment. The sun emits energy in the form of solar radiation, and technology like solar cells, also called photovoltaic or PV cells, convert the sunlight into usable energy. Solar cells use the PV effect to convert sunlight into electrical energy. Therefore, the third-generation solar cells rapidly developed because of good efficiency and a cheaper production cost. Example of third-generation solar cell is quantum dot solar cells, organic solar cell, copper zinc tin sulphide (CZTS), dye-sensitized solar cells (DSSC) and perovskite solar cells (PSC).

Among them, DSSC has attracted significant interest because it has good efficiency photon to electricity conversion, low production cost and easy fabrication process.

DSSC is an assembly of a working electrode soaked with a sensitizer or a dye and sealed to the counter electrode soaked with a thin layer of electrolyte, as shown in Figure 1.1.

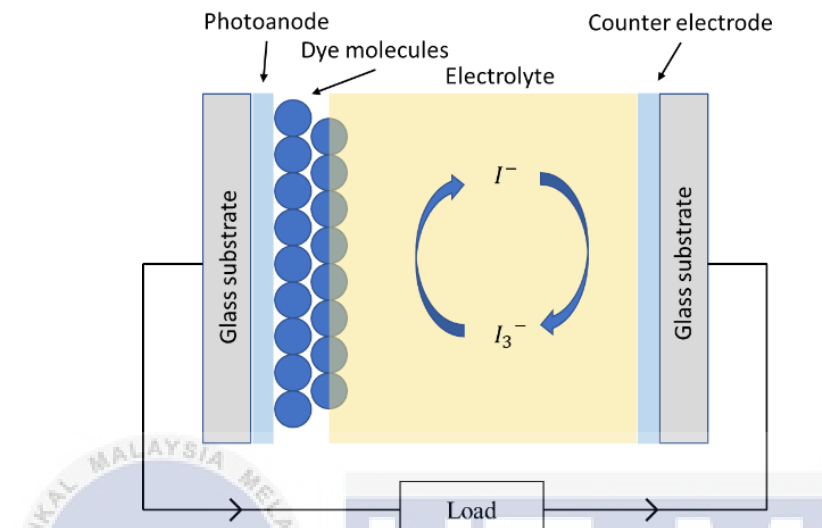


Figure 1.1: The working principle of dye-sensitized solar cells

In the structure of DSSC, the counter electrode is one of the significant components. The purpose of the counter electrode is to carry back the electrons from the circuit into holes in the dye molecules by the catalyzing reduction. The ideal counter electrode materials are high conductivity and have excellent electrocatalytic activity to maximize the charge transport between an external circuit and an electrode while minimizing the redox couple.

The counter electrode can be deposited using spin coating, doctor blade, sputtering and electrochemical deposition. Between these methods, the electrochemical deposition is suitable for depositing the counter electrode layers of DSSC because it can control the structures and size of layers on conducting materials. Electrochemical deposition, also known as electrodeposition, is the process of depositing a thin layer of metal to a conductive surface by passing an electrical current through the solution