OPTICAL AND PHOTOELECTROCHEMICAL STUDIES OF TUNGSTEN DISELENIDE (WSe_2) THIN FILMS FOR SOLAR PANELS

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials)(Hons.)

by

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Sekian dimaklumkan. Terima kasih.

Yang benar,

____

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Universiti Teknikal Malaysia Melaka.

DECLARATION

I declare that this thesis entitled "Optical and Photoelectrochemical Studies of Tungsten Diselenide (WSe_2) Thin Films for Solar Panels" is the result of my own research except as cited in the references.

Signature : ……………………………….

Name : IZLIN ANNE KAMELIA BINTI KAMARULBAHRIN

Date : 6 June 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) (Hons.).
The members of the supervisory committee are as follow:

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ABSTRAK

Tungsten Diselenide (WSe_2) adalah salah satu sebatian logam peralihan dichalcogenide (MX_2, di mana M = Mo, W, Sn, Ni, Cd, Zn dan X = Se, S, Te) yang mempunyai potensi untuk digunakan bagi tujuan sel solar. Filem nipis telah berkembang dengan elektroenapan dengan parameter yang berbeza semasa pemendapan (10-30 minit dengan selang 5 minit) dan potensi pemendapan (-1.384 V dan -1.372 V) yang telah diambil dari kitaran voltammetri. Ketebalan filem nipis telah dikira dengan kaedah perbezaan berat gravimetrik dimana peningkatan pada masa pemendapan adalah berkadar terus dengan ketebalan filem itu. Kajian struktur telah mendedahkan struktur heksagon (a = b = 0.3297 nm dan c = 1,2982 nm). Kajian permukaan morfologi melalui Mikroskop Imbasan Elektron (SEM) menunjukkan permukaan tidak rata dan berlubang pada filem nipis yang telah dideposit. Filem yang telah disintesis pada 25 minit menunjukkan filem nipis yang paling rata dan seragam di atas substrat kaca. Penyepuhlindapan dilakukan pada 1 jam pada $300^{o}C$ telah dilakukan pada filem nipis untuk mendedahkan butiran lebih terperinci yang mendedahkan ciri-ciri filem nipis dengan lebih lanjut. Kajian optik telah dijalankan menggunakan UV-Visible Spektrofotometer dan menghasilkan filem nipis yang memberikan nilai jurang paling optimum pada 1.25eV untuk filem nipis yang telah dimasukkan pada tempoh 30 minit. Plot Mott-Schottky mendedahkan semikonduktor jenis p dengan parameter semiconduktor lain.

ABSTRACT

Tungsten Diselenide (WSe_2) is a metal dichalcogenide compound (MX_2, where M = Mo, W, Sn, Ni, Cd, Zn and X = Se, S, Te) that has the potential to be used for solar cell purposes. The thin film had been grown via electrodeposition with the varying parameters of deposition time (10, 15, 20, 25, 30 minutes) and deposition potential (-1.384 V and -1.372 V). Thickness of the thin film had been calculated by the Gravimetric Weight Difference Method where an increase in deposition time is directly proportional to the thickness of the the film. The surface morphology studies via Scanning Electron Microscope (SEM) revealed irregular and pinholes on the thin film deposited. The film that had been deposited at 25 minutes show the smoothest and uniform thin film deposited on the glass substrate. Annealing at 1 hour at 300^{o}c had been done to the thin film to reveal more prominent grains which revealed further thin film characteristics. Structural studies have revealed a hexagonal structure ($a = b = 0.3297$ nm and $c = 1.2982$ nm). The optical studies had been conducted using a UV-Visible Spectrophotometer and produced a thin film with the lowest bandgap value of 1.25eV for the thin film that had been deposited at 30 minutes. Mott-Schottky plots revealed a p-type semiconductor.

DEDICATION

For those who wish to save Mother Nature to make a better future.

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Å	-	Angstrom
A	-	Optical absorption, angle between solar ray and vertical line
Ag	-	Silver
AgCl	-	Silver Chloride
a.u.	-	arbitrary unit
BCC	-	Body Centered Cubic
^oC	-	Celcius
Cd	-	Cadmium
cm	-	Centimeter
Cu_2S	-	Copper Sleenide
CuKα	-	Copper K-alpha
Cu_xSe_y	-	Copper Selenide
CdZnO	-	Cadmium Zinc Oxide
Cu_2ZnSnS_4	-	Copper Tin Zinc Sulfide
CZTS	-	Copper Zinc Tin Sulfide
CV	-	Cyclic Voltammetry

DC	-	Direct Current
D_p	-	Crystallite size
g	-	Gram
K	-	Kelvin
EDS	-	Energy Dispersive Spectroscope
EDX	-	Energy Dispersive X-Ray Spectroscopy
E_g	-	Band gap energy
Epa	-	Anodic Peak Potential
Epc	-	Cathodic Peak Potential
eV	-	Electron volt
FCC	-	Face Centered Cubic
HCP	-	Hexagonal Closed Pack
keV	-	Kilo Electron Volt
h	-	Planck's constant ($6.62607004 \times 10^{-34}$ m^2 kg / s)
HCl	-	Hydrogen Chloride
IL	-	Ionic Liquid
Ipa	-	Anodic Peak Current
Ipc	-	Cathodic Peak Current
ITO	-	Indium Tin Oxide
kT/e_o	-	Temperature dependant correction term
MX_2	-	Metal Dichalcogenide

mA	-	Miliampere
μA	-	Microampere
Mo	-	Molybdenum
$MoSe_2$	-	Molybdenum Selenide
MoX_2	-	Molybdenum Chalcogenide
mm	-	Milimeter
mV	-	Milivolt
NaOH	-	Sodium Hydroxide
N_D	-	Dopant density
Ni	-	Nickel
nm	-	Nanometer
PEC	-	Photoelectrochemical cell
pH	-	Potential of Hydrogen
rpm	-	Rotation pre minute
S	-	Sulfur
Se	-	Selenium
Se^{2-}	-	Selenide
SeO_2	-	Selenium Dioxide
SEM	-	Scanning Electron Microscope
Sn	-	Tin
t	-	Film thickness

T	-	Transmittance
TCO	-	Transparent Conductive Oxide
Te	-	Telurium
TMC	-	Transition Metal Chalcogenide
UV-Vis	-	Ultraviolet Visible
v	-	Frequency of light in hz
V	-	Electrical potential
V	-	Electrode applied potential
V_{FB}	-	Flat band potential
W	-	Tungsten
W^{+}	-	Tungsten ion
WO_3	-	Tungsten Trioxide
WSe_2	-	Tungsten Diselenide
XRD	-	X-Ray Diffraction
Zn	-	Zinc
ZnO	-	Zinc Oxide
ZnSe	-	Zinc Selenide
α	-	Absorption coefficient in cm^{-1}
ε	-	Dielectric constant of electrode material
ε_o	-	Permittivity of vacuum
Θ	-	Angle of diffraction

λ	-	Wavelength
β	-	Full width half maximum
$\beta_{1/2}$	-	Broadening diffraction line measured at half of its maximum intensity

CHAPTER 1

INTRODUCTION

This chapter is for the introduction of the final year project that covers the research background as well as the motivation, problem statement of the project. The problem statement has been stated in detail. In this chapter, the project scope is determined and outline has been progressed.

1.1 Background Studies

With the continuous growing population globally, there is always an increase in demand for energy. Although fossil fuels are now used to fulfill 86% of these needs, there is a need to find more alternate resources since non-renewable energy such as using petroleum or natural gases will eventually exhaust (Mediavilla *et. al.*, 2008). A steady growth in energy demand would probably result in a necessity for 55% more energy by 2030 (Mediavilla *et. al.*, 2008).

Semiconductors have been highly considered for its direct light energy to electrical energy conversion, with some studies showing semiconductors with indirect bandgaps reaching up to 1.42eV (Delphine *et. al.*, 2003). Studies have also been conducted on various metal-oxides as a favourable alternative material to be used in solar energy conversion due to its photoelectrochemical abilities. It is based on the water decomposition reaction by using semiconductor photoelectrodes, with a direct solar energy to chemical with high caloric fuel conversion as a result (Aroutiounian *et. al.*, 2005).

There are two types of films; thick and thin. They both are categorized with their thickness with thin films being defined as an extremely thin layer of substance measuring up from a fraction of a nanometer to a maximum of 1 micron thick (provided it does not have a substrate). Anything thicker than 1 micron is considered a thick film but anything thicker than 5 micron is known as a foil. Thin film characteristics might differ from its bulk characteristics. As an example, in a bulk an iron substance might possess higher strength than that of aluminium in every layer; but in thin films, the aluminium substance would be far stronger due to its crystallographic nature. Nanoparticles are highly dependent on the atomic nature of a material itself. Films require a base material or substrate but foils do not.

High quality thin films can be synthesized using various methods including chemical vapour deposition, pulsed laser, evaporation, molecular beam epitaxy, and sputtering. An alternative method using electrodeposition can also produce similar quality thin films and is the chosen technique to synthesis for this research. Electrodeposition is preferred due to its low cost and simplicity. It can be carried out in ambient atmosphere without requiring a vacuum system (Dharmadasa *et. al.*, 2006).

Electrochemical deposition (electrodeposition) is the process of flowing current form an external source through an electrochemical cell. The experiment usually consists of the working electrode which is used in conjunction with a counter electrode and a reference electrode. All of the electrodes will then be immersed in an electrolyte. A DC power (usually within the miliwatt range of ~2.0V and ~1.0mA) is applied across the anode and cathode at which the cathode will attract the positive ions, discharged and will chemically react to form Tungsten Diselenide (Dharmadasa *et. al.*, 2005).

Cyclic Voltammetry is the method of acquiring the potential range about electrochemical reactions (Andrienko, 2008). It is done by measuring the cycling potential of a working electrode and its resulting current that develops in the electrochemical cell under conditions at which the voltage is in excess and is predicted by the Nernst equation.

1.2 Problem Statement

Since the need to engineer renewable energy source increases, one must consider the materials used to make the solar panels. The existing solar panels used globally typically use pure silicon for their semiconducting wafers since it is the most available resource as it is made of silicon dioxide more known as sand. Even though it is abundant, the process needed to create the pure wafer silicon form is quite expensive, thus we have come up with another resource to possibly lower the cost for producing the wafers.

Next, silicon as an intrinsic semiconductor is highly dependent on its existing conducting properties to be able to generate electricity; hence we have tried out a possibly more resourceful way to combine transition metal dichalcogenide compounds (MX_2, where M = Mo, W, Sn, Ni, Cd, Zn and X = Se, S, Te) as to not exhaust a single resource too fast. Silicon also has a low conversion efficiency of 12~14% while an ideal efficiency would be around 1~2% which would have an efficiency of a conductive material.

A compound consisting of tungsten and selenium is chosen as the material to be studied for the synthesis of solar cell panels as theoretically, it will be better in comparison to silicon as well as the combination of other transition metals. This is also supported in some of the previous studies which will be stated in the literature review. Further support for the study of Tungsten Diselenide will be explained further in this report.

1.3 Objectives of the Project

The objective for conducting this research study based on WSe_2 thin films is as follows;

a) To synthesis stoichiometric Tungsten Diselenide (WSe_2) binary thin films by electrochemical route
b) To analyse the deposition parameters and structural studies of Tungsten Diselenide (WSe_2) by X-Ray Diffraction and Scanning Electron Microscopy
c) To study the optical and photoelectrochemical properties of binary WSe_2 thin films due to the effect of variable deposition times and deposition potential

1.4 Scopes and Limitations

The WSe_2 thin films will be synthesized using electrochemical deposition method at ambient atmosphere. The electrolyte that will be used for development of the thin films will be composed of Tungsten Trioxide (WSO_3) and Selenium Dioxide (SeO_2) as well as distilled water and Sodium Hydroxide in order to encourage more Se^{2-} development. Thickness of the formed thin films is to be measured using the gravimetric weight difference method at which the thin film samples are broadly cleaned for removal of interfering substance. Morphological and compositional analysis of the WSe_2 will be done via optical microscope, Scanning Electron Microscope (SEM) and Energy Dispersive X-Ray Spectroscopy (EDX). Optical studies of the WSe_2 will be done via UV-Visible Spectrophotometer and semiconducting parameters is investigated using the Mott-Schottky Plot.