FABRICATION OF CADMIUM SULFIDE AND CADMIUM TELLURIDE SOLAR CELLS AND THEIR CHARACTERISATIONS

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A dissertation submitted in fulfilment of the
requirements for the award of the degree of
Master of Science (Physics)

Faculty of Science
Universiti Teknologi Malaysia

JUNE 2014

To beloved mother, father and wife

ACKNOWLEDGEMENT

First of all, my heart and soul say thanks to God “ALLAH” (SWT), the Lord Almighty, for His generousity to giving me the health, strength and ability to complete this thesis.

I would like to express my sincerest appreciation to my project supervisor Prof. Dr. Samsudi Sakarani for his advice, guidance, encouragement, spent a lot of time to assist and consult me in this venture.

Furthermore, this thesis would not have been possible without the very pleasant and creative working atmosphere that at the Vacuum Laboratory, Physics Department Faculty Science, Universiti Technologi Malaysia, Skudai.

I shall forever be grateful to my parent, my siblings, their families and my wife for their belief in me even when I did not and for their unending support, spiritually and emotionally. To them I am highly indebted and words alone cannot describe my gratitude.

ABSTRACT

The thin film CdTe based solar cells have the potential for high efficiency and have been investigated for 40 years due to their variations in flexibility in manufacturing technology, rapid deposition, and an excellent match to the solar spectrum. Cadmium Telluride (CdTe) is a promising thin film photovoltaic (PV) material due to its near ideal bandgap of ~ 1.5 eV and its high optical absorption coefficient. The typical CdTe thin film solar cell was a substrate configured with a window layer (CdS). The gold (Au) was used as an absorber (CdTe) and a back contact. Both semiconductor films, CdS and CdTe, were deposited by high vacuum evaporation at room temperature, and deposited on glass substrates with fluorine doped tin oxide (FTO) front contact. The back contact was made to enhance carriers flow from CdTe layer to the electrode. The structure and morphology of the prepared cells were determined by X-ray diffraction (XRD), Energy Dispersive X-ray (EDX) top views and Field Emission Scanning Electron Microscopy (FESEM) cross-section. The XRD of the prepared films showed a polycrystalline of cadium sulphide and cadium telluride structure with peaks at $2\theta = 26.54^{o}$ and 23.71^{o}, respectively. It was found that the distance between the created particles (d) is 3.34 Å for CdS, and 3.6 Å for CdTe. The FESEM image showed clearly the layers of fabricated cell and the junction between N-type and P-type was a visible from cross-section. The efficiency of cells was investigated by using three different thicknesses of CdS and CdTe. Efficiency about 7.98 %, I_{cs} = 19.1 mA and V_{oc} = 0.76 V were achieved by deposited thin layer of CdS and thick layer of CdTe with a gold as a back contact.

ABSTRAK

Sel-sel solar yang diperbuat daripada tapak filem tipis CdTe mempunyai potensi kecekapan yang tinggi dan telah dikaji selama lebih 40 tahun kerana kelebihannya dalam teknologi pembuatan, pemendapan pantas, dan sifatnya yang sesuai sebagai pasangan kepada spektrum suria. Foto-voltan filem tipis Cadmium Telluride (CdTe) dikenalpasti sebagai bahan yang berpotensi tinggi kerana keunikan nilai jurangnya iaitu ~1.5 eV selain pekali penyerapan optiknya yang tinggi. Pada kebiasaannya, CdTe filem nipis sel solar adalah sejenis substrat yang dikonfigurasikan dengan lapisan tetingkap (CdS). Emas (Au) digunakan sebagai penyerap (CdTe) dan penghubung belakang. Proses pemendapan kedua-dua filem semikonduktor, CdTe dan Cd telah dilakukan menggunakan pemendapan vakum tinggi yang dibiarkan pada suhu bilik. Kepingan kaca yang mempunyai penghubung depan oleh fluorin yang didopkan timah oksida (FTO) digunakan sebagai substrat. Penghubung belakang dibuat untuk meningkatkan pengaliran cas-cas pembawa daripada lapisan CdTe ke elektrod. Struktur dan morfologi sel-sel dikaji dengan x-ray pembelauan (XRD), Sebaran Tenaga sinatan-x (EDX) dan keratan rentas Field Emission Scanning Electron Microscopy (FESEM). XRD filem tersebut menunjukkan proses polihabluran antara struktur kadmium sulfida dan kadmium Telluride dengan puncak masing-masing di 2θ = 26.54° dan 23.71°. Kajian XRD menunjukkan jarak antara zarah ialah (*d*) 3.34 Å untuk Cd dan 3.6 Å untuk CdTe.

Imej keratan rentas FESEM menunjukkan dengan jelas lapisan-lapisan sel dan simpangan antara jenis-n dan jenis-p. Kecekapan sel-sel Cd dan CdTe dikaji dengan menggunakan tiga ketebalan yang berbeza. Menurut kajian yang dilakukan, sel-sel tersebut menunjukkan nilai kecekapan sekitar 7.98 %, dengan I_{CS} = 19.1 mA dan V_{oc} = 0.76 V. Nilai ini diperolehi daripada proses pemendapan antara lapisan nipis Cds dan lapisan tebal CdTe dengan emas sebagai penghubung belakang.

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LIST OF ABBREVIATION/ SYMBOLS

A	Area of solar cell
A	The diode quality factor
Å	The angstrom
Ag	Silver
Au	Gold
^{o}C	Celsius
$CdCl_2$	Cadmium chloride
CdS	Cadmium sulphide
CdTe	Cadmium telluride
CSS	Close Space Sublimation
Cu	Cupper
d	Distance between particles
E_o	Vacuum energy
E_c	Conduction band energy
EDX	Energy Dispersive X-ray
EF	Fermi energy level
E_g	Energy bandgap
E_{gn}	Energy bandgap (electron)
E_{gp}	Energy bandgap (hole)
E_v	Valence band energy
eV	Electron volte

FF	Fill Factor
FESEM	Field Emission Scanning Electron Microscopy
FTO	Flourine doped Ten Oxide
HF	Hydroflouride acid
HVE	High Vacuum Evaporation
I_m	Maximum current
IV	Current and Voltage
In_2O_3	Indium(III) Oxide
I_{gen}	Generated current
I_{sat}	Saturation current
I_{sc}	Short circuit current
J_{sc}	Current dencity
k	Poltzmann's constant
K	Kelvin
KV	Kilovolts
mA	Milliampere
MOCVD	Meta Organic Chemical Vapor Deposition
mW	Milliwatt
n	Electron
n	Order diffraction
η	Efficiency
N_A	Doping concentration in the holes
N_D	Doping concentration in the electrons
nm	Nanometer
p	Hole
P_m	Maximum power
q	Charge
Si	Silicon
Sq	Square
T	Temperature
TCF	Transparent Conducting Films
TCO	Transparent Conducting Oxide
UV	Ultra violet
µm	Micrometer

V	Voltage
V_A	Voltage applied
V_m	Maximum voltage
V_{oc}	Open circuit voltage
VTD	Vapor Transport Deposition
X	The electron affinity energy
χ_n	Electron affinity
χ_p	Hole affinity
ZnO	Zinc Oxide
ZnO_2	Zinc peroxide
λ	Wavelength of X-ray
θ	Diffraction angle
Ω	Ohm
ϕ_B	Schottky barrier
ϕ_m	The metal work function
ϕ_n	Fermi level N-type
ϕ_p	Fermi level P- type
ϕ_s	The semiconductor work function

CHAPTER 1

INTRODUCTION

1.1 Background

About 66% of the world electrical power provide by fossil fuels, and world's total energy demands about 95%. As worldwide requirement of energy is more than supply, due to this reason the total cost of suppling electricity becomes expensive. Due to use these fossil such as, coal, gas and oil the global warming and climate have been changed. Also using of fossil fuels to produce electricity and transportation vehicles products carbon dioxide, sulphur and nitrogen oxide leads to acide rain. Hence, it is necessary to look for clean, efficient and sustainable form energy source. The solar energy is one of the most important significant renewable source of energy, which is abundant. The sun is continual source of light and heat. About 5,000,000 tons of energy per second emits from the sun in gama ray. All these rays move to the ground's surface, some of them is absorbed and some of them re-emitted towards universe. The total energy radiate from the sun toward the earth about 98% within 0.25μm to 3μm wavelength (Bapanapalli, 2005).

CdTe is a nearly perfect absorber material for solar cell because the bandgap closely matches the peak of the solar spectrum, relatively high absorption coefficient and good electronic properties in the polycrystalline phase. Fabricating high-efficiency CdS/CdTe solar cells with an ultra-thin absorber layer is a challenging yet highly desirable step in improving CdTe technology. Most of today’s CdTe solar cells utilize an absorber layer which is about 2.5 μm to 8 μm thick. Thinning this layer down typically results in poorer cell performance due to shunting, incomplete photon absorption, fully depleted CdTe layer or interference between the main and the back contact junction when the CdTe layer thickness approaches a certain limit. While some of these losses are fundamental, others can be minimized by careful optimization of the fabrication steps (Rogach, 2000).

Figure 1.1 shows the global market share of the different PV technologies for the years 2008 and 2009.The crystalline silicon accounts for 85% of the PV market. The biggest change this past decade has been the emergence of CdTe thin-film technology from 8% in 2008 to 13% in 2009. First Solar has brought CdTe to mass production and in 2009 it became the world's first PV manufacturer to exceed 1 GW/year production rate capturing 13% of the global market (Palekis, 2011).

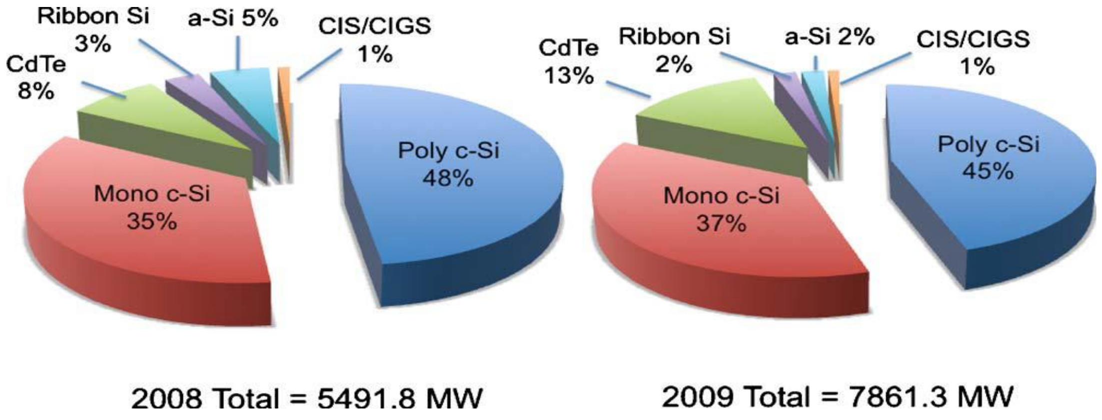

Figure 1.1: Market share for PV technologies (Palekis, 2011)

1.2 Problem Statement

Cadmium telluride (CdTe) has been recognized as a very promising material for thin-film solar cells. Furthermore, it is a II–VI compound semiconductor with a direct optical bandgap 1.5 eV that is nearly optimally matched to the solar spectrum for photovoltaic (PV) energy conversion. It has a high absorption coefficient, which means that 99% of photons with energy greater than the bandgap (E_g) that can be absorbed within 2 cm^2 of CdTe film. In contrast, cadmium sulfide (CdS) with its large bandgap and chemical stability, is an N-type semiconductor used as a window layer in many types of solar cells in conjunction with absorbers CdTe. The best cell efficiencies attained so far are 16.5% for CdTe and CdS. Thin films of CdS have been studied extensively over the past three decades (Wu *et al*., 2004). Based on the fact that CdS has been the most widely used and most successful N-type window layer, thin film solar cells of CdS with CdTe has proposed as a new solar cell. Various techniques such as chemical vapor deposition, magnetron sputtering, and chemical bath deposition have been used to make uniform and transparent CdS films to produce high efficiency solar cells (Kumazawa *et al*., 1997; Moutinho *et al*., 2003; Aksu *et al*., 2011; Bhandari *et al*., 2013).

In the present study, different materials have been proposed to produce a high efficiency thin film solar cell layer by layer based on CdTe and CdS heterojunction by using high vacuum thermal evaporation. The gold (Au) will be used as a back contact due to its work function greater than P-type CdTe. Inaddition, silver (Ag) will be used as electrode to measure the current and voltage that created by the solar cell.

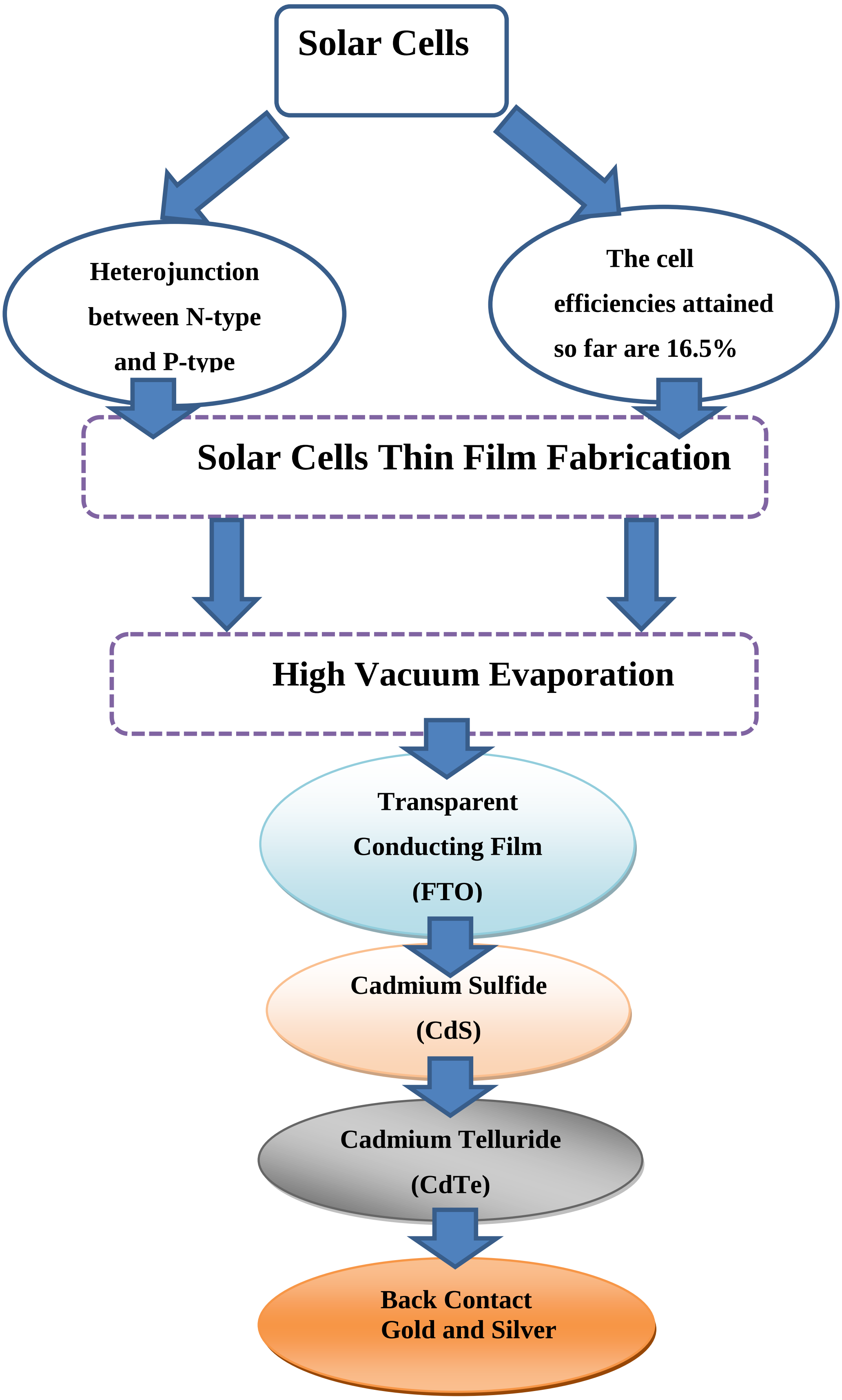

Figure1.2: Flowchart of the research work

1.3 Research Objectives

This study embarks on the following goals:

i) To fabricate CdS/CdTe solar cells using high vacuum evaporation .

ii) To characterise the structure of CdS/CdTe solar cells.

iii) To determine the performance of electrical characteristics based on current – voltage measurement.

1.4 Scope of the research

The current study was splited into three main scopes to achieve the stated objectives. First, the proposed solar cell samples will prepared by using the basic of N-type and P-type (CdS/CdTe). As a supplementary step, gold and silver will perform as contact back materials by using high vacuum evaporation. Second, X-ray diffraction (XRD) and Field Emission Scanning Electron Microscopy (FESEM) will use to identify the structure and amorphouse phase of the prepared solar cell. Finally, a significant measurement for the current and voltage (IV) will calculate taking the consideration of dark and light effect.

1.5 Significant of the study

The current study will be done to clarification of making CdS/CdTe solar cells by using high vacuum evaporation and using gold (Au) as contact layer with silver (Ag) for electrode. Furthermore, understanding solar cell working based in PN junction and determines electrical properties of solar cells based on current and voltage measurement in light and dark condition.

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