A NUMERICAL STUDY ON PHOTOVOLTAIC CELL PERFORMANCE AT HIGH TEMPERATURE

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by

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(1130910634)

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DECLARATION OF THESIS

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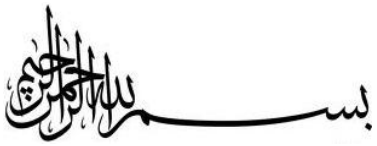

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LIST OF SYMBOLS

E_g	Band-gap energy
I_0	Intensity of incident light
I_S	Saturation Circuit Current
I_{SC}	Short Circuit Current
P_{out}	Output Power
V_{OC}	Open Circuit Voltage
$V_{OCdeficit}$	Open Circuit Voltage deficit
c	Velocity of light
h	Plunk's Constant
I	Intensity of transmitted light
K	Boltzmann's Constant
T	Temperature
x	Penetration depth
α	Absorption co-efficient
β, γ	Vershini's parameters
λ	Wavelength of light
q	Charge of electron

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Si	Silicon
GaAs	Gallium Arsenide

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LIST OF ABBREVIATIONS

PV Photovoltaic

OC Open Circuit

SC Short Circuit

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Kajian berangka bagi Prestasi Bimbit Photovoltaic di Suhu Tinggi

ABSTRAK

Ini kerja-kerja penyelidikan membentangkan peningkatan ciri-ciri sel photovoltaic di atas suhu bilik. Kesan suhu ke atas ciri-ciri yang berbeza daripada sel photovoltaic telah dianalisis secara matematik. Antara ciri-ciri sel photovoltaic pertama sekali, penghantaran cahaya dan ciri-ciri penyerapan yang telah disiasat. Kemudian litar terbuka voltan, arus litar pintas dan ciri-ciri kuasa keluaran sel photovoltaic telah disiasat. Akhirnya kesan suhu ke atas kadar pertukaran semua ciri-ciri ini telah dianalisis dengan menggunakan Si dan GaAs dalam lapisan aktif sel photovoltaic. Keputusan berangka yang diperolehi dibandingkan. Keputusan perbandingan menunjukkan bahawa ciri-ciri penyerapan, voltan litar terbuka, arus litar pintas dan kuasa output telah meningkat tetapi perubahan ciri-ciri ini telah dikurangkan dengan ketara dengan menggunakan GaAs. Sebagai keputusan, GaAs boleh dipertimbangkan sebagai bahan alternatif terbaik untuk mereka-reka sel solar dalam beberapa dekad akan datang.

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A Numerical Study on Photovoltaic Cell Performance at High Temperature

ABSTRACT

This research work presents the improvement of photovoltaic cell characteristics above room temperature. The effect of temperature on different characteristics of the photovoltaic cell has been analyzed mathematically. Among the characteristics of photovoltaic cell first of all, the light transmission and absorption characteristics were investigated. Then the open circuit voltage, short circuit current and the output power characteristics of the photovoltaic cell were investigated. Finally the effect of temperature on the rate of change of all these characteristics was analyzed using Si and GaAs in the active layer of the photovoltaic cell. The numerical results obtained were compared. The comparison results revealed that the absorption characteristics, open circuit voltage, short circuit current and the output power have been increased but the variation of these characteristics have been reduced significantly by using GaAs. Therefore GaAs can be considered as the best alternative material to fabricate solar cell in upcoming decades.

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CHAPTER 1

INTRODUCTION

1.1 Background

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At the current rate of fossil fuel consumption, we are using up our energy resources faster than physical processes produce them. We are likely to start running out of adequate oil reserves in the very near future. Assuming that human civilization will exist for many more than the next couple of hundred years, and taking into account the increasing fossil fuel consumption by countries that were once non-consumers, continuing on without having another alternative source of energy is not an option. Almost 85% of our energy consumption is from fossil fuels. However only 7% of the consumed energy comes from renewable energy sources and only 1% of which is from solar energy. The statistical data of overall energy consumption is shown in Figure 1.1 and the consumption of solar energy has been presented in Figure 1.2.

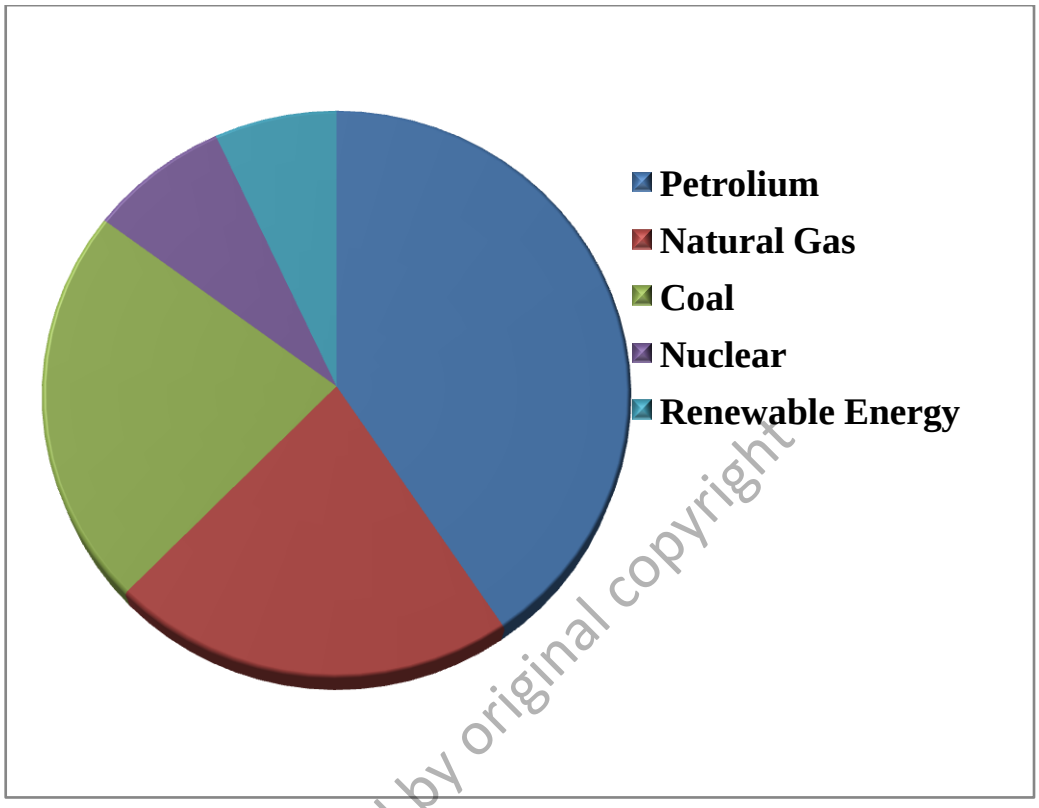

Figure 1.1: The different sources of energy.

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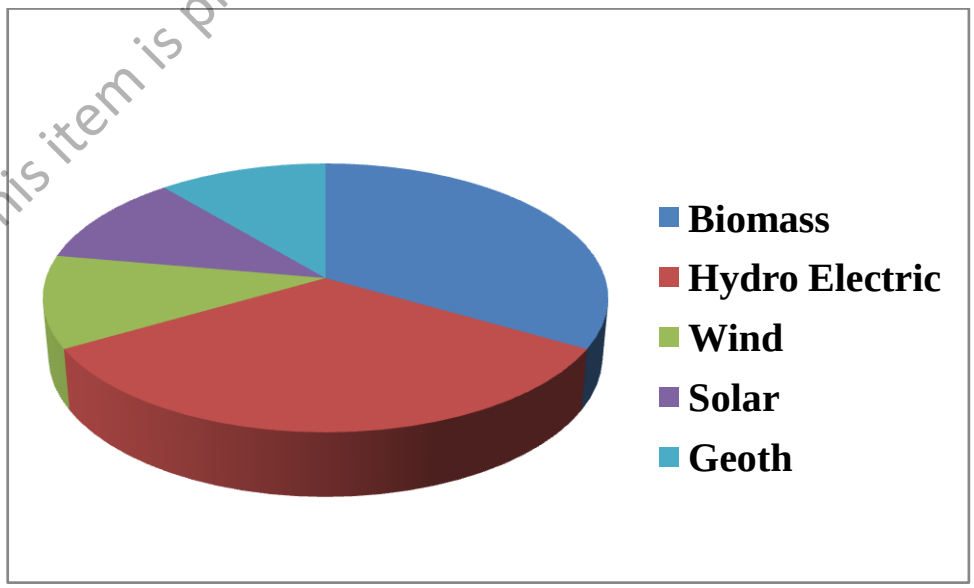

Figure 1.2: The different sources of renewable energy.

This is also the common knowledge that the use of fuels like oil and gas in homes, cars and industry has brought us to the problem of global warming. (Mor, Varghese,Paulose, Shankar,& Grimes, 2006).

Figure 1.3: Environment pollution from burning of fossil fuels.

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`The extreme production of harmful gases like carbon monoxide has destroyed the ozone layer hence we receive both the harmful and harmless sunrays. Among all the renewable energy sources, solar energy holds the most promise for providing a sustainable energy source. Scientists estimate that our Sun will continue producing solar energy for another five billion years (Fara, Ghatas, Amgad, Noaman,& Daoud, 2012).

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Figure 1.4: Different types of renewable energy sources.

Definitely it is not a matter to worry about running out of solar energy because it is the ultimate renewable energy available all over the world. In one hour enough sunlight reaches to the earth to supply its energy needs for an entire year. So it is not only sustainable, but also provides more than enough energy for overall demand. Researchers just need to continue improving the solar technology so that more of this energy can be captured to convert into electricity.

1.2 Problem Statement

Power crisis has become a severe problem all over the world. Recently it has been reported that different sources of energy pollutes our environment in different ways and in different degrees (Mahrane,Chik,&Chikouche, 2010). The solar energy is widely used around the world because it is the most environmental friendly energy source ever discovered (Sharaf, & Yang, 2005).

The existing PV cells are fabricated using conventional bulk materials like Si(Doi, Tsuda, Sakuta & Matsui,2003), Ge (Fan et al. 2010), GaN and AlN. However there are some issues remain which is about material quality of layers including the p-type doping(Huang, Semichaevsky, Webster, Johnson, &Goldman,2011). Recently researchers have found that GaAs is thought to have better potential in providing higher stability in device performance. Besides some unique properties of GaAs, such as the strong polarization, piezo-electric effect and many others have made it attractive to the researchers worldwide.

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Silicon based PV cells had been used widely all around the world. It is one of the primary limitations in achieving high output power of PV cells. Therefore, this research has been devoted on GaAs based PV cell to achieve higher output power. Few problems have been detected from previous PV cells like local increase in the dark forward current of a cell usually that is caused by the materials. Besides the existing PV cells is too bulky and it require a large space area to install.

Additionally, it is possible to reduce the number of PV cells in a PV module by increasing the output power of the cell. If the number of total PV cells is reduced the cost and the space used to install a PV panel will be reduced as well. Therefore, a cost

reduction will be achieved to install the PV system. Furthermore, the efficiency of the PV system is inversely proportional to the number of PV panel used. Therefore if the number of the PV panels can be reduced the efficiency of the overall system will be improved. So the number of PV panel used can be decreased to achieve the required power if the output power of the PV cell is improved. On the other hand efficiency is directly proportional to the output power. Therefore in order to increase the efficiency the main focus is to increase the output power. Hence a new solution to increase the output power will be determined by changing the material used to fabricate PV cells. This thesis is based on characteristics analysis of GaAs based PV cell which will be compared to the existing material like Silicon.

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1.3 Objectives of the Research

The aim of this research work is to study the different properties of PV cell and improve the certain characteristics above room temperature. Theoretical analysis of the temperature dependence of certain characteristics of PV cell has been performed through mathematical approach. The effect of temperature on absorption characteristics of incident light by the active layer material, open circuit voltage, short circuit current and output power of the PV cell has been investigated extensively. These numerical analysis of the temperature dependence have been performed using GaAs as the active layer material.

MATLAB software has been used to analyze the mathematical formulae which provided analytical friendly environment that can provide consistently good results, to improve knowledge in research and at the same time to solve the problems.

Recently it has been reported that GaAs can be a challenging material to design high efficient devices. Therefore GaAs has been selected as the active layer material to investigate the characteristics of PV cell in order to improve the stability. Besides, solar energy is using renewable source which is a green technology. It will help our environment from any kind of pollution. Therefore I have devoted my research on GaAs based PV cells.

The main objective of this research work is to investigate the temperature dependence of the characteristics of PV cell using GaAs. The following characteristics of PV cell have been investigated extensively above room temperature. The main objectives of this research are as follows:

- To derive mathematical formulation of GaAs PV cell performance
- To investigate the GaAs PV cell performance
- To compare the performance of GaAs PV cell with existing PV cells.

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1.4 Scope of the research

PV cells are used in many different applications, covering a power range from 1 mW to multi MW. Traditionally, the most common application of PV has been for electrical loads those cannot be easily plugged into the electricity grid, either because they should be transportable – such as solar calculators, watches etc. or because the electricity grid does not exist at a particular location. When the grid is located far away from a particular application, PV is being used to provide "remote power". Examples of these applications are houses not connected to grid power, telecommunications, remote villages, water pumping and space. However, a recent and rapidly growing application

for photovoltaic is for residential or building integrated which are connected to the electricity grid. During the day, power is used from photovoltaic, and at night power is used from the electricity grid. The main problems of the performance of PV cells are associated with the effect of temperature variation of the environment.

In this research work the effect of temperature variation has been reduced by using GaAs as the active layer material. Therefore it is highly expected that the outcome of this research work will be used to develop a PV cell with lower temperature sensitivity.

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1.5 Thesis Outline

This report has been divided into six chapters for the study of characteristics analysis of GaAs based PV cell above room temperature. The content of each chapter will be explained clearly in this sub topic.

Chapter 1 presents the introduction of the research including the overview of the present research, problem statement, objective and the scopes of the research. The objective of it is to find out the suitable material to design a PV cell so that it can achieve a better performance above room temperature.

Chapter 2 will include the analysis of the existing research which is related to this present research and that is why this Chapter is known as Literature Review. It will clearly explain about the present status of research on PV cell. All the information that had been included in this research has been summarize from the related books, journals and conferences. By the way this chapter is the key for ideas to complete the thesis.

Research Methodology will be discussed in Chapter 3 on how this thesis progress works. It will be explained clearly step by step that had been taken to identify the parameters that affect the efficiency of PV cells and the software used to run the simulation will be discuss in this chapter too. Some theory related to the mathematical formulae used in this research has been presented in this chapter also.

MATLAB software has been used in this research work to analyze all the parameters that had been identified based on mathematical formulation. In Chapter 4 the discussion will give the details of the result of each parameters and easy to others to understand this thesis.

Each report consists of a chapter to conclude all and make recommendation and it is same as this thesis. Chapter 5 will discuss more on the achievement and the ways to improve this research work. The commercialization potential of this research work has been discussed in this chapter.

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CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The high sensitivity of an existing PV cell is a challenge to the researchers in the field of engineering nowadays. Temperature variation causes the degradation of PV system performance nowadays. The aims of this research are to study and analyze on the effect of temperature on the PV cell characteristics. Furthermore, this research also focuses on selecting the proper material to design a PV cell with better performance in its characteristics at high temperature.

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2.2 Solar Energy

The most efficient energy converting life forms on the planet today are photosynthesizing plants. They directly take in the number-one source of energy, solar energy, and convert it into bio-chemical energy, which they use to carry out life functions. The way in which humans power all aspects of our advanced society, however, is at the other end of the spectrum. We use solar energy, which is stored in the fossilized remains of plant and animal matter deposited many meters underground, which takes millions of years to form - hardly an efficient way of obtaining energy.