Design and Simulation of Ultra-Thin CdS-CdTe Thin-Film Solar Cell

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Design and Simulation of Ultra-Thin CdS-CdTe Thin-Film Solar Cell

A Thesis Submitted to The Faculty of Science and Engineering, Department of Electronics and Communications Engineering, East West University; Dhaka, Bangladesh in Partial Fulfillment of The Requirements for The Degree of Bachelor of Science in Electronic and Telecommunication Engineering.

Department of Electronics and Communications Engineering
Faculty of Science and Engineering
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DECLARATION

This is to certify that this thesis is based on research is our original work. Not any part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

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APPROVAL

The thesis titled "**Design and Simulation of Ultra-Thin CdS-CdTe Thin-Film Solar Cell** " has been submitted to the Department of Electronics and Communications Engineering, Faculty of Science and Engineering, East West University; Dhaka, Bangladesh in partial fulfillment of the requirements for the degree of Bachelor of Science in Electronic and Telecommunication Engineering on December 2014 by the following students and has also been accepted as satisfactory, under complete supervision of the undersigned.

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Finally, we would like to express our gratitude to our beloved parents for their tremendous inspiration and supports that they provided us with.

Dedicated to Our Beloved Parents

ABSTRACT

Cadmium telluride (CdTe) has long been recognized as a strong candidate for thin film solar cell applications. It has a band gap of 1.45 eV, which is nearly ideal for photovoltaic energy conversion. Due to its high optical absorption coefficient essentially all incident radiation with energy above its band-gap is absorbed within 1±2 mm from the surface. Thin film CdTe solar cells are typically hetero junctions, with cadmium sulfide (CdS) being the n-type junction partner.Cadmium telluride (CdTe) is the leading material for realization of low cost and high efficiency solar cell for terrestrial use. In this work, the CdTe conventional structure was investigated and achieved the maximum conversion efficiency of 25.16% with CdS. To explore the possibility of ultra-thin and high efficiency CdS-CdTe solar cell, the CdTe absorber layer and CdS window layer were decreased and found that 1 µm thin CdTe layer showed reasonable range of efficiency. Moreover, it was found that there were scopes to increase cell efficiency by reducing the cadmium sulfide (CdS) window layer thickness. The CdS window layer was reduced to 50 nm. All the simulation have been done using Analysis of Microelectronic and Photonic Structures (AMPS 1D) simulator. The maximum conversion efficiency of 25.16% (*Voc*= -1.078 V, *Jsc*= 26.330 mA/cm^2, FF = -0.887) was achieved with 1 µm- CdTe absorber layer, 50 nm-CdS window layer.

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CHAPTER I

INTRODUCTION

1.1 MOTIVATION

According to the American Energy Information Administration (EIA) and to the International Energy Agency (IEA), the world-wide energy consumption will on average continue to increase by 2% per year. A yearly increase by 2% leads to a doubling of the energy consumption every 35 years. This means the world-wide energy consumption is predicted to be twice as high in the year 2040.

By far the highest increase in world-wide energy consumption is predicted to be from all three fossil fuels: oil, coal and natural gas. The renewable energies are predicted to grow as well, but much less than fossil energy. Nuclear energy is predicted to grow relatively moderate. The International Energy Agency (IEA) predicts a strong increase of the carbon dioxide emissions by the year 2030. Additionally, IEA investigated to which extent the above mentioned emissions of CO2 could be prevented if politics applied rigorous measures. From all measures investigated, nuclear energy was found to have the least effect (only 10%). Almost 80% of the desired effects are due to increasing the energy efficiency.

Worldwide energy usage in 2012 averaged 17 TW and 80% of that energy came from fossil fuel like gas, oil and coal [1]. The energy consumption is increasing day by day with the increasing of population growth and the developments of underdeveloped areas. According to the European Photovoltaic Industry Association, the predicted energy consumption for 2050 would be 30TW [2].

The need for electricity has constantly risen world-wide over the last years. This is not only true for the so-called developing countries but alsoin particular for all well-developed countries. In order to fulfil the demand, obviously additional power plants have to be built. Which technology is best for generating electricity? This question certainly has to be answered on a case by case base. But it is very concerning that nuclear power plants more and more seem to be chosen as "the" technology of the future.

Fossil fuels, like gas and oil, are not renewable energy. Once they are gone they can't be replenished. Someday these fuels will run out and then mankind will either need to come up with a new way to provide power or go back to life as it was prior to man's use of these things. Fossil fuels create massive pollution in the environment. This pollution affects waterways, the air we breathe, and even the meat and vegetables that we eat. These fuels are expensive to retrieve from the earth and they are expensive to use. *Other, more Eco-friendly energy sources like wind and solar energies are relatively inexpensive and easy to produce.*

1.2 IMPORTANCE OF SOLAR CELL

Solar-energy systems allow us to capture free sunlight and convert it into usable power for our daily life. Solar energy can be used to heat and cool our home, but it has almost no impact on the global climate. By comparison, electricity generated by power plants produces carbon dioxide emissions that scientists say pose serious threats to the environment. While nonrenewable energy sources like oil, gas and coal are becoming increasingly scarce, the sun’s energy is limitless. Wherever sunlight shines, electricity can be generated .Having a system that creates solar energy means we use less electricity from our utility company and that can contribute to lower heating and cooling costs.

The more sunlight harnessed by the system, the less electricity we need from our utility supplier. An investment in a solar-energy system may improve the value of our home, thanks to its ability to lower the cost of heating and cooling. The sun has been around for billions of years and is likely to burn on for billions more to come. And when we consider how a trusted name like Lennox is putting it to economical use in the home, it’s easy to see solar energy’s future is bright.

Solar panels can be used for a wide variety of applications including remote power systems for cabins, telecommunications equipment, remote sensing, and of course for the production of electricity by residential and commercial solar panel systems.

There are many reasons why we should all use solar panels to provide a source of clean, cheap and renewable energy for our homes. We think the main reason why we should use solar panels at home is because, its energy actually taken from the sun which means that it's natural and less harmful for our planet so it could keep our environment clean.

1.3 IMPORTANCE OF CdS-CdTe SOLAR CELL

Thin-film cadmium telluride (CdTe) solar cells are the basis of a significant technology with major commercial impact on solar energy production. Large-area monolithic thin film modules demonstrate long-term stability, competitive performance, and the ability to attract production-scale capital investments. Cadmium telluride (CdTe) has long been recognized as a strong candidate for thin film solar cell applications. It has a band gap of 1.45 eV, which is nearly ideal for photovoltaic energy conversion. Due to its high optical absorption coefficient essentially all incident radiation with energy above its band-gap is absorbed within 1-2 μm from the surface. Thin film CdTe solar cells are typically hetero-junctions, with cadmium sulfide (CdS) being the n-type junction partner. Small area efficiencies have reached the 16.0% level and considerable efforts are underway to commercialize this technology [8].

Cadmium telluride is one of the leading thin film materials for solar cell applications. Small area laboratory devices have demonstrated efficiencies of 16.0% while large area modules have exceeded the 9.0% level. The fact that a variety of deposition technologies can be used to fabricate efficient CdTe solar cells demonstrates the flexibility of this material with regards to the method of fabrication, and sets it apart from other thin film technologies.

CdTe panels have several advantages over traditional silicon technology. These include:

The necessary electric field, which makes turning solar energy into electricity possible, stems from properties of two types of cadmium molecules, cadmium sulfide and cadmium telluride. This means a simple mixture of molecules achieves the required properties, simplifying manufacturing compared to the multi-step process of joining two different types of doped silicon in a silicon solar panel.

Cadmium telluride absorbs sunlight at close to the ideal wavelength, capturing energy at shorter wavelengths than is possible with silicon panels

Cadmium is abundant, produced as a by-product of other important industrial metals such as zinc, consequently it has not had the wider price swings that have happened in the past two years with silicon prices.

1.4 OBJECTIVES

The main objectives of this work are designing, modeling and simulation of higher efficiency CdS-CdTe single junction solar cells by using AMPS 1-D software. The major goal of this study is to develop higher efficiency cost effective CdS-CdTe based solar cell.

The specific aims of this research work are as follows:

i. Design of high efficiency CdS-CdTe single junction solar cell
ii. The optimization of layer thickness of CdS and CdTe materials.
iii. The optimization of Back Contact.
iv. Simulation of the designed CdS-CdTe solar cells by AMPS 1-D software.

1.5 THESIS ORGANIZATION

This thesis is organized into four chapters as illustrated in Figure 1.1. Chapter 1 exposes a brief motivation, importance of using solar cell and illustrates the importance of CdS-CdTe thin film solar cell and the objectives of this study.

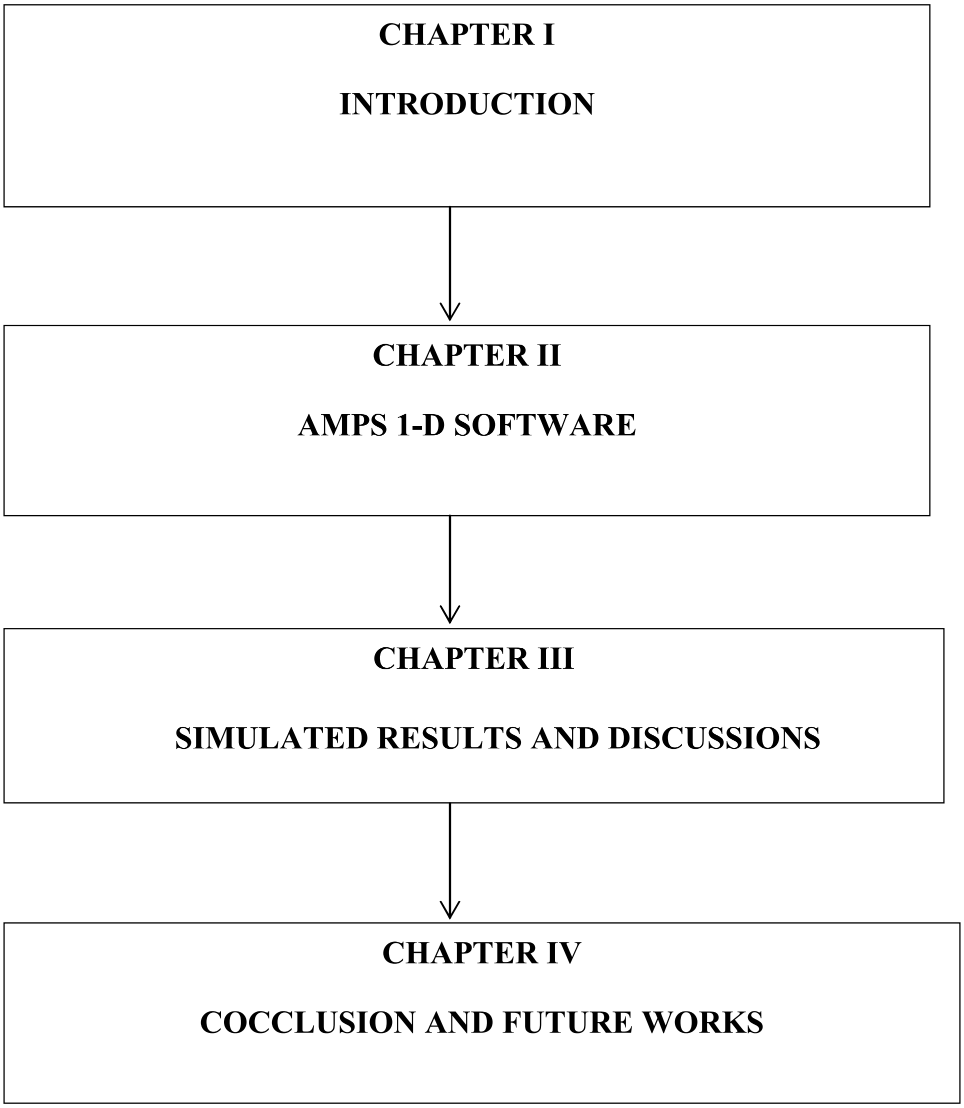


Figure 1.1: Overview of the thesis organization

Chapter 2 presents the details about the simulation software AMPS and its features. This chapter also presents how AMPS works and the necessary layer parameters which are used for simulating the proposed solar cell structure.

Chapter 3 focuses on the optimization of p-type CdTe and n-type CdS absorber layer thickness, the great influence of back contact to design proposed solar cell structure. This chapter also represents the final proposed structure of CdS-CdTe solar cell.

Chapter 4 illustrates the conclusion on this work and recommends the future work.

CHAPTER II

AMPS 1-D SOFTWARE

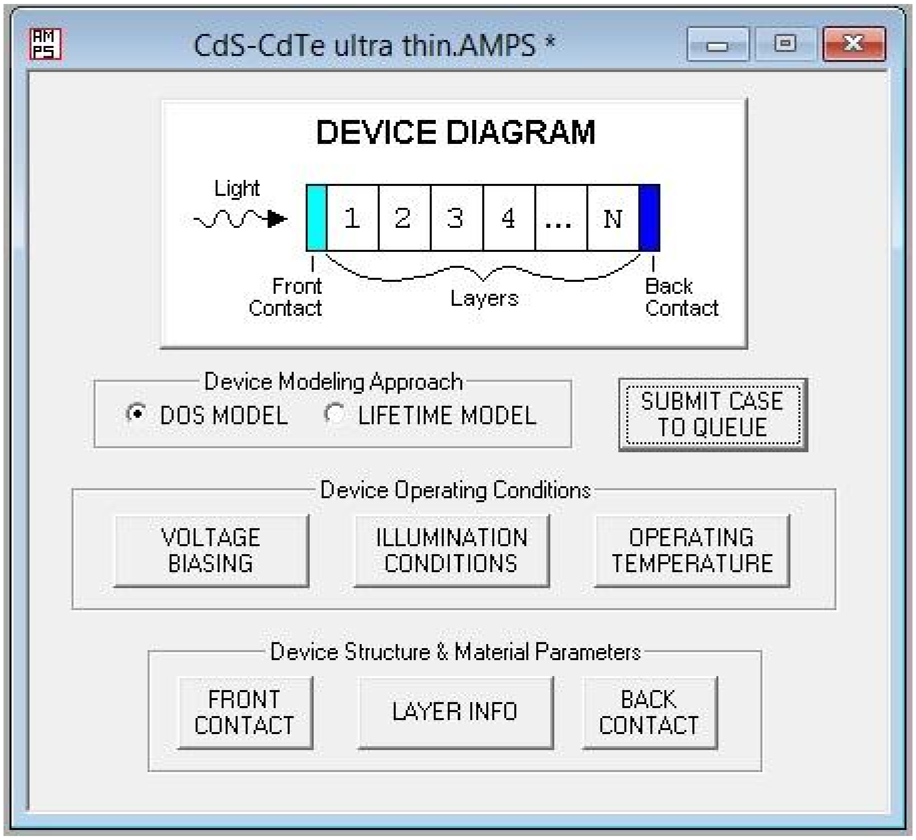
2.1 INTRODUCTION

A numerical solar cell simulator is a computer program that numerically solves the "Semiconductor Equations" for a given solar cell structure and parameters. Numerical simulation of a solar cell is a very important technique to predict the effect of physical changes on solar cell performance and to test the viability of the proposed cell structures. Several numerical programs have been developed and widely used and AMPS 1-D is one of them. In this work, AMPS 1-D software has been utilized to simulate the CdS-CdTe thin film solar cell. This chapter discusses the set-up of the conventional cell model with the AMPS software. The AMPS can analyze the transport in a variety of:

- Crystalline solar cell
- Mon-crystalline solar cell
- Amorphous solar cell
- Multi-junction solar cell structures
- Compositionally-graded detector and solar cell structures
- Homo-junction and Hetero-junction p-n and p-i-n, solar cells and detectors;

2.2 AMPS 1-D AND ITS FEATURES

AMPS stand for Analysis of Microelectronic and Photonic Structures. It was engineered to be a very general and versatile computer simulation tool for the analysis of device physics and device design. It is a one-dimensional (1-D) device physics code which is applicable to any two terminal devices. It can be for diode, sensor, photo-diode, and photovoltaic device analysis. The AMPS 1-D software was developed by Professor Stephen Fonash in Electronic Materials and Processing Research Laboratory at Pennsylvania State University. Under Electric Power Research Institute (EPRI) support the AMPS-1D project was initiated and developed for the UNIX operating system. A few years later, there was a demand for AMPS-1D on PCs. Hence, a PC version was developed for the OS/2 operating system. The BETA version 1.0, is used here which is widely used in solar cell research commonly. In figure 2.1 an AMPS window is shown:



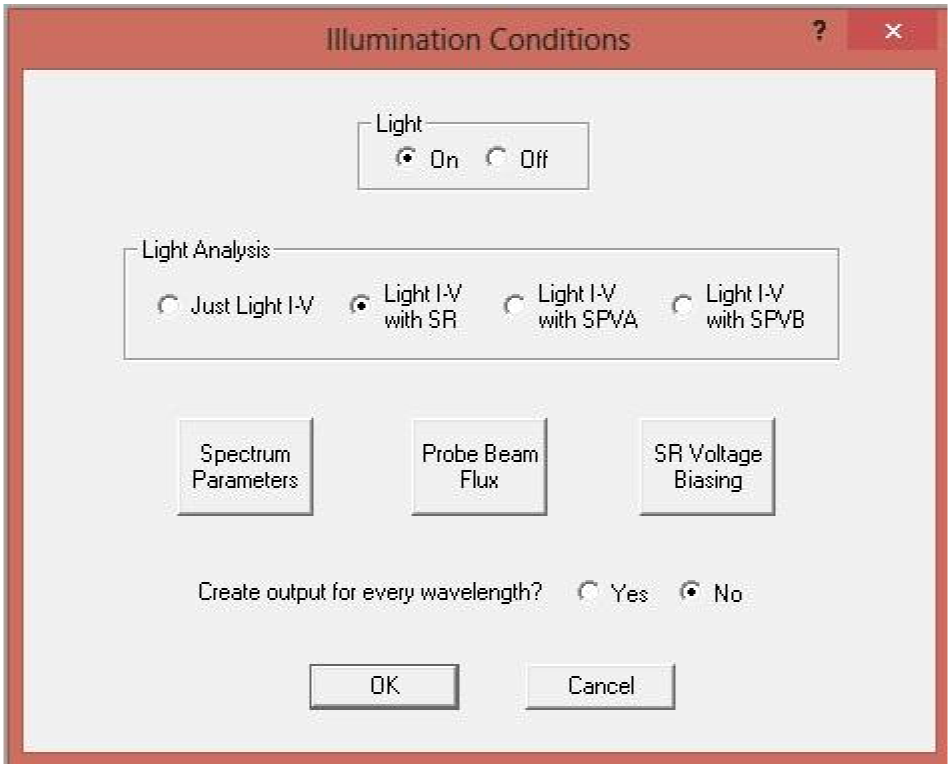
Device Modeling Approach: ● DOS MODEL ○ LIFETIME MODEL

Figure 2.1: AMPS window for simulation

There is an on line course about AMPS simulation by Professor Stephen Fonash. The AMPS 1-D programs ask the user to input the specific parameters of the different layers to build the structure of the device need to be tested. When running the AMPS simulation, the programs expects a set of default parameters. The user can save the default case and reset the parameters to be varied for a particular configuration.

The advantages of AMPS include its user friendliness as the stability in general. It also has a very flexible plotting program, in which the user can generate output ploys such as J-V curves, spectral response, band diagrams, carrier concentrations, current density, electrical field distribution, and recombination profiles.

However, AMPS has some disadvantages, such as the need to input all information including spectrum parameters by hand and the lack of interface treatment so that an interface in some cases need to be approximated by thin layers. Figure 2.2 shows the AMPS window for illumination condition.



Light: ● On ○ Off

Light Analysis: ○ Just Light I-V ● Light I-V with SR ○ Light I-V with SPVA ○ Light I-V with SPVB

Create output for every wavelength? ○ Yes ● No

Figure 2.2: AMPS window for illumination condition

There are three types of parameters that are necessary to enter in the device simulation window before any AMPS simulation starts:

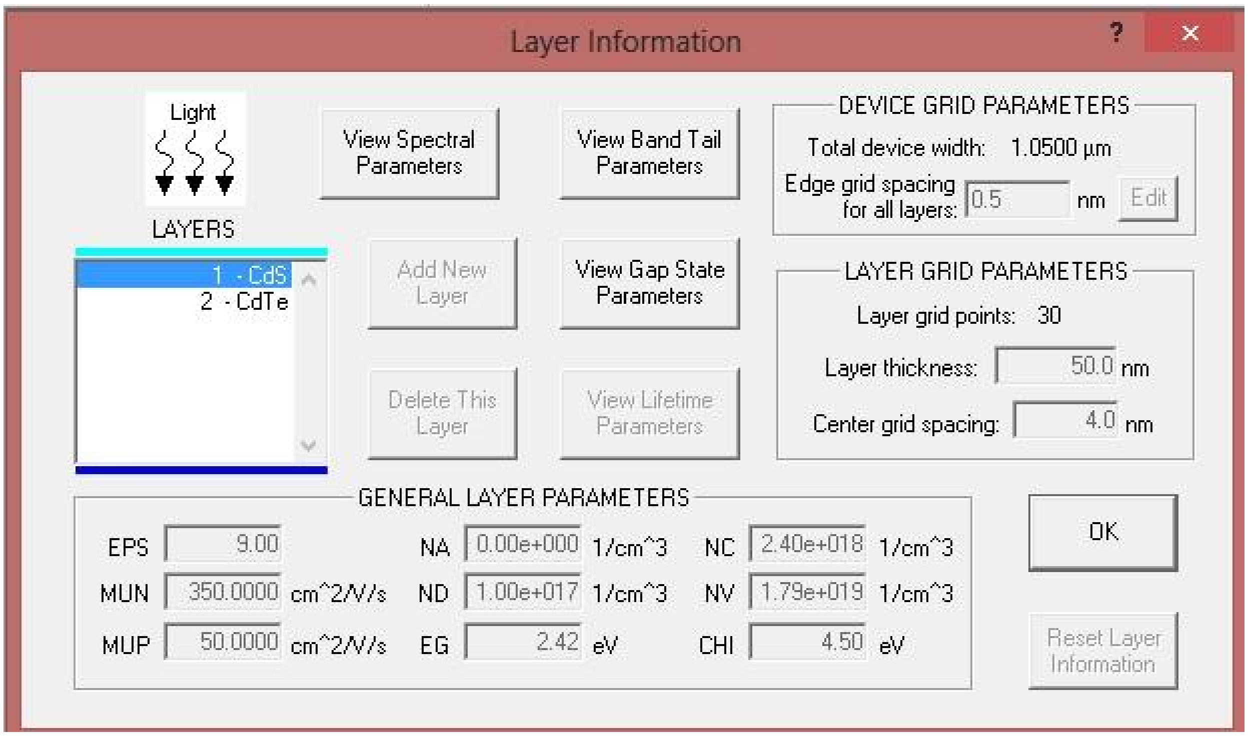
1. The material properties for each layer with front and back contacts.
2. Environmental conditions such as operating temperature.
3. Modeling settings: model type, grid spacing, for the numerical calculations, bias voltages.

2.3 AN OVERVIEW OF HOW AMPS WORKS

The physics of device transport can be captured in three governing equations: Poisson's equation, the continuity equation for free holes, and the continuity equation for free electrons. Determining transport characteristics then becomes a task of solving these three coupled non-linear differential equations, each of which has two associated boundary conditions. In AMPS, these three coupled equations, along with the appropriate boundary conditions, are solved simultaneously to obtain a set of three unknown state variables at each point in the device: the electrostatic potential, the holes quasi-Fermi level, and the electron quasi-Fermi level. From these three state variables, the carrier concentrations, fields, currents, etc. can then be computed. To determine these state variables, the method of finite differences and the Newton-Raphson technique are incorporated by the computer. The Newton-Raphson Method iteratively finds the root of a function or roots of a set of functions if given an adequate initial guess for these roots. In AMPS, the one-dimensional device being analyzed is divided into segments by a mesh of grid points, the number of which the user decides. The three sets of unknowns are then solved for each particular grid point. We note that AMPS allows the mesh to have variable grid spacing at the discretion of the user. As noted, once these three state variables are obtained as a function of x, the band edges, electric field, trapped charge, carrier populations, current densities, recombination profiles, and any other transport information may be obtained.

2.4 LAYER INFORMATION

The thickness of the different layers of the cell material (CdS-CdTe) is chosen by varying with greater range to get better efficiency of the cell. Dielectric constants, band gaps, mobility and effective density of states are calculated from numerical analysis by using the relation found in literatures [9]. All these layer parameters have been inserted in the simulation window of AMPS simulator as shown in Figure 2.3.The entire parameters listed in the table 2.1 needs to input manually in AMPS. The figure 2.3 is an AMPS window for input layers parameters.



1 - CdS
2 - CdTe

Total device width: 1.0500 µm
Edge grid spacing for all layers: 0.5 nm

Layer grid points: 30
Layer thickness: 50.0 nm
Center grid spacing: 4.0 nm

EPS	9.00		NA	0.00e+000	1/cm^3	NC	2.40e+018	1/cm^3
MUN	350.0000	cm^2/V/s	ND	1.00e+017	1/cm^3	NV	1.79e+019	1/cm^3
MUP	50.0000	cm^2/V/s	EG	2.42	eV	CHI	4.50	eV

Figure 2.3: AMPS window for input layer information.

TABLE 2.1: The Device Parameters in AMPS

- Boundary Conditions:

Parameters	**Description**
PHIBO=ϕ_{bo}	Ec-Ef in at x=o (eV)
PHIBL=ϕ_{bL}	Ec-Ef in at x=L (eV)

- Surface Recombination Speed:

Parameters	**Description**
SNO	Electrons at x=0 interface (cm/sec)
SPO	Hole at x=0 interface (cm/sec)
SNL	Electrons at x=L interface (cm/sec)
SPL	Hole at x=L interface (cm/sec)

- Reflection Coefficient for light impinging on the front and back surfaces:

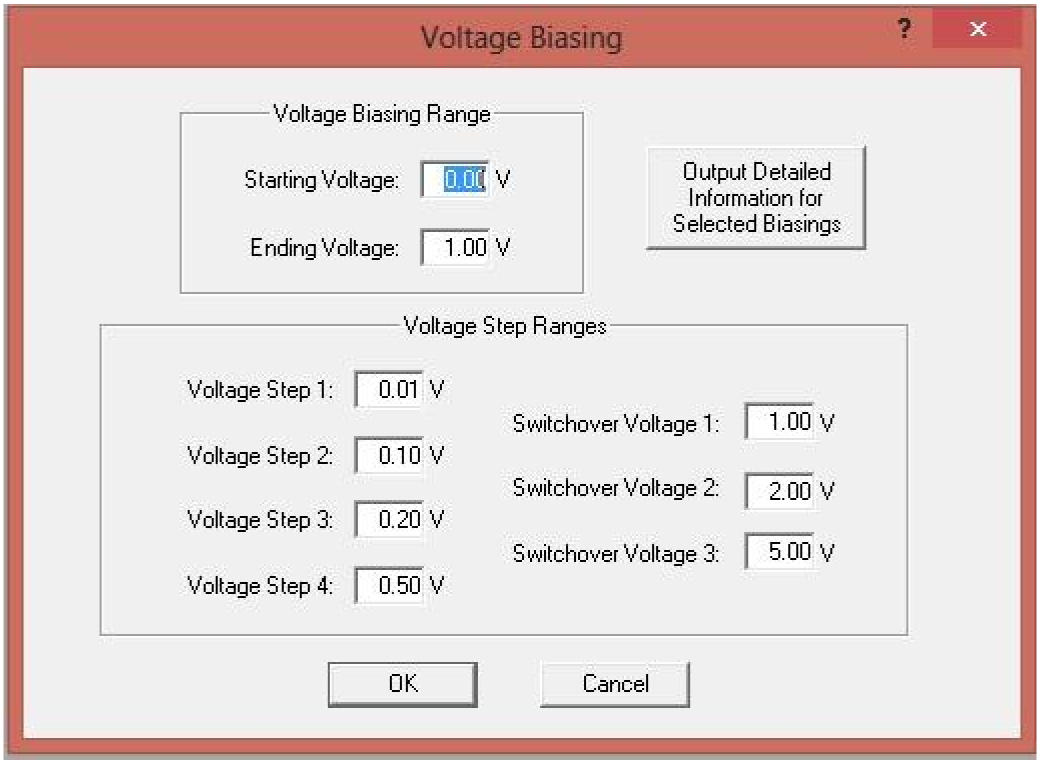
Parameters	**Description**
RF	Reflection Coefficient at x=0 (front surface)
RB	Reflection Coefficient at x=L (back surface)

- Parameters of Layer Information:

Parameters	**Description**
Eg	Energy band gap (eV)
EPS	Relative Permittivity
MUN	Electron mobility (cm^2 /V-sec)
MUP	Hole mobility (cm^2 /V-sec)
N_A	Acceptor concentration (cm^{-3})
N_D	Donor concentration (cm^{-3})
CHI	Electron affinity (eV)
N_C	Effective density of states in the conduction band(cm^{-3})
N_V	Effective density of states in the valence band(cm^{-3})

All numerical calculation for this work unless specified used a surface recombination velocity of 10^3 cm/s, which corresponds approximately to the thermal velocity of the electrons, meaning that the entire carrier will recombine if they can reach surface. The front surface reflectivity limits quantum efficiency and therefore *Jsc*of the cells. This parameter is set to R_F= 0.1 (10%) in order to reflect the experimental spectral response data of CdS-CdTe solar cells with typical front layer. The back surface reflection has negligible influence on the thicker cell performance. In the case of thicker cells the reflection photon has a little chance but for ultra-thin cells it might be an important factor. This parameter is set to R_B=0.9 (90%) in order to get reflected back energetic photons from the back surface. The voltage biasing window contains information about the voltage which needs to be applied for proper simulation.

Attention must be given to the gird points when setting the layer thickness. AMPS only allow 2000 grid points to be used by a model. Settings can be made if the 2000 grid points are breached. One can adjust the center grid spacing to lower down the grid points. The center grid is the reference point of AMPS to calculate the layer thickness. Voltage bias condition window in AMPS shown in Figure 2.4



Voltage Biasing Range

Starting Voltage: 0.0 V

Ending Voltage: 1.00 V

Voltage Step Ranges

Voltage Step 1: 0.01 V

Voltage Step 2: 0.10 V

Voltage Step 3: 0.20 V

Voltage Step 4: 0.50 V

Switchover Voltage 1: 1.00 V

Switchover Voltage 2: 2.00 V

Switchover Voltage 3: 5.00 V

Figure 2.4: AMPS window for biasing voltage

The operating temperature for all cells was set to 300K (27^0 C).

CHAPTER III

SIMULATED RESULTS AND DISCUSSIONS

3.1 INTRODUCTION

In this work, the single junction CdS-CdTe solar cell structure was designed. Optimization of the single junction CdS-CdTe solar cells has been done by varying different parameters. The I-V characteristics curve of CdS-CdTe optimized solar cell as it shows the efficiency, open circuit voltage (Voc), short circuit current density (Jsc), and fill factor (FF) of the proposed cell. The effect of doping concentration has been discussed. The influence of back contact and temperature were also investigated for the proposed CdS-CdTe solar cell.

3.2 THE p-TYPE CdTe AND n-TYPE CdS ABSORBER LAYER THICKNESS OPTIMIZATION

One of the main objectives of solar cell research is to utilize less material by making the cell thinner; thinning will lower the production cost, time and the energy need to produce the cell as well as reduced cell materials. All of these factors will lead to cheaper and affordable solar cells. Thus reduction of absorber layer thickness will be explored in this part of work.

In this analysis, we have varied the CdTe layer thickness from 100 nm up to 1 µm, CdS window layer thickness from 50 nm to 200 nm aiming to efficient and thinner CdS/CdTe solar cell.

To investigate the effect of p-CdTe layer thickness varying from 100nm to 1000nm when n-CdS was fixed as 60nm on the proposed solar cell has been simulated using all the parameters at Table 3.1 and the observed result are shown in Figure 3.1, 3.2, 3.3, 3.4.

Table 3.1: Parameters of p-CdTe for Simulation

Type	EPS	MUN	MUP	N_A (cm^{-3})	N_D (cm^{-3})	Eg (eV)	N_C (cm^{-3})	N_V (cm^{-3})	CHI (eV)	D (nm)
p-CdTe	9.40	500	60	$5*10^{15}$	0	1.50	$9.08*10^{17}$	$6.33*10^{18}$	4.28	1 µm

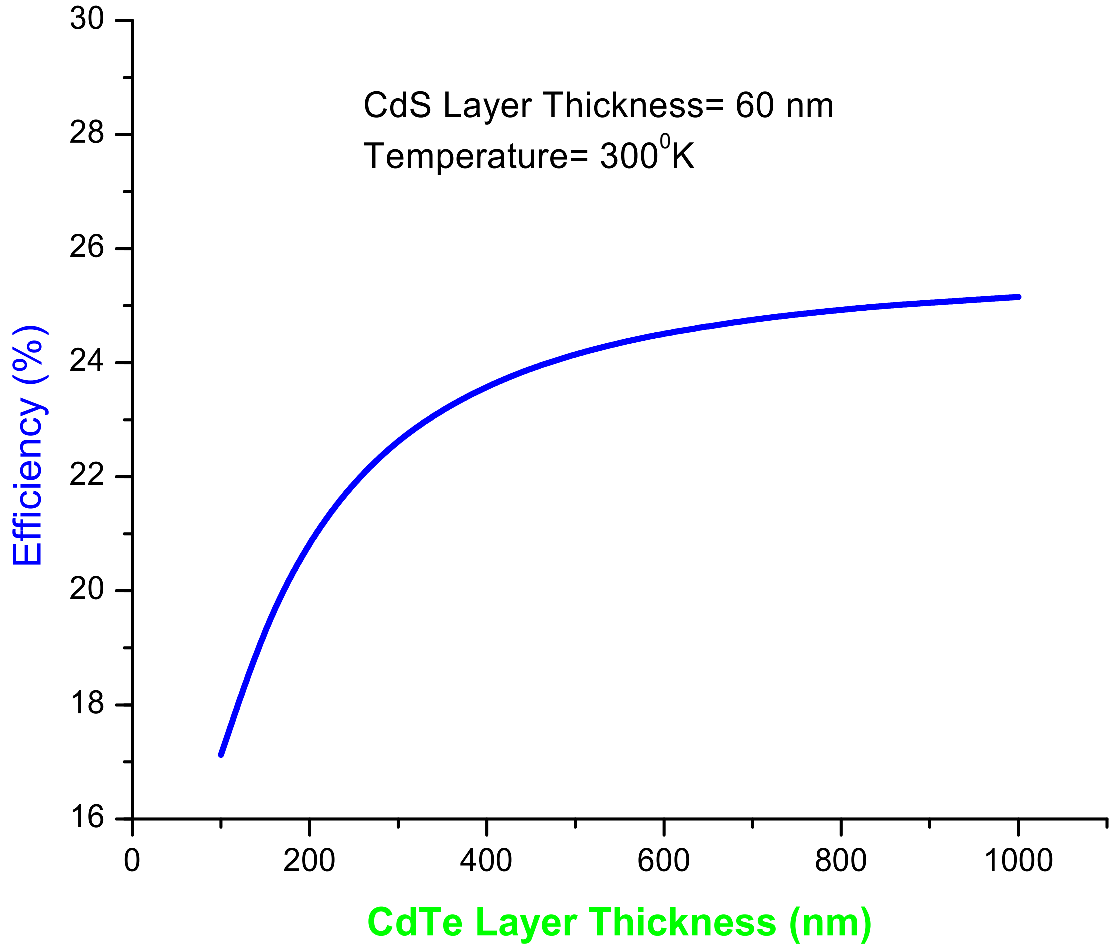


Figure 3.1: CdTe layer thickness Vs. Efficiency

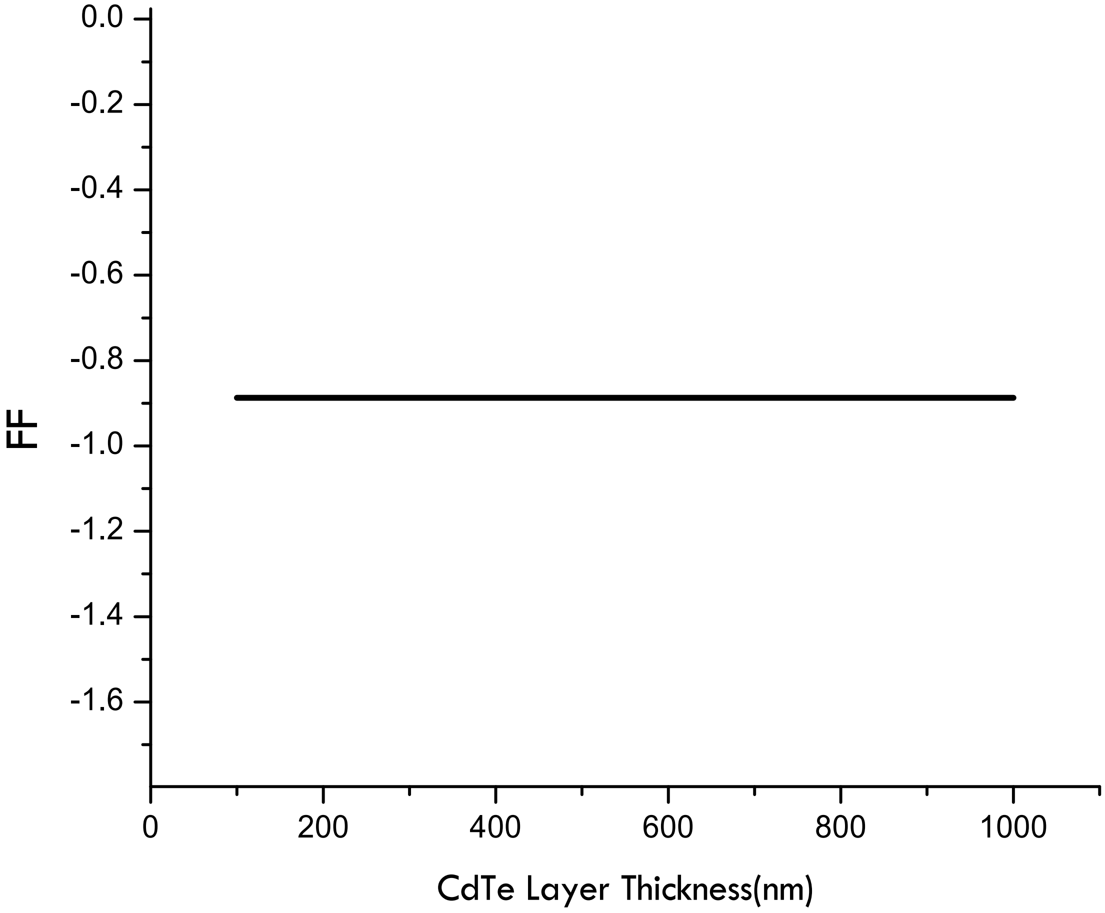


Figure 3.2: CdTe Layer Thickness Vs. Fill Factor

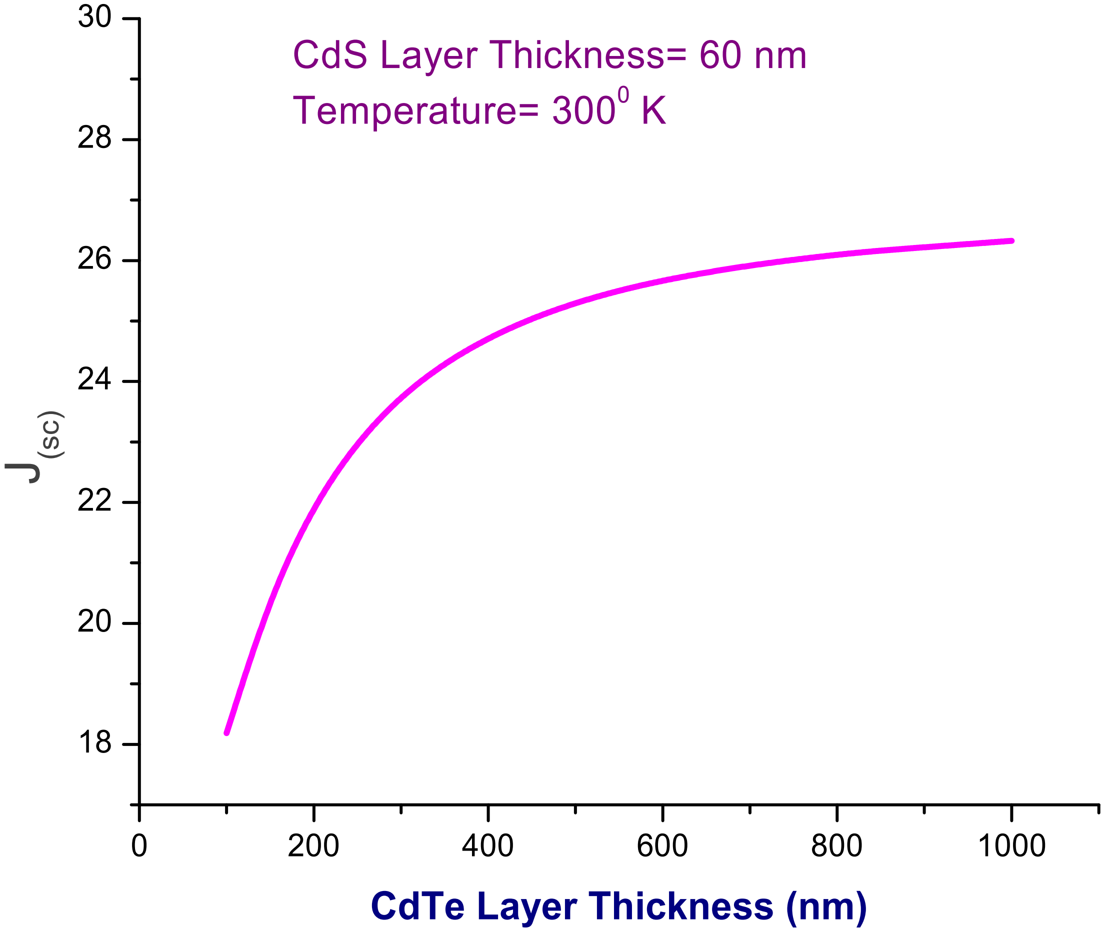


Figure 3.3: CdTe Layer Thickness Vs. Short Circuit Current Density

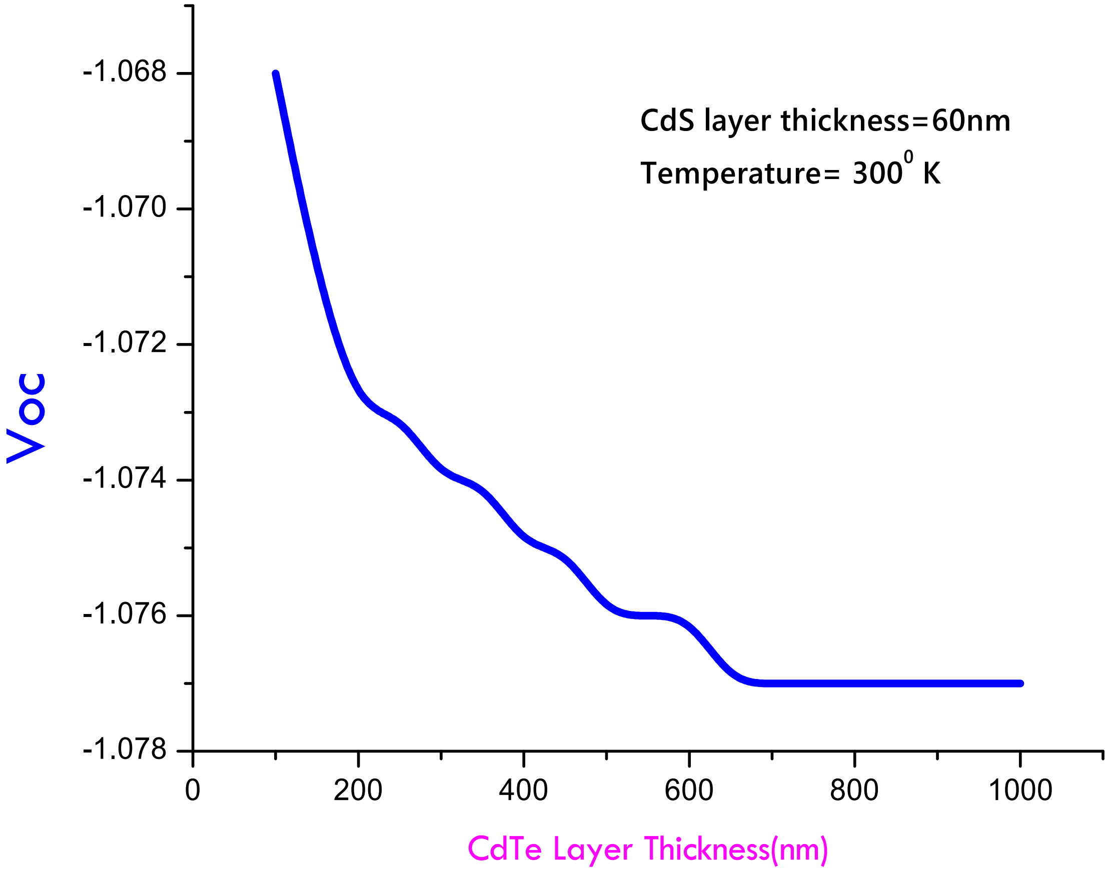


Figure 3.4: CdTe layer Thickness Vs. Open Circuit Voltage

It is clear, from the Figure 3.1, 3.2, 3.3, 3.4 that cell output parameters gradually increased from 100nm to 1000nm of CdTe thickness. However, Voc and Efficiency shows higher increasing rate of CdTe thickness but Jsc follows the rapid changes where Fill Factor(FF) is almost constant because of the bulk resistivity of the ultra-thin CdTe absorber layer is less.

Since, the 1000nm thick CdTe cell has shown good conversion efficiency of 25.154%

(Voc=-1.078 V, Jsc=26.325 mA/cm^2, FF=-0.887) , the selection of 1 μmCdTe absorber layer can be accepted.

To investigate the effect of n-CdS layer thickness varying from 50nm to 200nm when p-CdTe was fixed as 1000nm on the proposed solar cell has been simulated using all the parameters at Table 3.2 and the observed result are shown in Figure 3.5, 3.6, 3.7, 3.8.

Table 3.2: Parameters of n-CdSfor Simulation

Type	EPS	MUN	MUP	N_A (cm^{-3})	N_D (cm^{-3})	Eg (eV)	N_C (cm^{-3})	N_V (cm^{-3})	CHI (eV)	D (nm)
n-CdS	9.00	350	50	0	10^{17}	2.42	$2.40*10^{18}$	$1.79*10^{19}$	4.50	50nm

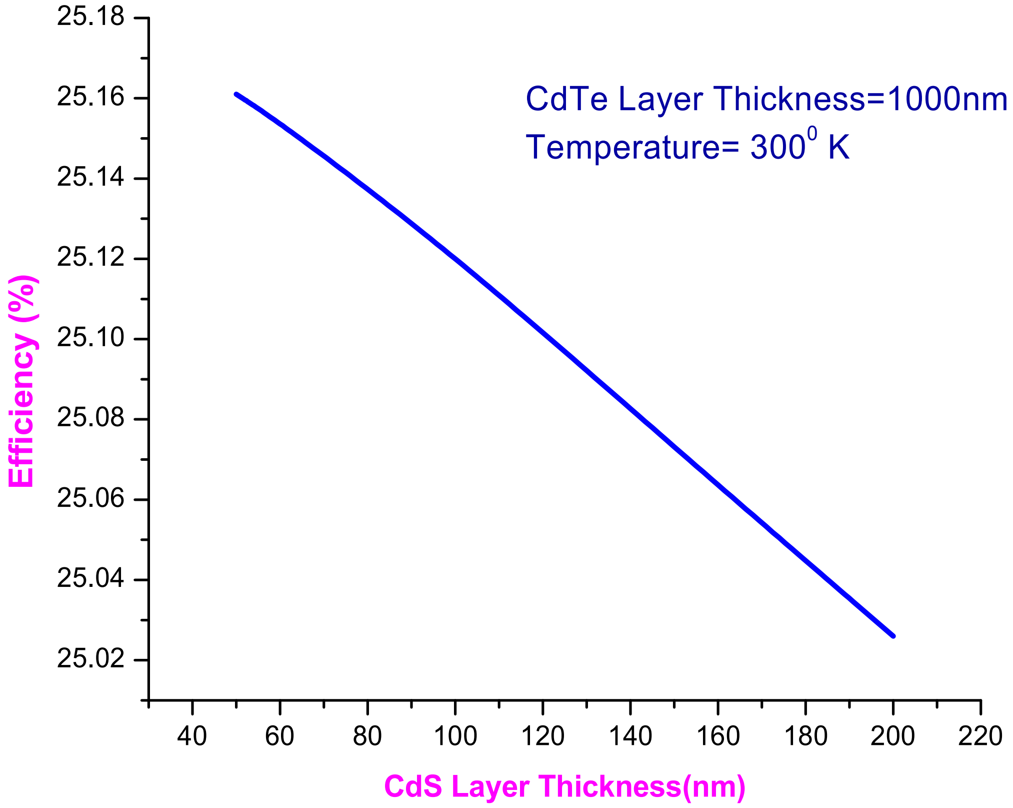


Figure 3.5: CdS Layer Thickness Vs. Efficiency

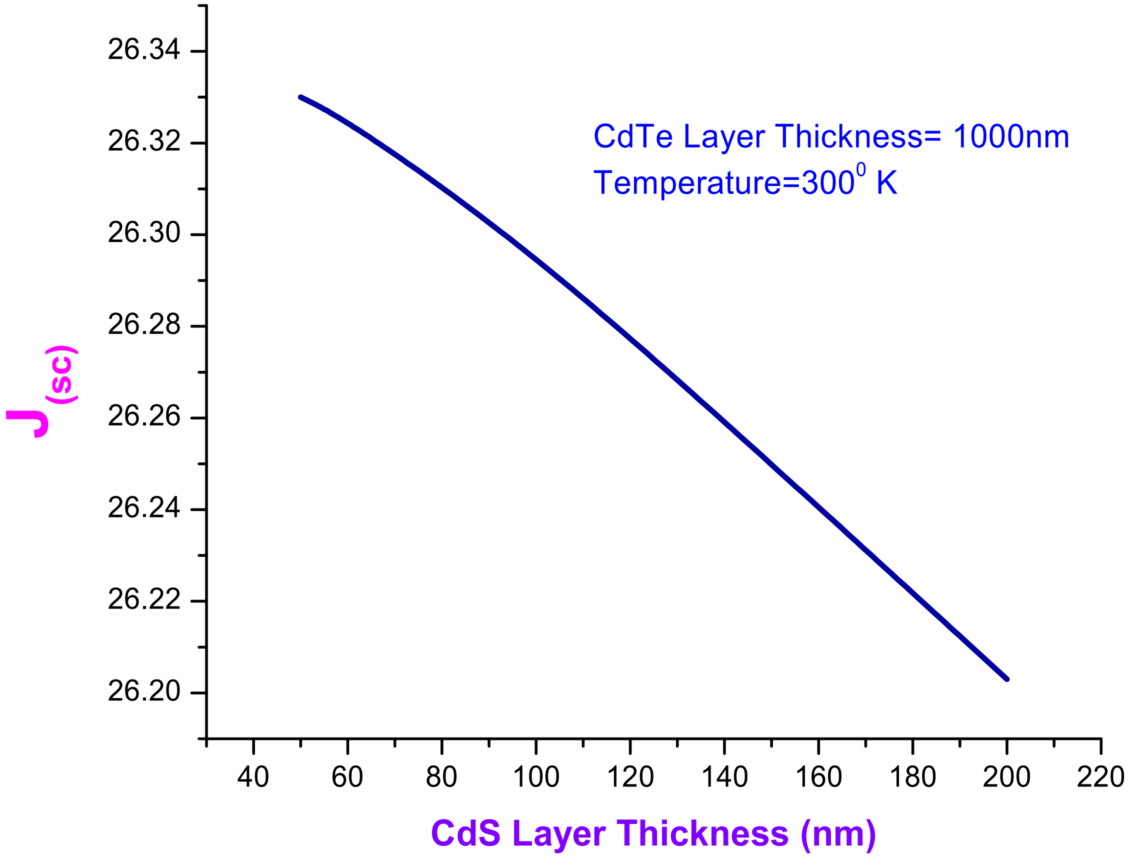


Figure 3.6: CdS Layer Thickness Vs. Short Circuit Current Density

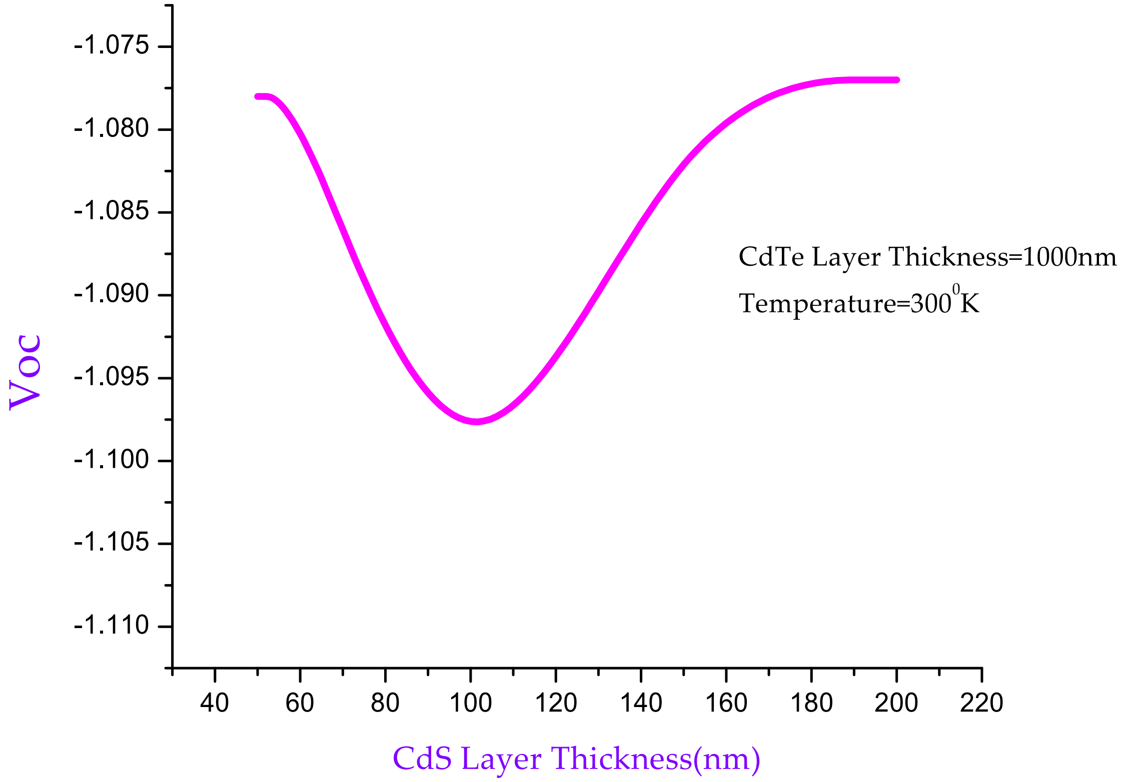


Figure 3.7: CdS layer Thickness Vs. Open Circuit Voltage

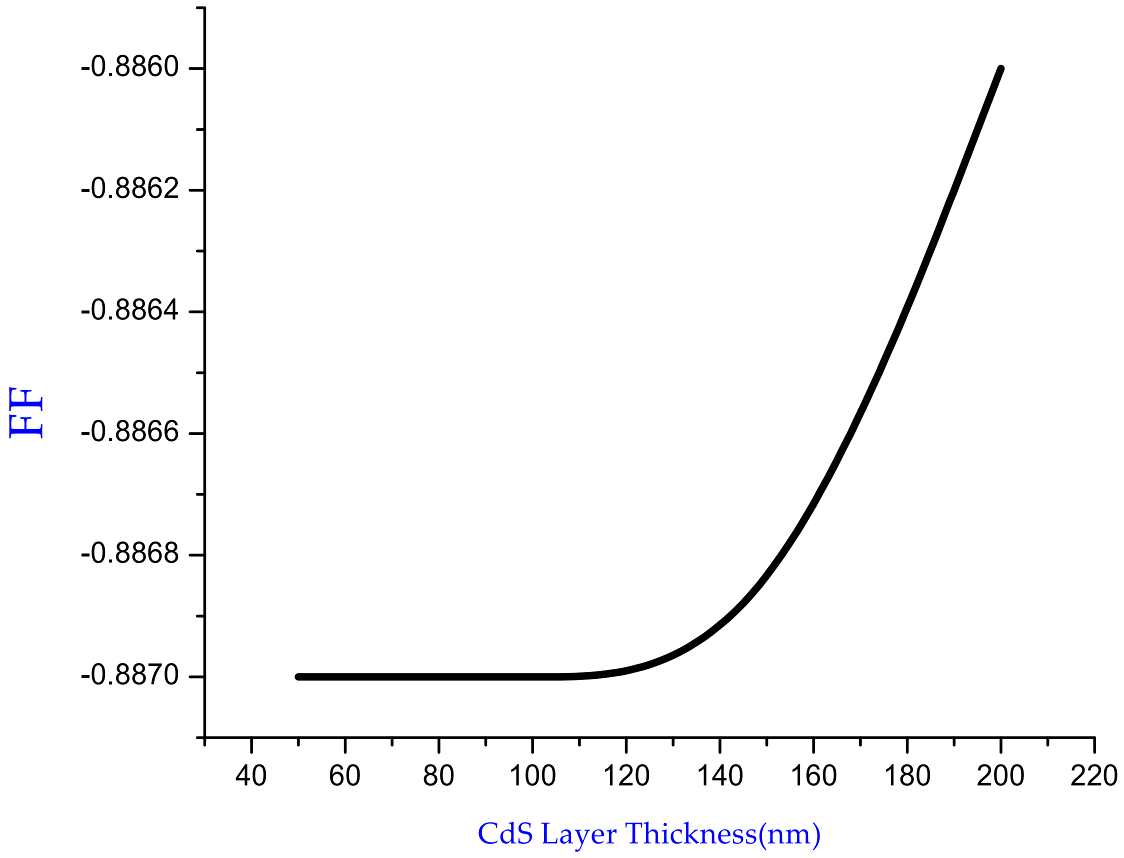


Figure 3.8: CdS Layer Thickness Vs. Fill Factor

It is clear, from the Figure 3.5, 3.6, 3.7, 3.8 that cell output parameters gradually decreased from 50nm to 200nm of CdS thickness. However, Voc and Efficiency shows higher, when decreasing rate of CdTe thickness but Jsc follows the rapid changes where Fill Factor(FF) is almost constant because of the bulk resistivity of the ultra-thin CdTe absorber layer is less.

Since, the 50nm thick CdS cell has shown good conversion efficiency of 25.161%

(Voc=-1.078 V, Jsc=26.3330 mA/cm^2, FF=-0.887) , the selection of 1 μmCdTe absorber layer can be accepted.

3.3 BACK CONTACT INFLUENCE

The back contact has great influence on the performance of a solar cell. In AMPS simulation PHIBL and work function of a material are related. It is found from the figure 3.9, 3.10, 3.11, 3.12, when PHIBL is 0.6 eV, the efficiency is very poor. It is increasing rapidly after 0.6 eV and maximum when it is 1.3 eV. In the above value of PHIBL, efficiency, Jsc, FF, Voc increased slightly. So, PHIBL of 1.3 eV is the optimum which corresponds to metal Nickel (Ni) can be used as back contact. With this selected back contact of 1.3 eV, the efficiency is 25.161%. The parameters of front contact and back contact are listed in Table 3.3.

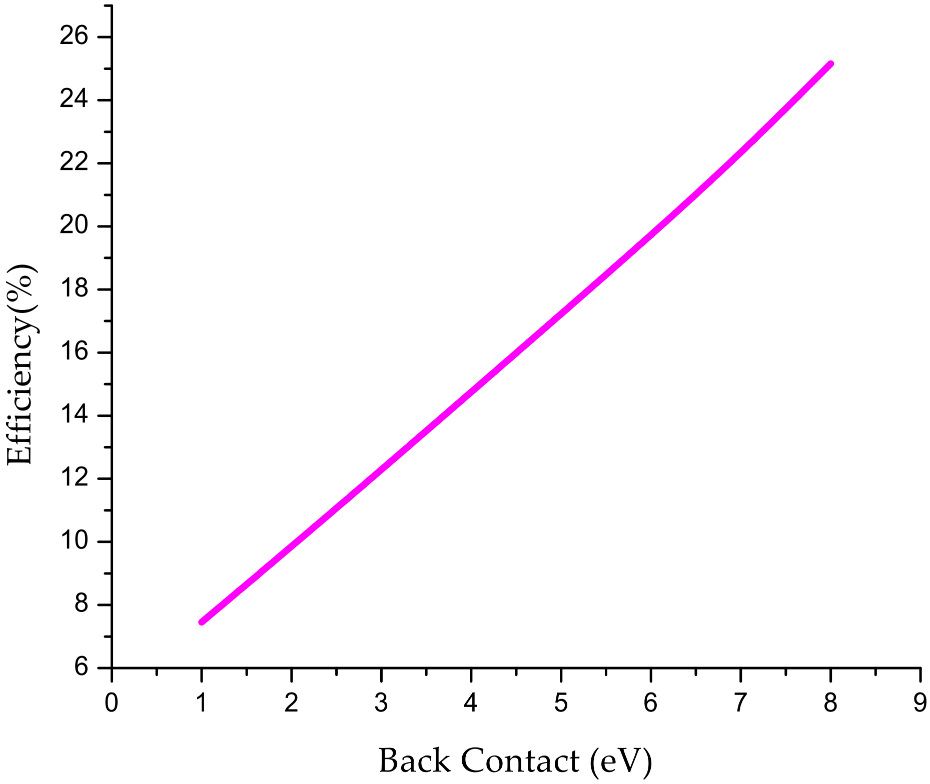


Figure 3.9: Back Contact Vs. Efficiency

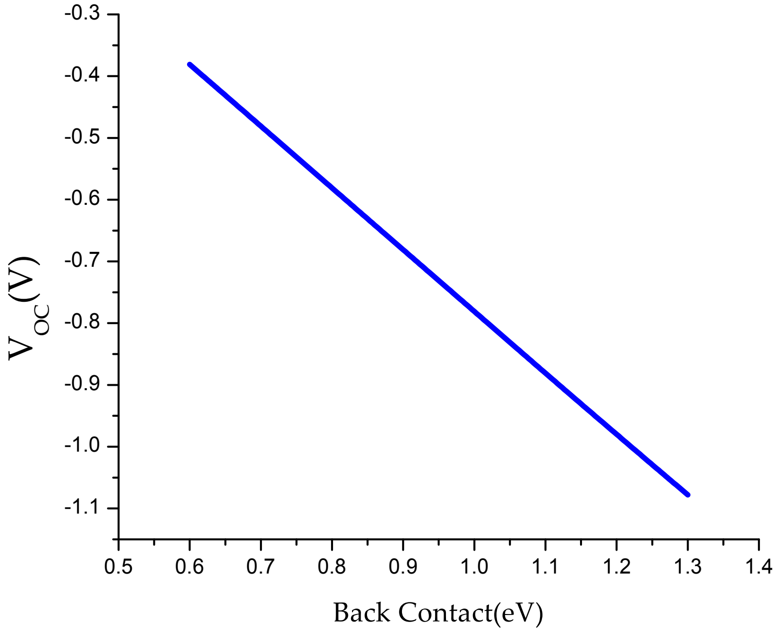


Figure 3.10: Back Contact Vs. Open Circuit Voltage

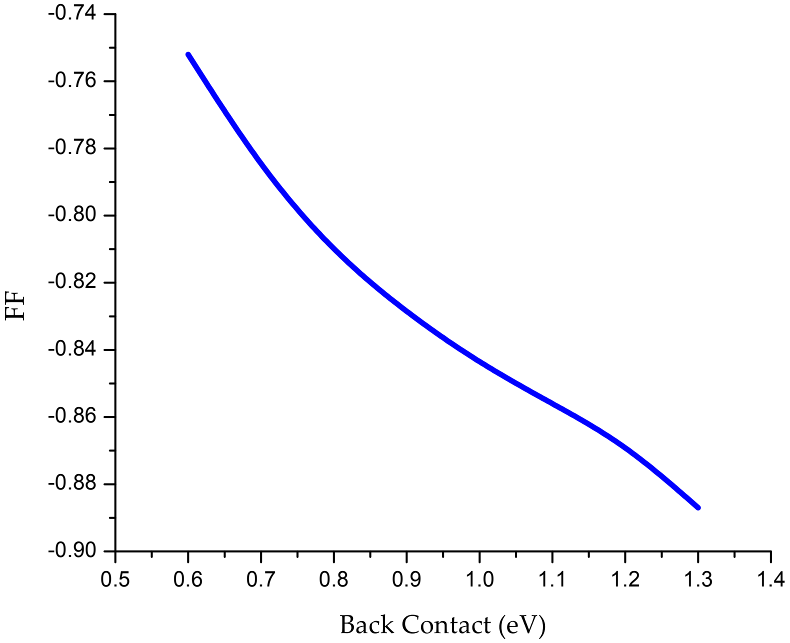


Figure 3.11: Back Contact Vs. Fill Factor

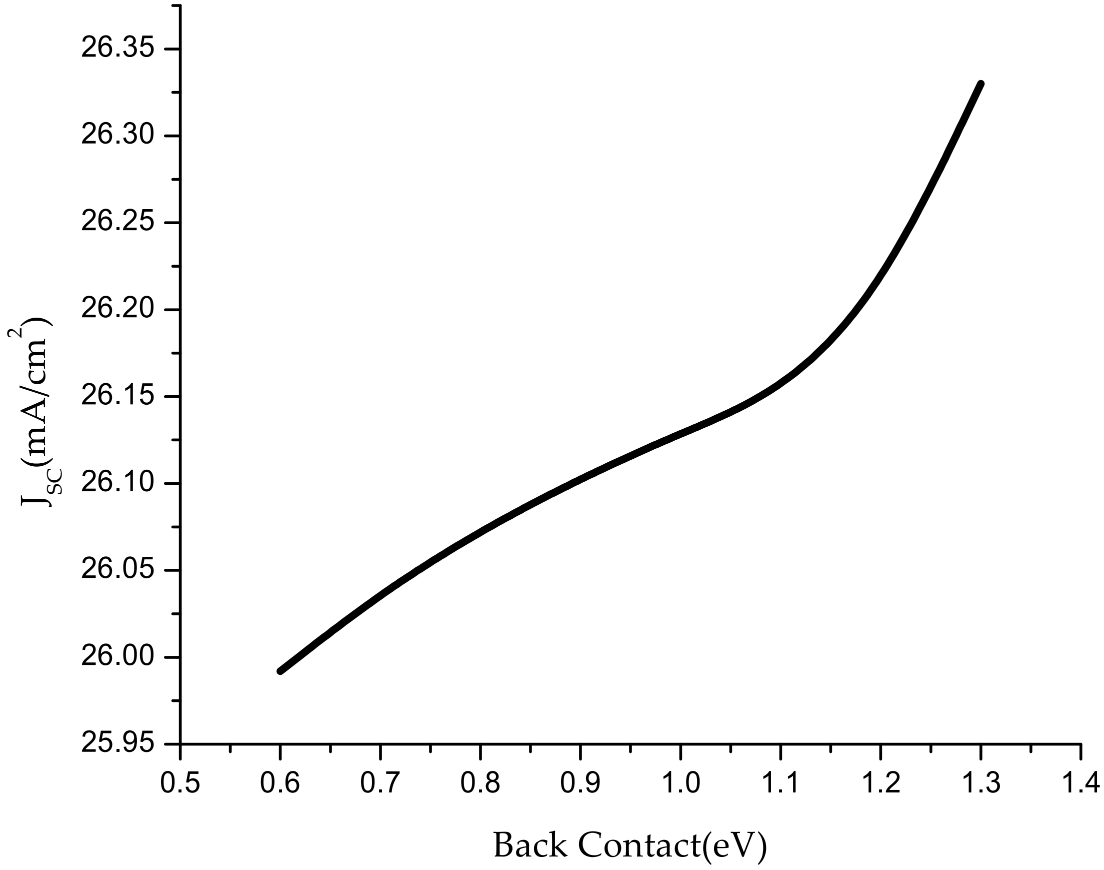


Figure 3.12: Back ContactVs. Short Circuit Current Density

Table 3.3: Front Contact and Back Contact Value for Simulation.

Front Contact Parameters	Back Contact Parameters
PHIBO=0.10 eV	PHIBL=1.30 eV
SNO=1*10^3 cm/s	SNL=1*10^3 cm/s
SPO=1*10^3 cm/s	SPL=1*10^3 cm/s
RF=0.10	RB=0.90

3.4 PROPOSED STRUCTURE OF ULTRA THIN CdS-CdTe THIN FILM SOLAR CELL

In the proposed CdS-CdTe solar cell structure, a p-type layer which acts as absorber layer and n-type layer are connected to form a single junction solar cell. A transparent and conducting oxide (TCO) is staged which acts as the front contact of the cell, generally deposited on high quality glass substrate. Sun light strike at the p-type material over which a transparent conductor is connected as front contact and in the back surface a metal conductor Ni, is connected as back contact material. This designed cell has shown in Figure 3.13 which is a typical structure of CdS-CdTe based solar cell.

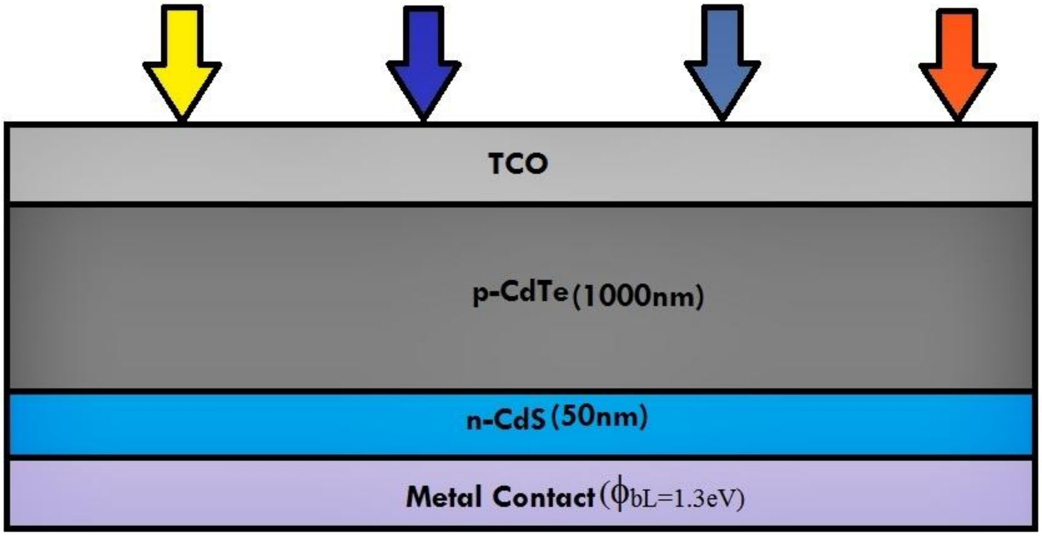


Figure 3.13: Final proposed CdS-CdTe solar cell structure

It is well known that the conventional silicon based solar cell requires over 100µm thick absorber layers. In this CdS-CdTe proposed cell structure, absorber layer is reduced to 1 µm which is 100 times less than the conventional Si based solar cells as well as the device volume also reduced. Material requirement reduced in CdS-CdTe based solar cell substantially as it is a direct band gap material with high absorption coefficient which will require less energy, time and money to produce thinner solar cells.

CHAPTER IV

CONCLUSION AND FUTURE WORKS

4.1 CONCLUSION

Utilization of the enormous energy of the sun by converting it into electricity is wonderful way to fulfill the energy demand of mankind. Photovoltaic solar cells are the only possible way to operate continuously without any kind of maintenance, non-polluting and have the potentiality to fulfill the demand of human.

In this thesis work a single CdS-CdTe solar cell has been designed and simulated by using AMPS 1-D simulator. Optimization of layer thickness of p-CdTe and n-CdS was analyzed. Also a great influence of back contact on solar cell was analyzed. In this work the temperature variation was negligible and almost constant at 300^0K. A highly efficient 25.16% (*Voc*= -1.078 V, *Jsc*= 26.33 mA/cm2 and FF = -0.887) ultra-thin CdS-CdTe solar cell has been obtained with CdTe thickness of 1 µm and CdS thickness of 50 nm. Efficient and cost effective ultra-thin film CdS/CdTe solar cell can be realized with 50 nm of CdS layer, 1 µm of CdTe layer. The thickness of the cell is reduced than other conventional solar cells and it will reduce the cost effectively. This work will play a vital role in the design of single junction CdS-CdTe solar cell.

4.2 FUTURE WORKS

a. The designed cells of this work need to be fabricated for further investigation.
b. Efficiency may be increase if a buffer layer is introduced between back contact and CdS.
c. It may be explored the effect of tandem solar cell.
d. Further studies can be made in using other factors that are constraints in thickness reduction of solar cell.
e. More research needs to be done on this material for its design process and the fabrication techniques.

LIST of ABBREVIATIONS

AMPS	Analysis of Microelectronic and Photonic Structure
CdTe	Cadmium Telluride
CdS	Cadmium Sulfide
I-V	Current-Voltage characteristics
TCO	Transparent and Conducting Oxide
T	Temperature
RF	Reflection coefficient for front surface
RB	Reflection coefficient for back surface
Eg	Energy band gap
EPS	Relative permittivity
MUN	Electron mobility
MUP	Hole mobility
FF	Fill factor
J_{SC}	Short Circuit Current Density
V_{OC}	Open Circuit Voltage
N_A	Acceptor Concentration
N_V	Donor Concentration

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