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Thesis Report

Enhancement of Conversion Efficiency
Of
CdTe/CdS p-i-n Solar Cell Using TCO and BSF Layers

Submitted by:
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Declaration

I hereby declare that I have completed project on the topic entitled “Enhancement of Conversion Efficiency of CdS-CdTe Solar Cell Using TCO, Intrinsic and BSF Layers” as well as prepared as research report to the department of Electronics and Communication Engineering East West university in partial fulfillment of the requirement for the degree of B.Sc. in Electronics and Telecommunications Engineering, Under the course “Research/Internship (ETE 498)”.

I further assert that this report in question is based on my original exertion having never been produced fully and/or partially anywhere for any requirement.

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Acceptance

This research report presented to the department of electronics and communication engineering, East West University is submitted in partial fulfillment of the requirement for degree of B.Sc. in Electronics and Telecommunications Engineering, under complete supervision of the undersigned.

.....

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Acknowledgement

First and foremost with all my heartiest devotion I am grateful to almighty Allah for blessing me with such opportunity of learning and ability to successfully complete the task.

A special Thanks with honor to my supervisor M. Mofazzal Hossain who was kind enough to allocate his valuable time to provide me with his humble guidance, motivating thought and encouragement.

.....
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2010-3-55-028

Abstract

A high efficiency CdTe/CdS solar cell is designed using an intrinsic CdTe layer and a highly doped CdTe as a back surface field (BSF) layer. With the combination of TCO layer (ZnO), CdS window layer, CdTe intrinsic layer, CdTe absorber layer and a BSF layer, the higher conversion efficiency is achieved which is about 26.81% in simulation. In addition to this, the work exclusively identify that the efficiency can be increased simply increasing the thickness of intrinsic layer. At 1.5 AM solar irradiance, the proposed cell structure had a V_{oc} of 1.10 V, a J_{sc} of 27.29 mA.cm⁻², and a fill factor of 89.1%, corresponding to an overall conversion efficiency of 33.19%.

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Chapter 1
Introduction

1.1 Solar Energy

Renewable energy is generally defined as energy that is collected from resources, which are naturally replenished, on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services.

Solar energy is radiant light and heat from the Sun harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic, solar thermal energy, solar architecture and artificial photosynthesis.

It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on the way they capture and distribute solar energy or convert it into solar power. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

1.2 Importance of Solar Energy

Renewable energy is increasingly viewed as critically important globally. One promising attempt is the application of solar cells to utilize the immense amounts of energy that the earth receives with every second from the sun.[1] Human beings have used solar energy since time immemorial. Solar power is used in a widespread of the ever so progressing technologies of the world.

Solar energy can prove to have an immense amount of constructive and helpful impact on the environment. Contrasting to the fossil fuels that we consume and use on a daily basis, solar energy does not fabricate the excessively injurious pollutants, like carbon dioxide, oxides of sulphur or oxides of nitrogen that are liable for the greenhouse effect which is known to lead to global warming, acid rain or other harmful processes.

Solar energy is ultra clean and its use reduces the quantity of contamination and toxic waste, not to forget pollution that the engendering plants have to produce.

Solar energy is natural and a sustainable source of energy that can be utilized in the use of making solar electricity, solar heating appliances, solar cooling appliances and also solar lighting appliances.

Another key aspect of using solar energy is that it has massive financial benefits. They can generally be seen in the reduction of the utility bills.[2] Also, solar energy does not require any fuel and thus avoid the problems of transportation of fuel or the storage of radioactive waste.

Solar cells make no noise at all and there are no moving parts in solar cells, which makes them long lasting and require very little maintenance. Solar energy provides cost effective solutions to energy problems where there is no electricity at all.[3]

In the developed and underdeveloped countries, where electricity is scarce or electricity hasn't reached yet, solar cells can be the source of energy to light their homes and may be the cities. Also, engineers are working on projects, which will help take the excess electricity that will be produced in the solar cells of the homes of the citizens and will contribute to the total regional, or national electricity grid to decrease the scarcity of electricity.

1.3 Generations of Solar Cell

Solar cell technologies are traditionally divided into three generations. First generation solar cells are mainly based on silicon wafers and typically demonstrate a performance about 15-20 %. These types of solar cells dominate the market and are mainly those seen on rooftops. The benefits of this solar cell technology lie in their good performance, as well as their high stability. However, they are rigid and require a lot of energy in production.

The second-generation solar cells are based on amorphous silicon, CIGS and CdTe, where the typical performance is 10 - 15%. Since the second generation solar cells avoid use of silicon wafers and have a lower material consumption it has been possible to reduce production costs of these types of solar cells compared to the first generation. The second-generation solar cells can also be produced so they are flexible to some degree. However, as the production of second-generation solar cells still includes vacuum processes and high temperature treatments, there is still a large energy consumption associated with the production of these solar cells. Further, the second-generation solar cells are based on scarce elements and this is a limiting factor in the price.

Third generation solar cells use organic materials such as small molecules or polymers. Thus, polymer solar cells are a sub category of organic solar cells.

The third generation also covers expensive high performance experimental multi-junction solar cells, which hold the world record in solar cell performance. This type has only to some extent a commercial application because of the very high production price. A new class of thin film solar cells currently under investigation is perovskite solar cells and show huge potential with record efficiencies beyond 20% on very small area. Polymer solar cells or plastic solar cells, on the other hand, offer several advantages such as a simple, quick and inexpensive large-scale production and use of materials that are readily available and potentially inexpensive. Polymer solar cells can be fabricated with well-known industrial roll-to-roll (R2R) technologies that can be compared to the printing of newspapers. Although the performance and stability of third generation solar cells is still limited compared to first and second generation solar cells[4]

1.4 Importance of CdS – CdTe Solar Cell

One of the most promising thin film candidates is CdTe owing to its higher conversion efficiency with reduced material usage and stable cell operation. CdTe solar cells have some advantages. Firstly, the layer of CdTe solar cells can be deposited using different low cost techniques such as Sputtering, Close-spaced sublimation (CSS), chemical bath deposition etc. Secondly, CdTe has a direct optimum band gap (1.45eV) with the high absorption coefficient over 5×10^5 /cm, which means that the incident photons with sufficient energy can be absorbed within a few micrometers of CdTe absorber thickness. The requirement of less material reduces relatively the cost of CdTe based solar cells. To date, the highest reported conversion efficiency of CdTe solar cell is 20.4%, which is still lower compared to the theoretical efficiency (near to 30%).

One of the reasons for choosing CdTe over Silicon is the cost of manufacturing. “First Solar”, the first manufacturer of Cadmium telluride panels to produce solar cells for less than \$1.00 per watt. Some experts believe it will be possible to get the solar cell costs down to around \$0.5 per watt.

Another reason for choosing CdTe over Si is the ease of manufacturing. 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.

Also, CdTe absorbs sunlight at close to the ideal wavelength, capturing energy at shorter wavelengths than is possible with silicon panels.

Cadmium is an abundant material, which is produced as a by-product of other important industrial metals such as zinc.[5]

1.4 Purpose of This Thesis

The purpose of this thesis is to design and simulate a single – junction, five-layer CdTe – CdS solar cell by the use of AMPS – 1D software. The main goal is to create the most efficient and cost effective solar cell by the use of CdTe and CdS materials.

In summary, the purpose of this research is –

1. To design a highly efficient five-layered CdS-CdTe solar cell
2. To optimize the layer thickness and doping density of BSF layer
3. To optimize the layer thickness of TCO layer
4. To optimize the layer thickness of intrinsic layer
5. To Simulate the whole design using AMPS-1D software

References:

1. “Numerical Modeling of CIGS Solar Cells: Definition of the Baseline and Explanation of Superposition Failure” by Markus Gloeckler,

Department of Physics, Colorado State University, Fort Collins,
Colorado, Spring

2. <http://www.solarpowernotes.com/why-solar-energy.html>
3. http://www.conserve-energy-future.com/Advantages_SolarEnergy.php
4. Krebs et. al., Energy Technology 2013 10.1002/ente.201300057
5. <http://www.solar-facts-and-advice.com/cadmium-telluride.html>

Chapter 2
AMPS–1D Software

2.1 INTRODUCTION TO MODELLING AND SIMULATION

The major objectives of numerical modeling and simulation in solar cell research are testing the validity of proposed physical structures, geometry on cell performance and fitting of modeling output to experimental results. Any numerical program capable of solving the basic semiconductor equations could be used for modeling thin film solar cells. The fundamental equations for such numerical programs are (i) Poisson's equation for the distributions of electric field (ϕ) inside the device and (ii) the equation of continuity for conservation of electrons and holes currents.

The AMPS-1D program has been developed to pragmatically simulate the electrical characteristics of thin film hetero-junction solar cells. It has been proven to be a very powerful tool in understanding device operation and physics for single crystal, poly-crystal and amorphous structures. To date, more than 200 groups worldwide have been using AMPS-1D for solar cell design.[1]

2.2 AMPS - 1D AND ITS FEATURES

AMPS is the abbreviation of Analysis of Microelectronic and Photonic Structures. It is a one – dimensional device simulation program and it is a very general program for analyzing and designing transport in microelectronics and photonic structures. AMPS – 1D is the creation of Professor Stephen J, Fonash of Pennsylvania State University and some of the students.

Later, IBM developed it with the support of the Electric Power Research Institute and equipment support.

For the modeling, design and the simulation of the Solar Cell for this thesis, the Beta version 1.0 is used here. The beta version is commonly used worldwide for the design of solar cells.

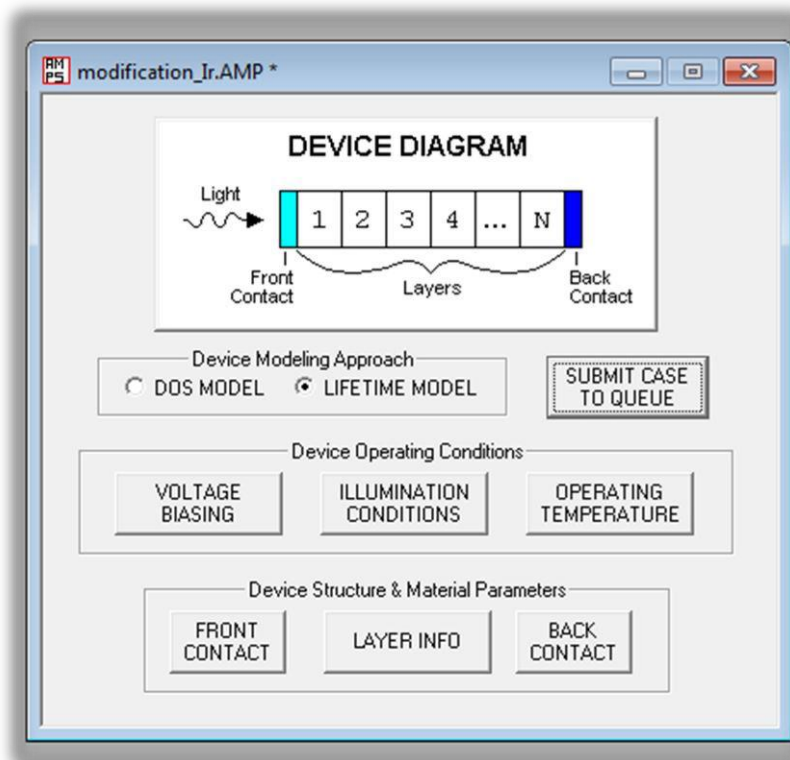


FIG – 2.1: AMPS 1D

AMPS may be used to examine a variety of device structures that include:

- Homojunction and heterojunction p-n and p-i-n, solar cells and detectors;
- Homojunction and heterojunction p-n, p-i-n, n-i-n, and p-i-p microelectronic structures;
- Multi-junction solar cell structures;
- Multi-junction microelectronic structures.

The advantages of AMPS include the user-friendly interface, flexible plotting program, spectral response, band diagrams, carrier concentrations, current density, and electrical field distribution and recombination profiles.

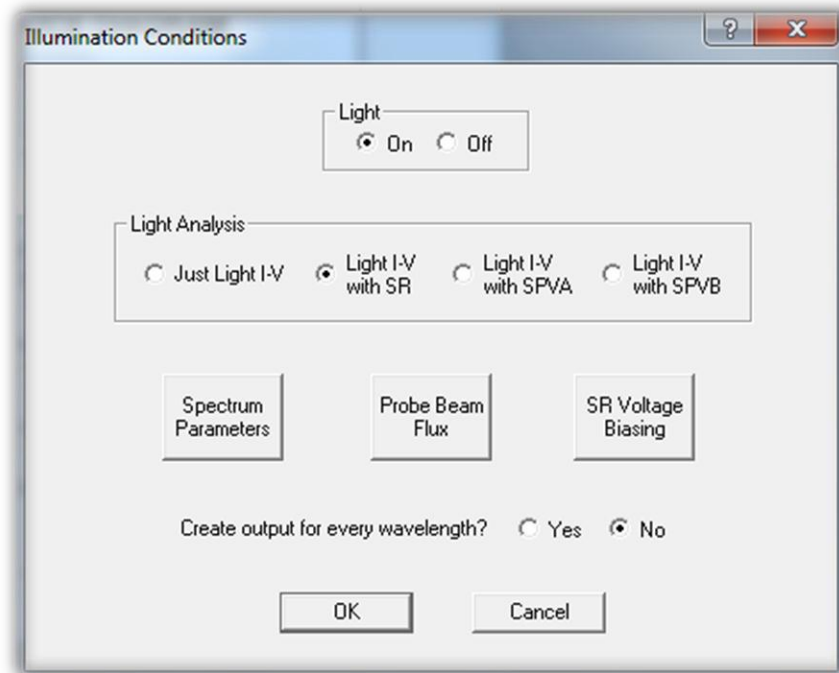


FIG – 2.2: ILLUMINATION CONDITIONS IN AMPS – 1D

2.3 AN OVERVIEW OF HOW AMPS WORKS

The theoretical calculations carried out using AMPS-1D for the analysis were based on Poisson's equation and the first-principle continuity equations of electrons and holes and used to analyze the carriers transport behavior of semiconductor electronic and optoelectronic device structures including solar cells.[2] 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 hole quasi-Fermi level, and the electron quasi-Fermi level. From these three state variables, the carrier concentrations, fields, currents, etc. can then be computed. Then, AMPS solves Poisson equation and the electron and hole continuity equations by using the method of finite differences and the Newton-Raphson technique.[3] 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. Once these three state variables are found 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

Varying the thickness of the various layers that are used and choosing the thickness for which the maximum efficiency is obtained choose the layer thickness. Dielectric constants, band gaps, mobility and effective densities of states are calculated from numerical analysis by using the relations found in the literatures.

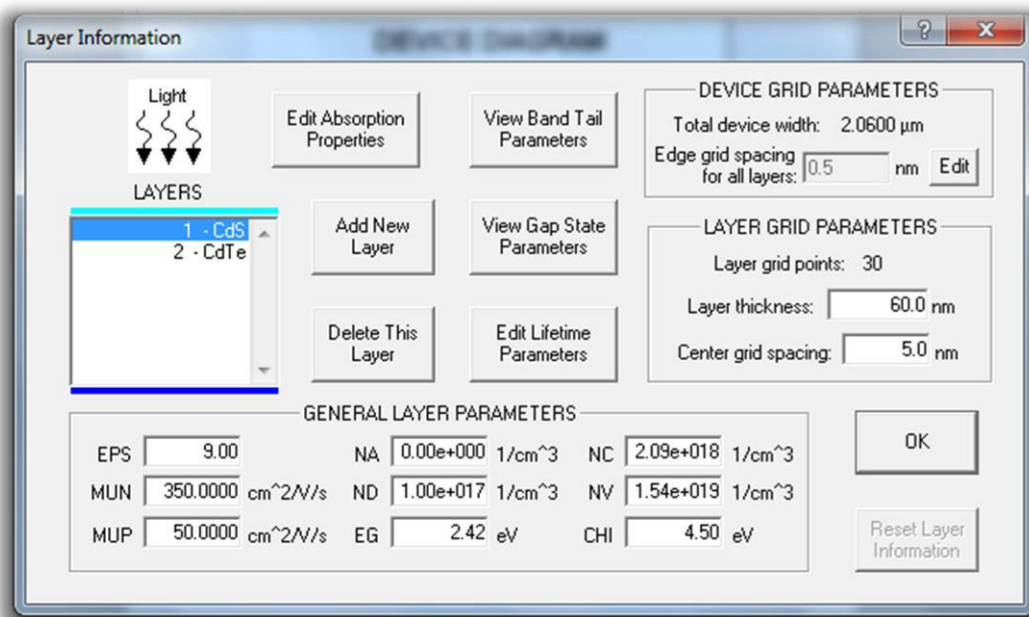


FIG – 2.3: LAYER INFORMATION ON AMPS – 1D

2.5 INPUT PARAMETERS

The following is a list of input parameters that AMPS needs to solve the set of transport equations and boundary conditions. In general, this list will apply to all current program versions, with some minor exceptions. The differences in the parameter list between each program version will be mentioned as they are discussed. Parameters, which only apply to non-equilibrium, are tagged.

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2.5.1 PARAMETERS THAT APPLY TO THE ENTIRE DEVICE:

1. Boundary conditions
 - $\text{PHIBO} = \Phi_{b0} = E_C - E_F$ at $x=0$ (eV)
 - $\text{PHIBL} = \Phi_L = E_C - E_F$ at $x=L$ (eV)
2. Surface recombination speeds
 - S_{NO} = electrons at $x=0$ interface (cm/sec)

- S_{PO} = holes at $x=0$ interface (cm/sec)
 - S_{NL} = electrons at $x=L$ interface (cm/sec)
 - S_{PL} = holes at $x=L$ interface (cm/sec)
3. Reflection coefficient for light impinging on front and back surfaces
 - R_F = reflection coefficient at $x=0$ (front-surface)
 - R_B = reflection coefficient at $x=L$ (back-surface reflection)
 4. Temperature T (K)

2.5.2 BASIC MATERIAL PROPERTIES

- a. EPS = relative permittivity ϵ_r at temperature T
- b. NC = effective density of states N_C (cm^{-3}) in the conduction band at temperature T
- c. NV = effective density of states N_V (cm^{-3}) in the valence band at temperature T
- d. EG = the mobility band gap $E_{G\mu}$ (eV) at temperature T
- e. EGOP = the optical band gap E_{Gopt} (eV) at temperature T
- f. CHI = electron affinity X_e (eV) at temperature T
- g. MUN = electron mobility μ_n ($\text{cm}^2/\text{V-sec}$) at temperature T
- h. MUP = hole mobility μ_p ($\text{cm}^2/\text{V-sec}$) at temperature T
- i. NA = Acceptor Concentration (cm^{-3})
- j. ND = Donor Concentration (cm^{-3})
- k. NC = Effective Density of States in the Conduction Band (cm^{-3})
- l. NV = Effective Density of States in the Valence Band (cm^{-3})

2.6 PARAMETER VALUES

The numerical calculations of this research used a recombination velocity of 103 cm/s, which corresponds to the approximately to the thermal velocity of the electrons. It suggests that entire carrier will recombine if they reach the surface.

The front surface reflectivity is set to $RF = 0.1$ in order to reflect the experimental spectral response data of CdS – CdTe solar cells with typical front layer.

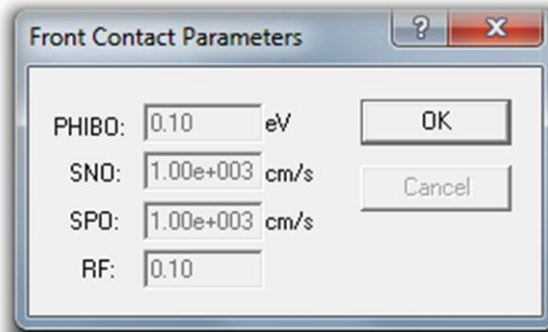


FIG – 2.4: FRONT CONTACT PARAMETERS

The back surface reflectivity parameter is set to $RB = 0.9$ in order to get the reflected back energetic photons from the back surface.

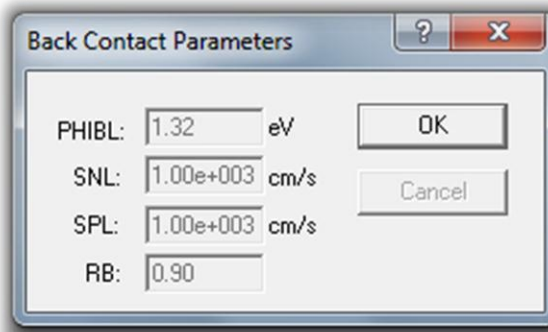


FIG – 2.5: BACK CONTACT PARAMETERS

The voltage-biasing window contains the information on the voltage to be applied.

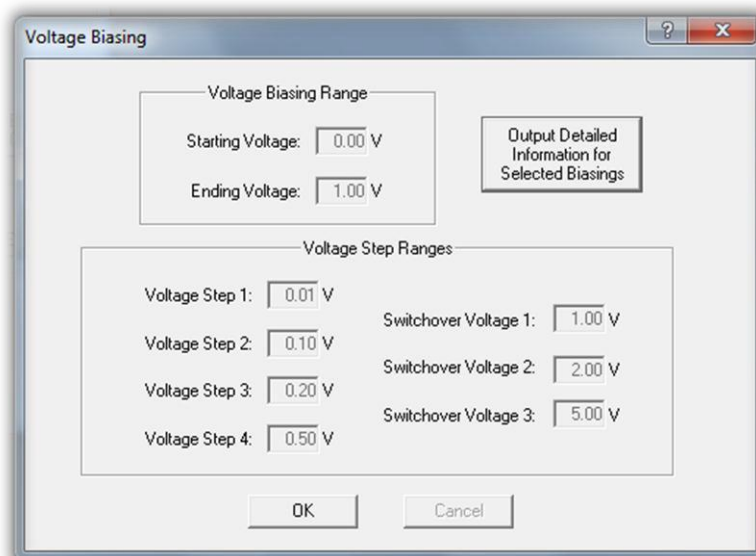


FIG – 2.6: VOLTAGE BIASING

The operating temperature for all cells was set to 300°K.

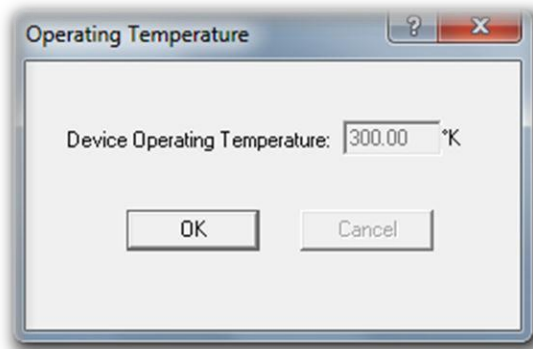


FIG – 2.7: OPERATING TEMPERATURE

References:

1. A Manual for AMPS – 1D
2. A.K Das, “Numerical Simulation of $\text{In}_x\text{Ga}_{1-x}\text{N}$ single junction solar cells using AMPS – 1D”, IOSR Journal of Applied Physics (IOSR-JAP), e-ISSN: 2278- 4861. Volume 6, Issue 2 Ver. III (Mar-Apr. 2014), PP 15-20
3. Samah G. Babiker, Yong Shuai, “Simulation of Organic Solar Cells Using AMPS-1D Program”, Research Journal of Applied Sciences, Engineering and Technology 4(5): 495- 499, 2012, ISSN: 2040-7467

Chapter 3

Simulated Results

3.1 Proposed Solar Cell

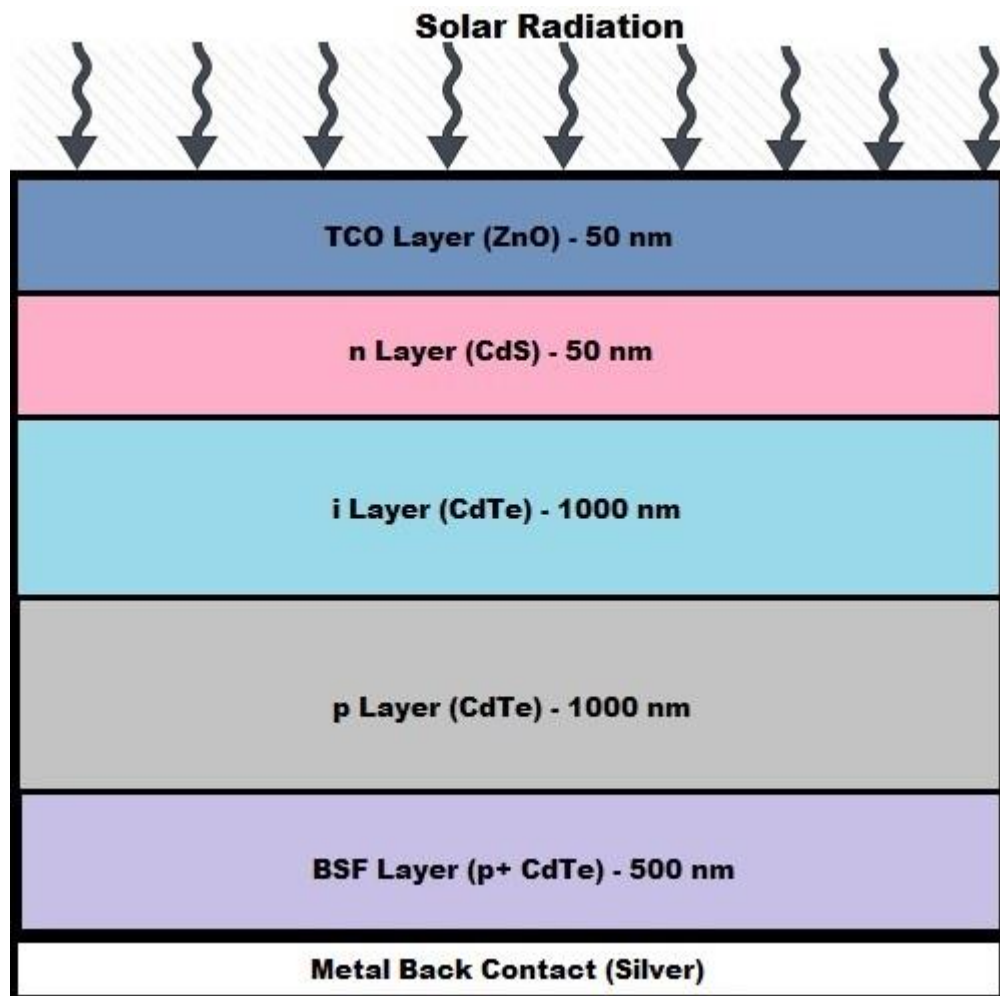


Fig-3.1: Proposed CdS-CdTe Solar Cell

The above figure 3.4 shows the structure of the proposed CdS-CdTe solar cell.

3.2 BSF Layer

An effect is employed at the rear surface to minimize the impact of rear surface recombination velocity on voltage and current if the rear surface is closer than a diffusion length to the junction. A "back surface field" (BSF) consists of a higher doped region at the rear surface of the solar cell. The interface between the high and low doped region behaves like a p-n junction and an electric field forms at the interface which introduces a barrier to minority carrier flow to the rear surface. The minority carrier concentration is thus maintained at higher levels in the bulk of the device and the BSF has a net effect of passivating the rear surface.[1]

| NO. | PARAMETERS | VALUES |
|-----------|------------------------------------|----------------------|
| 1 | Layer | BSF |
| 2 | TYPE | p ⁺ -CdTe |
| 3 | EPS | 9.40 |
| 4 | MUN | 320 |
| 5 | MUP | 40 |
| 6 | N _A (cm ⁻³) | 5×10 ²¹ |
| 7 | N _D (cm ⁻³) | 0 |
| 8 | E _G (eV) | 1.45 |
| 9 | N _C (cm ⁻³) | 8×10 ¹⁷ |
| 10 | N _V (cm ⁻³) | 1.8×10 ¹⁹ |
| 11 | CHI (eV) | 4.28 |
| 12 | CdS Thickness (nm) | 50 |
| 13 | CdTe Thickness (nm) | 1000 |
| 14 | BSF Thickness (nm) | 50 |
| 15 | Temperature (°K) | 300 |

Table-3.1: BSF Layer Parameters

By keeping the above parameters constant except NA and changing the value of NA from 5×10^{15} to 1×10^{19} the following output have been found.

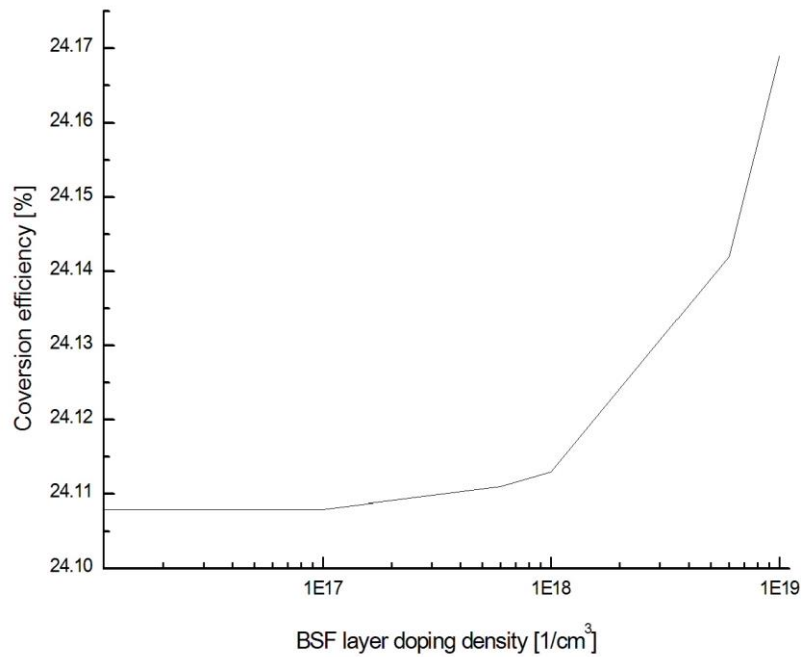


Fig-3.2: BSF layer NA vs. Efficiency

By keeping the above parameters constant except thickness and changing the value of thickness from 50 nm to 500 nm the following output have been found.

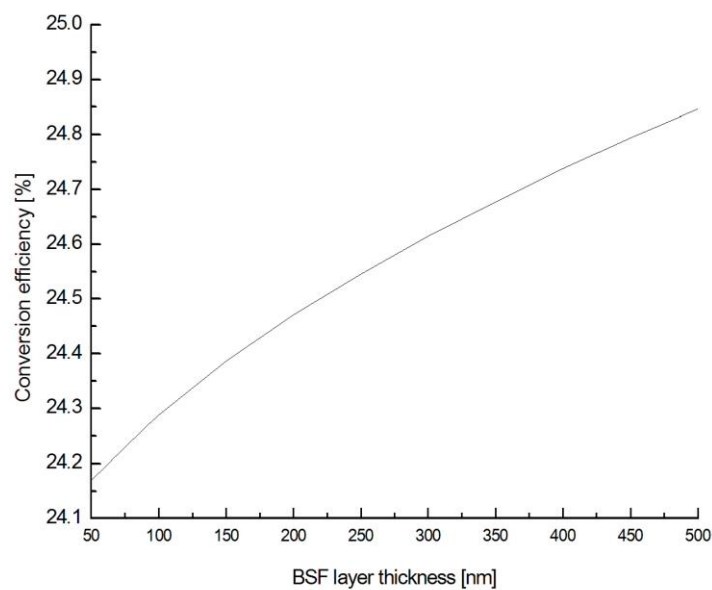


Fig-3.3: BSF Layer Thickness vs. Efficiency

The above two figure shows the effect of BSF layer on Cds-CdTe solar cell. From figure 3.1 when the doping density (acceptor concentration) increases there is a small change. In figure 3.2 it shows the effect of thickness of BSF layer. The layer thickness is changed from 50nm to 500nm. The change of efficiency due to thickness change is very small.

3.3 TCO Layer

Transparent conductive oxides (TCO) are doped metal oxides used in optoelectronic devices such as flat panel displays and photovoltaics (including inorganic devices, organic devices, and dye-sensitized solar cell). Most of these films are fabricated with polycrystalline or amorphous microstructures. Typically, these applications use electrode materials that have greater than 80% transmittance of incident light as well as electrical conductivities higher than 10^3 S/cm for efficient carrier transport. In general, TCOs for use as thin-film electrodes in solar cells should have a minimum carrier concentration on the order of 10^{20} cm⁻³ for low resistivity and a bandgap greater than 3.2 eV to avoid absorption of light over most of the solar spectra.[2] Mobility in these films is typically limited by ionized impurity scattering due to the large amount of ionized donors in the and is on the order of 40 cm²/(V·s) for the best performing TCOs. Current transparent conducting oxides used in industry are primarily n-type conductors, meaning their primary conduction is as donors of electrons. This is because electron mobilities are typically higher than hole mobilities, and the difficulty of finding shallow acceptors in wide band gap oxides to create a large hole population. Suitable p-type transparent conducting oxides are still being researched, though the best of them are still orders of magnitude behind n-type TCOs.

To date, the industry standard in TCOs is ITO, or tin-doped indium-oxide. This material boasts a low resistivity of $\sim 10^{-4}$ $\Omega \cdot \text{cm}$ and a transmittance of greater than 80%.[3] ITO has the drawback of being expensive. Indium, the film's primary metal, is rare (6000 metric tons worldwide in 2006), and its price fluctuates due to market demand (over \$800 per kg in 2006).[4] For this reason, doped binary compounds such as aluminum-doped zinc-oxide (AZO) and indium-doped cadmium-oxide have been proposed as alternative materials. AZO is composed of aluminum and zinc, two common and inexpensive materials, while indium-doped cadmium oxide only uses indium in low concentrations. Other novel transparent conducting oxides include

barium stannate and the correlated metal oxides strontium vanadate and calcium vanadate.

Binary compounds of metal oxides without any intentional impurity doping have also been developed for use as TCOs. These systems are typically n-type with a carrier concentration on the order of 10^{20} cm^{-3} , provided by interstitial metal ions and oxygen vacancies which both act as donors. However, these simple TCOs have not found practical use due to the high dependence of their electrical properties on temperature and oxygen partial pressure.[5]

| NO. | PARAMETERS | VALUES |
|-----------|---------------------------|----------------------|
| 1 | Layer | TCO |
| 2 | TYPE | SnO |
| 3 | EPS | 9.0 |
| 4 | MUN | 100 |
| 5 | MUP | 25 |
| 6 | $N_A(\text{cm}^{-3})$ | 1×10^{17} |
| 7 | $N_D(\text{cm}^{-3})$ | 0 |
| 8 | $E_G(\text{eV})$ | 3.6 |
| 9 | $N_C(\text{cm}^{-3})$ | 2.2×10^{18} |
| 10 | $N_V(\text{cm}^{-3})$ | 1.8×10^{19} |
| 11 | CHI (eV) | 4.5 |
| 12 | TCO Thickness (nm) | 50 |
| 13 | CdS Thickness (nm) | 50 |
| 14 | CdTe Thickness (nm) | 1000 |

| | | |
|----|--------------------|-----|
| 15 | BSF Thickness (nm) | 500 |
| 16 | Temperature (°K) | 300 |

Table-3.2: TCO Layer Parameters

Table 3.2 shows the parameters for TCO layer using SnO. By using these parameters the efficiency will increase up to 25.826%.

3.4 Intrinsic Layer

PIN photodiodes are used in fiber optic network cards and switches. As a photo detector, the PIN diode is reverse biased. Under reverse bias, the diode ordinarily does not conduct (save a small dark current or leakage). When a photon of sufficient energy enters the depletion region of the diode, it creates an electron-hole pair. The reverse bias field sweeps the carriers out of the region creating a current. Some detectors can use avalanche multiplication.

The same mechanism applies to the PIN structure, or p-i-n junction, of a solar cell. In this case, the advantage of using a PIN structure over conventional semiconductor p-n junction is the better long wavelength response of the former. In case of long wavelength irradiation, photons penetrate deep into the cell. But only those electron-hole pairs generated in and near the depletion region contribute to current generation. The depletion region of a PIN structure extends across the intrinsic region, deep into the device. This wider depletion width enables electron-hole pair generation deep within the device. This increases the quantum efficiency of the cell.

| NO. | PARAMETERS | VALUES |
|-----|-----------------------|-----------|
| 1 | Layer | Intrinsic |
| 2 | TYPE | CdTe |
| 3 | EPS | 9.40 |
| 4 | MUN | 320 |
| 5 | MUP | 40 |
| 6 | $N_A(\text{cm}^{-3})$ | 0 |

| | | |
|-----------|------------------------------------|----------------------|
| 7 | $N_D(\text{cm}^{-3})$ | 0 |
| 8 | $E_G(\text{eV})$ | 1.45 |
| 9 | $N_C(\text{cm}^{-3})$ | 8×10^{17} |
| 10 | $N_V(\text{cm}^{-3})$ | 1.8×10^{19} |
| 11 | CHI (eV) | 4.28 |
| 12 | TCO Thickness (nm) | 50 |
| 13 | CdS Thickness (nm) | 50 |
| 14 | i-layer Thickness (nm) | 50 |
| 14 | CdTe Thickness (nm) | 1000 |
| 15 | BSF Thickness (nm) | 500 |
| 16 | Temperature ($^{\circ}\text{K}$) | 300 |

Table-3.3: intrinsic Layer Parameters

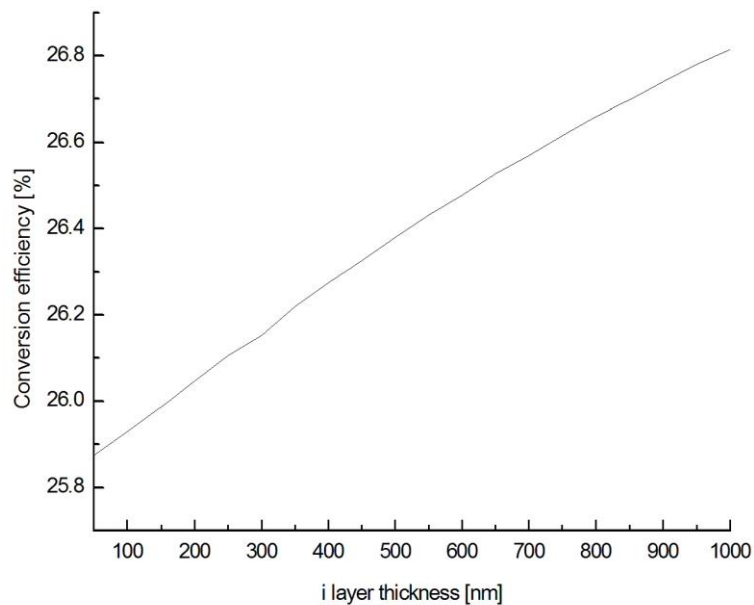


Fig-3.4: Intrinsic Layer Thickness vs. Efficiency

From the above figure 3.3 we can see that the efficiency increase almost linearly with the increased thickness of the intrinsic layer. So from this finding we can suggest that this is a very easy way to get desired efficiency however the cost will rise significantly when we take thicker intrinsic layer. So considering that factor we took maximum 1000 nm layer thickness.

3.5 Future Work

Practically CdTe can be doped not more than 1×10^{19} ($1/\text{cm}^3$) so if the doping density can be increased then the following result can be achieved with an conversion efficiency of 33.19%.

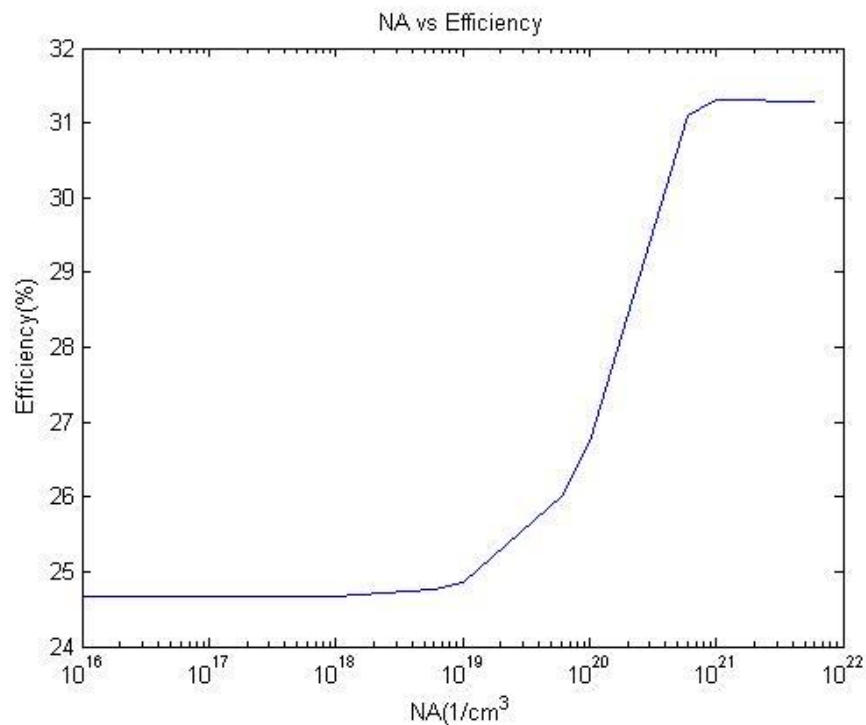


Fig-3.5: BSF layer NA vs. Efficiency

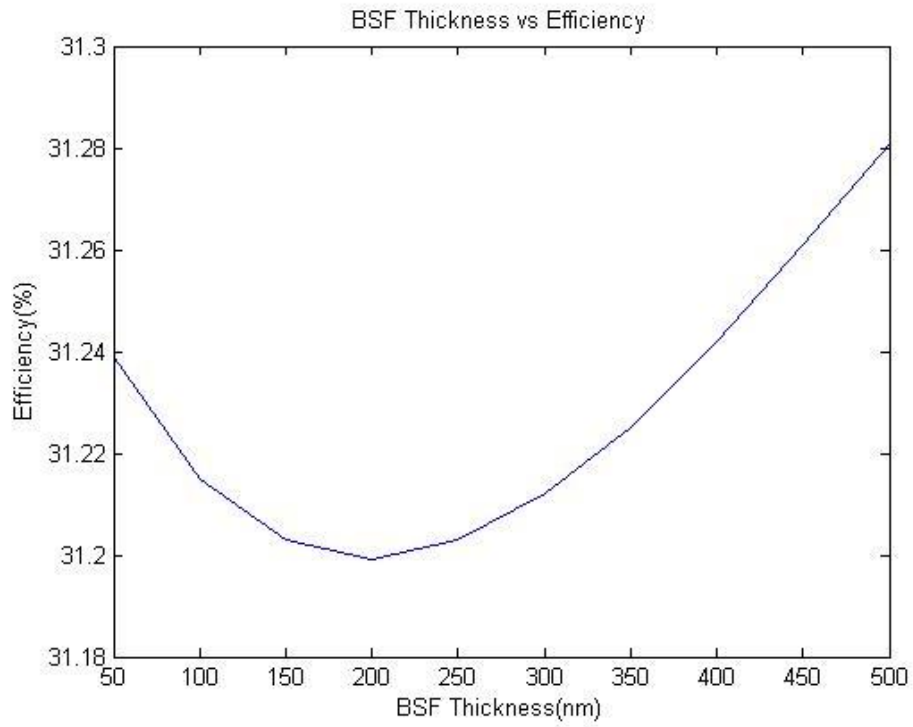


Fig-3.6: BSF Layer Thickness vs. Efficiency

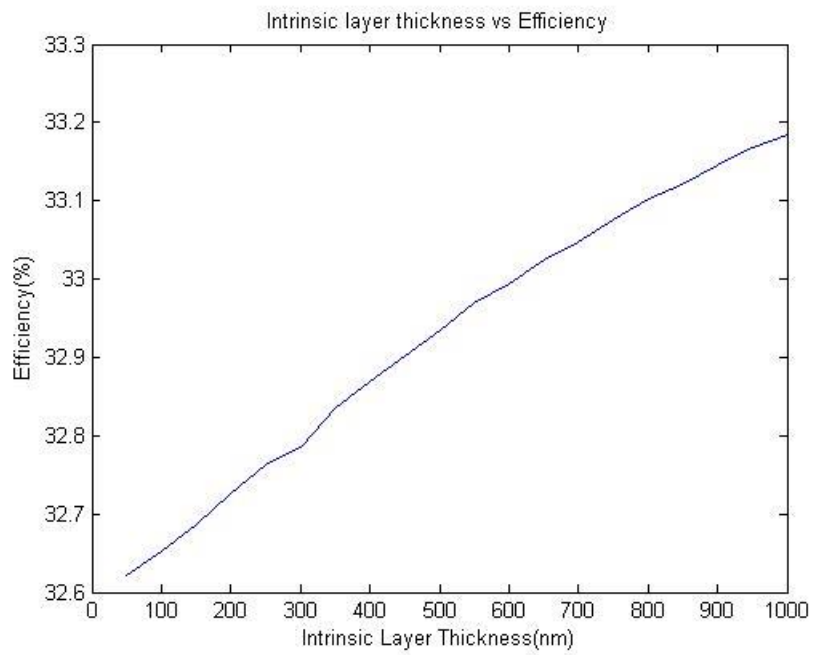


Fig-3.7: Intrinsic Layer Thickness vs. Efficiency

References:

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Chapter 4
Conclusion

In this experiment we have found that the efficiency of the solar cell increases as the acceptor concentration and thickness of the BSF layer is increased. There is also an effect of intrinsic layer in the efficiency of the proposed CdS-CdTe solar cell. Moreover the thickness of the intrinsic layer has an almost linear effect on the solar cell efficiency. But this results a significant rise in the cost so to balance out we cannot increase the thickness over a certain value. By this research the maximum of 26.81% is achieved by using SnO as TCO, CdTe as intrinsic layer and p+ CdTe as BSF layer. The short circuit current density is 27.29 mA.cm^{-2} and open circuit voltage is 1.10 V with a fill factor of 89.1%.

The thicknesses of the layers are 50nm TCO, 1000nm intrinsic and 500nm BSF layer.

In future the above-proposed solar cell should be implemented in the laboratory and compared with the results found in this thesis.