Study of performance evaluation of Nano wire CdS/Cited solar cell using SCAPS-1D Simulation program

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Abstract: Cds/CdTe solar cell both are most promising semiconductor materials used in the manufacturing of thin film solar cell. It provides high efficiency at lower fabrication cost. In this paper performance of Cds/CdTe solar cell are evaluated through the simulation program for solar cell SCAPS-1D. The CdS nano wire was inserted instead of planner CdS layer using simulation software SCAPS-1D.It has been observed that CdS nano wire increases the efficiency of CdS/CdTe solar cell. Different parameters such as effect of temperature, effect of series and shunt resistance, effect of thicknesses, interface state density, density of states were studied through SCAPS-1D simulation software.

Keyword: cadmium sulphide, cadmium telluride, thin film solar cell, Nano wire, SCAPS-1D simulation software.

1. INTRODUCTION: Thin film Cds/CdTe solar cell has become the most important and necessary alternate because of their efficiency and low cost. CdTe is the most promising and efficient material for the development of solar cell. The most important alternative is hetero junction structure with n type Cds which works as transparent window layer. Except the mismatch of lattice of 10% between Cds/CdTe, the developed heterojuction has excellent electrical properties which generates high fill factor of 0.77 which results in higher efficiency of solar cell.

2. OBJECTIVE OF STUDY:

(1) To increase the efficiency of solar cell.
(2) To achieve Optical advantages and large potential energy conversion efficiency.
(3) To improve the performance of solar cell by varying different parameters using simulation program SCAPS1-D

2.1structure of Thin Film Cds/Cdte Solar Cell:

Thin film Cds/CdTe solar cell has many different thin layers with thickness vary from nanometers to micrometers. Sun light incident on glass materials and enters through TCO layer and then absorbed by p type Cds and n type CdTe layer. Sun light can either absorbed in Cds/CdTe junction and CdTe layer. The materials used for making back contacts are copper or graphite. Transparent conductive oxide is normally filled with tin oxide or indium tin oxide.

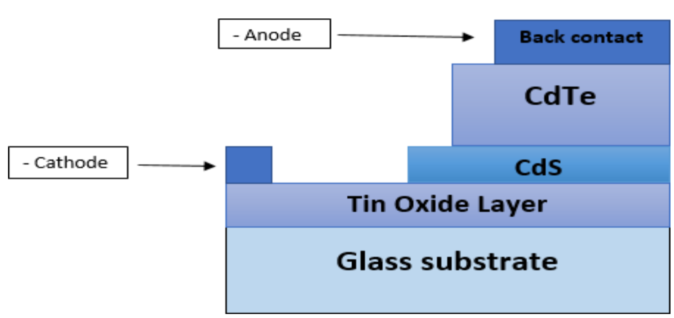

Figure1.Structure of typical CdS/CdTe solar cell

2.2implementation of Cds Nano Wire:

The use of CdS nano wire has become the most important because of its optical benefits and its conversion efficiency. Sunlight directly enters from glass substrate and photons are absorbed in CdS nano wire and P Type CdTe layer. Different synthesis has been considered to control the generation of CdS nano wire. Electrochemical synthesis is the most efficient method for this. In this method generation of CdS nano wire is to be controlled through the duration of time. These nano wires are perfectly fabricated in the perpendicular direction to the surface of substrate. CdS nano wire increases transmission of light in window layer so the absorption amount of light is increased in CdTe absorber.

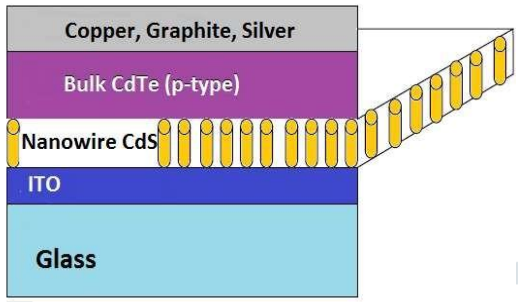

Figure2.Typical structure of CdS nanowire solar cell

4. LITERATURE REVIEW:

The earlier simulation was done by Lee using SCAPS1-D simulation software, ADEPT developed in Purdue. Lee and Gray explained the effect of non-ideal back contact, effect of grain boundaries and described the set of parameters consistence with measured cell performance.

Some simulation parameters were described by Fahrenbruch. This simulation study explains the effect of thin layer of CdS between TCO and CdTe regions. Simulation was performed for finding J-V curves.

In this software all the parameters are independence of temperature. It is possible to simulate the graded junction. When definition of device is completed, the user can simulate J-V in dark, light and spectral response measurement. AMPS software is slow as compare to any other simulation program.

Now a days several simulation programs are available. Mark S.Lundstorm developed the first solar cell simulation program (TFSSP) for his Ph.D thesis. Other programs are thin film semiconductor simulation program (TFSSP), solar cell analysis program in one dimension (SCAPS1-D), solar cell analysis program in two dimension(SCAPS2-D),PUPHS and PUPHS2D.

This paper is focused on SCAPS1-D which has been used as tool for the simulation of thin film CdS/CdTe and nw-CdS/CdTe solar cell.

5. ANALYSIS OF THE STUDY:

5.1Simulation of CdS/CdTe solar cell:

For evaluation the performance of CdS/CdTe solar cell simulation software SCAPS-1D is used. This software used for the simulation of I-V characteristics of Nano wire CdS/CdTe solar cell. All the basic parameters were entered in SCAPS-1D software. This software only takes thin layer parameter, so Nano wire CdS layer was include as thin layer with high absorption constant (9.6x105)

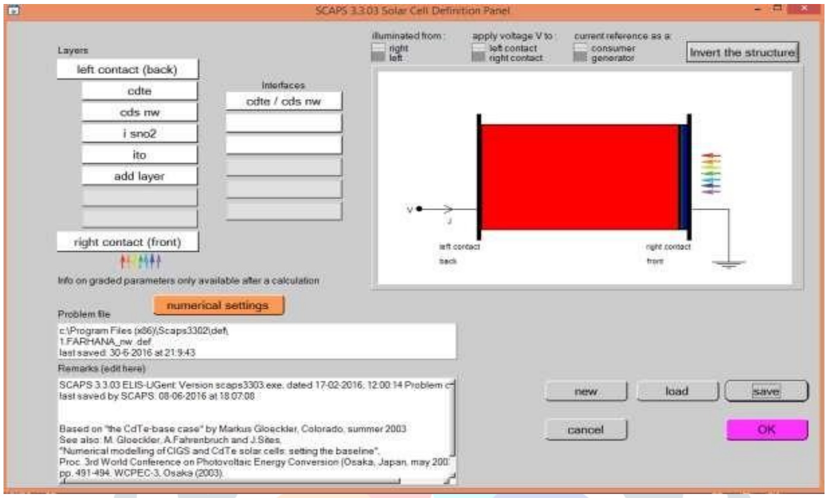

Figure3.Definition Panel of SCAPS-1D for CdsNw/Cdte Solar Cell

5.2About Software:

SCAPS-1D (A solar cell capacitor simulator) is one dimensional solar cell simulation program developed at ELIS at University Of Gent,Belgium.this program was developed for evaluating and developing cell structure of CdTe and $CuInSe_2$ family. Simulation program SCAPS 3.3.07 was used for the simulation of CdS/CdTe solar cell and nano wire CdS/CdTe solar cell. It takes only thin layer parameter.

Table1.Parameters Used For Simulation of Nw Cds/Cdte Solar Cell In SCAPS-1D

Parameters	**CdTe**	**CdS nw**	**CdS-nw/CdTe interface**	**i-SnO2**	**ITO**
thickness (µm)	8	0.090	---	0.100	0.150
bandgap (eV)	1.5	3.490	---	3.600	3.650
electron affinity (eV)	3.9	4.000	---	4.400	4.800
dielectricpermittivity (relative)	9.4	9.000	---	9.000	8.900
CB effective density of states ($1/cm^3$)	1.000E+18	8.000E+19	---	2.200E+19	5.200E+18
VB effective density of states ($1/cm^3$)	8.000E+18	8.000E+18	---	1.800E+19	1.000E+18
Electron thermal velocity (cm/s)	1.000E+7	1.000E+7	---	1.000E+7	2.000E+7
Hole thermal Velocity (cm/s)	1.000E+7	1.000E+7	---	1.000E+7	1.000E+7
Electron mobility (cm^2/Vs)	5.000E+2	1.000E+2	---	1.000E+2	1.000E+1
hole mobility (cm^2/Vs)	4.000E+1	2.500E+1	---	2.500E+1	1.000E+1
Allow Tunneling	---	Yes	---	---	---
Effective mass of Electrons	---	1.900E+1	---	---	---
Effective mass of holes	---	8.000E+1	---	---	---
Shallow uniform acceptor density NA ($1/cm^3$)	1.000E+16	---	---	1.000E+15	---
shallow uniform donor density ND ($1/cm^3$)	---	1.150E+17	---	1.000E+15	1.000E+15
absorption constant A (1/cm $eV^{(½)}$)	9.600E+5	9.600E+5	---	1.000E+5	1.000E+5
Defect type	Single Acceptor	---	acceptor	---	---
Capturecrosssectionelectrons (cm^2)	1.000E-15	---	1.00E-13	---	---
Capture cross sectionholes (cm^2)	1.000E-12	----	1.00E-13	---	---
energetic distribution	Single	---	single	---	---
Reference for defect energy level Et	Above Ev	---	Above Ev of CdTe	---	---
Energy level with respect toReference (eV)	0.090	---	0.100	---	---
Nt total ($1/cm^3$) uniform	9.900E+13	---	1.60E+12	---	---

Table2.Parameters for Front and Back Contact

Parameters	Back contact	Front contact
Thermionic Emission/ surface recombination velocity (cm/s)	---	---
Electrons	1.000E+5	1.000E+5
Holes	1.000E+5	1.000E+5
Metal work function (eV)	5	5.0216
Majority Carrier barrier height(eV)	---	---
relative to E_f	0.4	0.2216
relative to E_v	0.2271	0

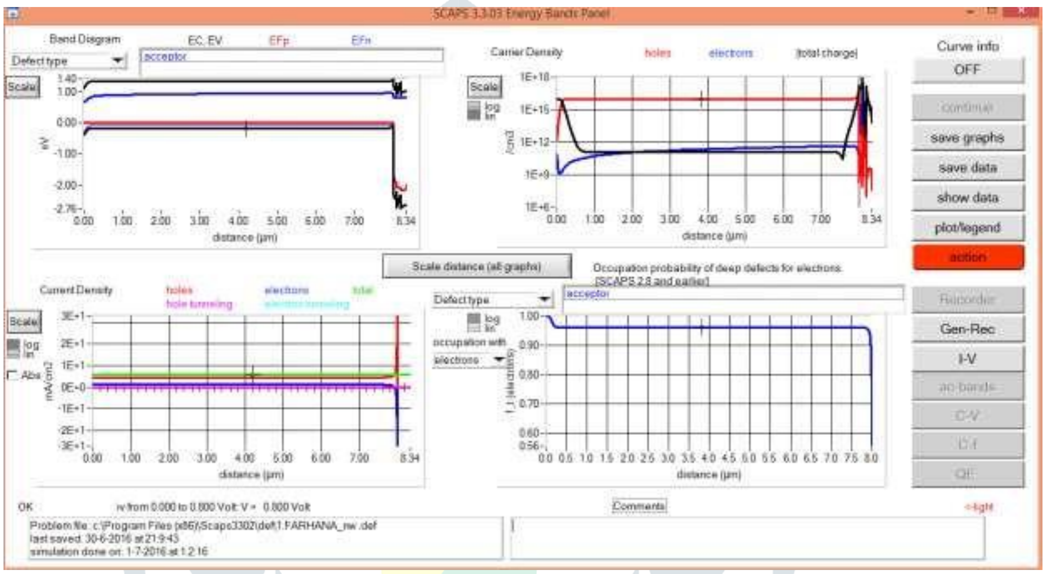

Figure4.SCAPS-1D Energy Band Panel

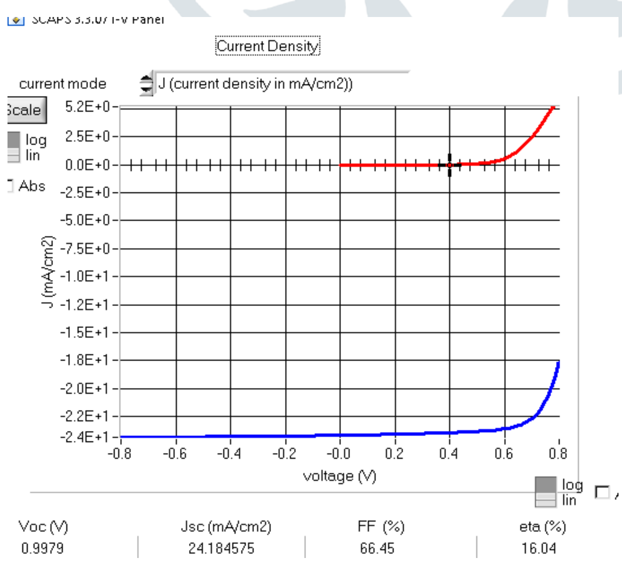

Figure 5.I-V curve for dark (red) and light (blue) condition for nw CdS/CdTe solar cell

5.3 Efficiency At Temperature 300K

Table 3.nwCdS/CdTe Solarcell Efficiency for Temperature 300k

Open circuit voltage, V_{OC}(V)	0.9979
Short circuit current, J_{SC}(mA/cm^2)	24.184575
Fill Factor, FF (%)	66.45
Efficiency (%)	16.04

5.4Effect of Series And Shunt Resistance

Table 4. Effect of Series and Shunt Resistance

	RED CURVE	BLUE CURVE
Series resistance (Ω.cm^2)	0	8
Shunt resistance (Ω.cm^2)	1000	250
V_{OC} (V)	0.8733	0.8649
J_{SC}(mA/cm^2)	24.184575	23.354913
Fill Factor, FF (%)	73.43	54.58
Efficiency (%)	15.51	11.02

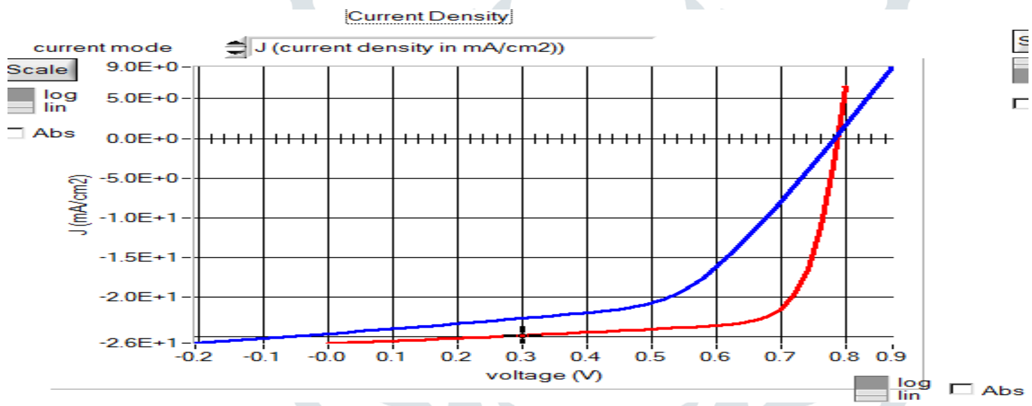

Figure 6.Effect of Both Series and Shunt Resistance

Finding: The effect of series and shunt resistance is obtained in SCAPS-1D software as shown in above curve.

5.5 Effect of Temperature

Table 5. Effect Of Temperature

Temperature(K)	Voc (V)	Jsc(mA/cm2)	FF (%)	Efficiency (%)
300	0.8761	24.184575	75.69	16.04
315	0.8467	24.182197	74.73	15.30
330	0.8019	24.179519	74.81	14.50
350	0.7586	24.175470	72.94	13.38
365	0.7233	24.172232	71.52	12.50
380	0.6785	24.169442	70.88	11.62
400	0.6284	24.168835	68.78	10.45
415	0.5909	24.173489	67	9.57
430	0.5533	24.184467	65.04	8.70

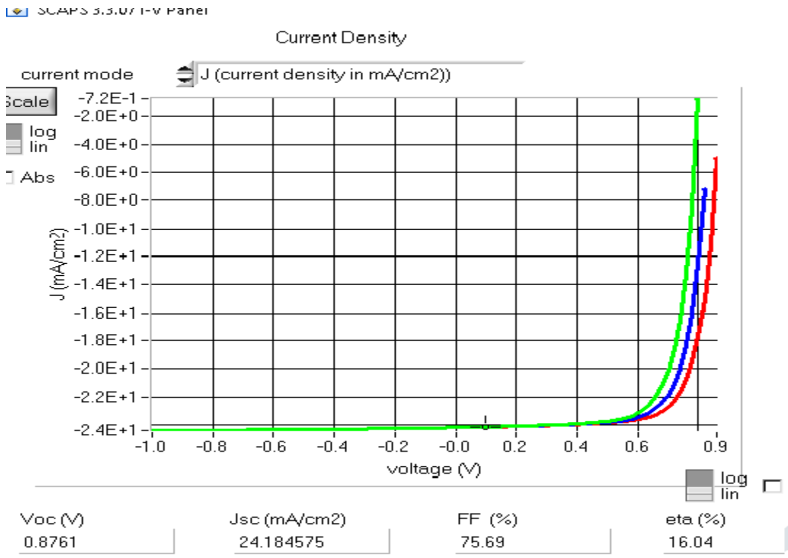

Figure7.Effect of temperature (Red curve for 300K,Blue curve for 315K and Green curve for 330K)

Finding : from the above table it can be seen that with increase of temperature efficiency of solar cell decreases.

5.6 Effect of interface state density

The interface density between layers nw CdS and CdTe varied in simulation software SCAPS-1D.

The range of interface state density is from 5.88×10^{11} to 6.35×10^{14} cm^{-2}.

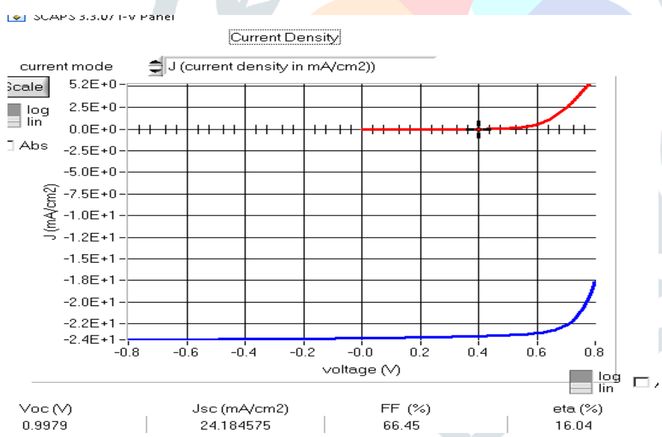

Figure 8. SimulatedJ-Vcharacteristicsat300KforN$_{it}$:$1.00 \times 10^{12}$$cm^{-2}$for dark(red) and light (blue) condition

Table 6. Effect of Interface State Density

N_{it}	V_{oc}	J_{sc}	Fill Factor	Efficiency
5.88E11	0.8009	28.786763	82.24	18.50
6E11	0.8005	28.783824	82.11	17.45
1E12	0.9979	24.184575	66.45	16.04
5E12	0.7756	16.065179	73.28	9.67
1E13	0.7613	9.4770353	70.21	5.12
5E13	0.7234	1.4299689	68.04	0.86
1E14	0.7167	0.6579568	72.69	0.45
3E14	0.7078	0.6556945	81.19	0.20
6.35E14	0.7012	0.3456782	83.23	0.12

5.7 The Effect Of Thickness

Table 7.Effect of Thickness

CdTe (um)	Voc (V)	Jsc(mA/cm2)	FF (%)	Efficiency (%)
1	0.6003	15.274658	75.75	1.88
2	0.6632	16.242972	81.14	8.74
3	0.6853	20.056855	81.52	11.21
4	0.7000	21.713272	81.91	12.45
5	0.7000	22.559333	83.70	13.22
6	0.7478	23.042657	79.97	13.78

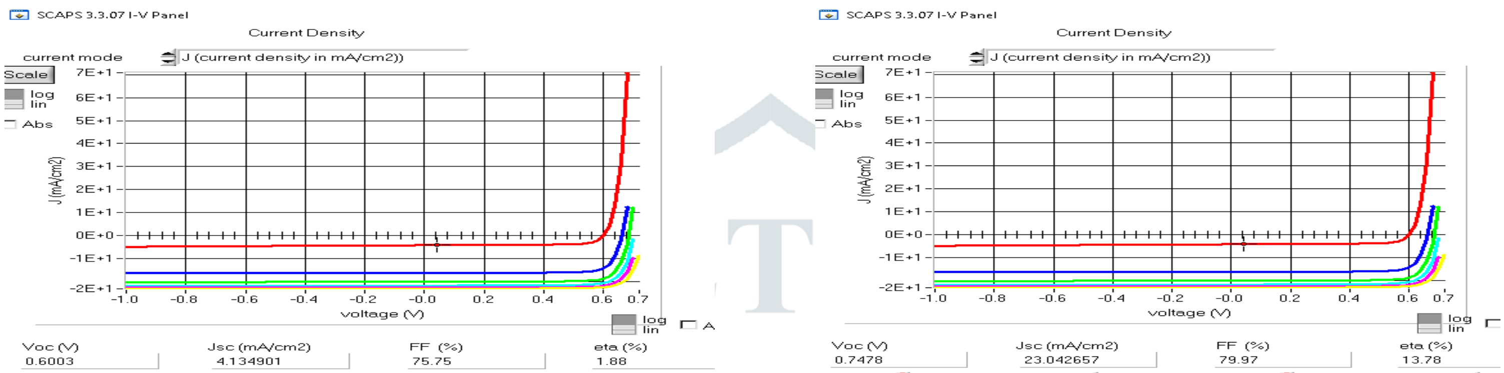

Figure 9. Effect of thickness

Finding: from above table it is concluded that with increase of thickness of CdTe layer efficiency of solar cell also increases.

6. Conclusion: CdSnano wires have many advantages such as increase open circuit volatage because of reduced junction area. Short circuit current is also improved because of higher optical transmission through CdSnano wires. CdS/CdTe solar cell with planner CdS films and with nano wire CdS are simulated using SCAPS-1D.The simulation of nwCdS/CdTe was observed using SCAPS-1D simulation program to find out different parameters which are responsible for improving the efficiency of solar cell. The effect of various parameters such as temperature, series and shunt resistance,interface state density was observed. The I-V curve was observed without convergence failure.

7.Reference

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