Numerical Analysis of Cadmium Telluride Solar Cell

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Abstract:
CdTe solar cell is very popular photovoltaic because of lower cost and higher stability. The main issue is to create stable ohmic contact between CdTe base layer and back contact. Only technique used to solve this is to insert BSF layer between absorber layer and back contact. This paper highlights the analysis of reference and proposed cell. From simulation it can be seen that by inserting BSF layer cell efficiency can be improved with optimum thickness of CdTe layer. The reference cell shows the efficiency 19.68 %(Voc=0.7838, Jsc =29.845294, FF =84.14).After inserting back surface field layer and with minimum thickness of absorber layer cell efficiency is increased up to 22.92% (Voc= 2.6232, Jsc =30.770710, FF =28.39).

Keywords: *Cadmium telluride solar cell, Cu2Te layer, SCAPS-1D.* .

I. Introduction:

CdTe always creates attraction for many researchers because of its benefits of high efficiency, low cost, high stability and possibilities of large scale fabrications. Bandgap of CdTe is 1.45 eV. This band gap is very close to minimum band gap of solar cell. So all the photons greater than band gap of CdTe can be engrossed by very skinny absorber layer. So minimum use of thickness can give advantages of reduced use of material and cost of production. The most important issue is to create steadyohmic contact on p type base layer of solar cell. Normally Cadmium telluride needs material higher than 5.7 e V for making stable ohmic contact. No metals can have such large value of metal work function to create better contact with negligible resistance with Cadmium Telluride. Generally Copper is used as back contact. The main disadvantage of Cu is that it does not give stable result. It also leads to reduction of efficiency with time due to diffusion of Cu with front contact which creates effect of shunting. The technique used to overcome this effect is to inserting BSF layer. The main aim of inserting this layer is to achieve high efficiency in solar cell and reducing shunting and schottkey effect. The proposed cell and reference cell is simulated using SCAPS-1D program.

II. Objective:

The main purpose of this study is to achieve following objectives.

1. To study performance characteristics of reference and proposed cell.
2. To compare efficiency of reference and proposed cell.

Figure 1 (a) Reference structure

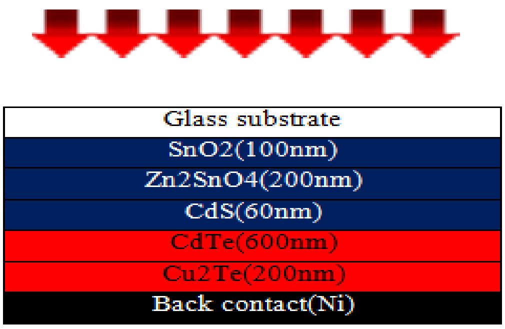

Figure 1 (b) Proposed structure

III. Research methodology:

SCAPS-1D program is used for this research. It is the program developed by Department of Electronics and Information system (ELIS) of university of Gantt, Belgium. This program was specially designed for CdTe and CuInSe2 family. In this program different layers can be defined. Different interface states can be placed in between these layers. All measurements can be taken for light and dark conditions which is a function of temperature. Different types of results such as current density, carrier density and quantum efficiency can be calculated using this one dimensional software. This software is working at 300K temperature. Following parameters are used in SCAPS-1D.

Table 1. Parameters used in SCAPS-1D

Parameters	SnO2	Zn2SnO4	CdS	CdTe	Cu2Te
Thickness (μm)	0.1	0.2	0.06	0.1-5	0.2
Relative permittivity	9	9	10	9.4	10
Electron mobility (cm^2/Vs)	100	320	100	320	500
Hole mobility (cm^2/Vs)	25	30	25	40	100
Electron concentration(cm^{-3})	10^{17}	10^{19}	10^{17}	$5x10^{15}$	10^{21}
Band gap (e V)	3.6	3.35	2.42	1.45	1.18
NC(cm^{-3})	$2.2x10^{18}$	$2.0x10^{18}$	$2.2x10^{18}$	$8.0x10^{17}$	$7.8x10^{17}$
NV(cm^{-3})	$1.8x10^{19}$	$1.5x10^{19}$	$1.8x10^{19}$	$1.8x10^{19}$	$1.6x10^{19}$
Affinity(e V)	4.50	4.50	4.50	4.28	4.20
Electron thermal velocity (cm/s)	$1x10^7$	$1x10^7$	$1x10^7$	$1x10^7$	$1x10^7$
Hole thermal velocity (cm/s)	$1x10^7$	$1x10^7$	$1x10^7$	$1x10^7$	$1x10^7$

IV. Literature review:

Martin et al (2010) conducted study of CdTe solar cell using AMPS-1D simulator. He concluded that cell efficiency linearly decreased with increasing of temperature. He also observed that Cadmium telluride solar cell shows better stability at higher temperature. Ouedraogo et al (2013) conducted study of CIGS (Copper-Indium-Gallium-DIselenide) and CdS using SCAPS-1D simulator. He observed the effect of thickness on efficiency of cell. He concluded that performance is improved by reducing the thickness of skinny CdTe layer. Harmid and Fatima (2013) conducted

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study of CdTe solar cell by using SCAPS-1D simulation program. The main purpose of this work was to determine the influence of absorber layer thickness, electron affinity on the performance of CdTe thin film solar cell.

V. Analysis of result:

To achieve higher performance of CdTe cell, thickness of CdS layer has been reduced up to 60nm.This may allow forward leakage current in CdS layer with front contact through possible effect of pinholes. So high resistive material (Zn_2SnO_4) had been inserted between SnO2 and CdS layer to reduce this unwanted forward leakage current. Theoretically 2000 nm thickness of absorber layer is efficient to absorb all photons incident on solar cell for the band gap value higher than absorber layer. However to avoid pinhole effect and limitation of uniformity thickness of CdTe layer is set at 5000nm.The numerical analysis was carried out by SCAPS-1D simulation software to eliminate the thickness of Cadmium Telluride absorber layer to reduce cost of material and usage of material. The absorber layer thickness is changed from 100nm to 5000nm for both reference and proposed cell to show the possibilities of ultrathin CdTe layer. From simulation it can be seen that both for reference and proposed cell output parameters remain unchanged for absorber layer thickness higher than 2000nm and affected near 1000nm.By reducing thickness below 1000nmof CdTe Jsc and Voc reduces slowly but FF increases below 50nm. The Jsc decrease sharply at thickness less than 50nm due to short minority carrier diffusion length but FF increases due to deduction of bulk registration. All these lead to reduce efficiency of solar cell. For CdTe thickness below 1000nm it was not possible to achieve high efficiency. So it was necessary to modify reference structure with Copper Telluride known as noble BSF material. The proposed structure has been shown in figure.

With comparison of reference structure it can be seen that Voc and Jsc of proposed cell had been increased below absorber layer thickness of value 1000nm. This is due to reduction of minority carrier recombination. FF had been stabilized with increase in value due to reduction of bulk resistance. The result analysis shows that output parameters are improved with ultra-thin absorber layer with Cu2Te as BSF layer. The highest conversion efficiency was obtained by using proposed structure of solar cell.

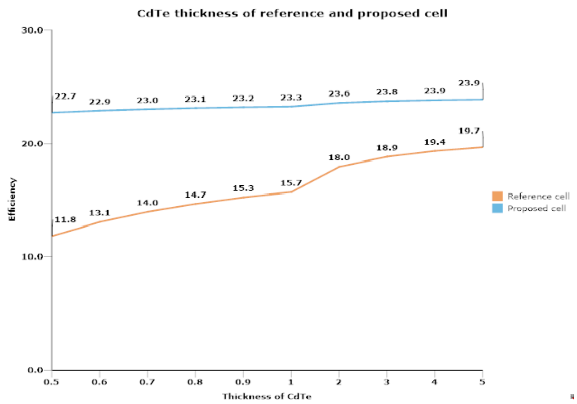

Figure (2) efficiency vs. CdTe thickness graph for reference and proposed cell.

The result analysis shows that output parameters are improved with ultrathin absorber layer with Cu_2Te as BSF layer. The highest conversion efficiency can be achieved by using the proposed cell.

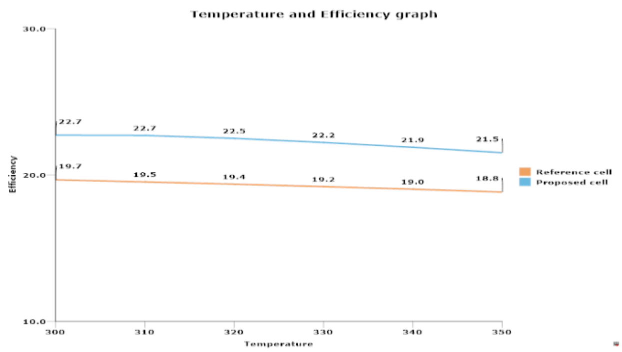

Figure (3) efficiency vs. Temperature graph for reference and proposed cell.

It can be seen from figure (3) that efficiency linearly decreases with increase of temperature for both reference and proposed cell. The CdTe solar cell with back surface field layer shows better stability than CdTe cell without back surface field layer. The proposed cell shows higher stability at higher temperature as compared to reference cell.a

Table 2. Performance parameters of both cells Performance parameter	Reference cell	Proposed cell
CdTe Thickness(µm)	5.0	0.6
Output Voltage(Voc)	0.7838	2.6232
Current Density (mA /cm^2)	29.845294	30.770710
FF (%)	84.14	28.39
Efficiency (%)	19.68	22.92

VI. Conclusion:

The result shows that in presence of back surface field layer higher performance of cell can be achieved with minimum thickness of absorber layer. The reduction will also result to reduce the material consumption and hence will reduce the material cost. Low cost materials (Cu, Ni) can be used as back contact without interrupting cell efficiency and stability. Further it is advisable to investigate proposed cell using standard fabrication technique for practical implementation.

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