Single Junction and Dual Junction Thin Film Solar Cells

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Abstract:
This paper presents a Novel approach for the fabrication of thin film Solar Cell (TFSC). This proposed model simplifies the complex fabrication process of thin film solar cell in some easy steps which is more clearly visualizing method. The work is carried out in two stages which demonstrate the fabrication flow of single junction and Dual junction. A review is also done to show different generation of solar cells, Choice of material of TFSC and basic performance parameters of solar cell. On this basis, a comparison is also done in Single junction with Dual junction Solar cell. The modeling of TFSC is done through SilvacoDev-edit tool in which different layered structure, their dimensions and materials respectively, are taken from related research work.

Keywords:*Dev-edit (TCAD SILVACO), Solar cell,Thin film Solar Cell (TFSC)*

I.INTRODUCTION:

Today the world is facing major problems related to limited availability of fossil fuels and hydrocarbons and the consequences of increasing consumption on the environment, quality of life and human health. For these regions the concerns are being shifted towards other sources of Renewable energy , an emerging solution of this problem and one of the most prevalent form is Solar which using photovoltaic technology solar energy,becomes available and widely exportable.

TodayPV technology is considersufficiently reliable and is experiencing sufficiently growth and Development, advantage ofPV technology is that the operation and Maintains PV power plant has a verylow cost operation of these system are silent, and does not produce air pollution. The current trends in PV panels are dominated by Si cell. Si have high efficiency but are costly to construct due to last thickness of the cell required in alternative to Si cells is thin film solar cell (TFSC) [1].

TFSC is second generation solar cell and uses material such as Copper Indium Gallium Selenide (CIGS).CIGS have lower cost of production, due to reduced thickness , (up to a 100 times thinner then Si cell), leaking performance compare to Si CIGS solar cell with a bad gap 2.13eV have reached the performance of polycrystalline Si with a record efficiency of 20.3% using denominated tandem triple and multi-junction solar cell consisting of layers with different band gap in order to utilize different energy regions of the solar spectrum , an increase is efficiency spectrum. Several researchers are trying to fabricate reliable cell with wide band gap in order to use them as a top cell.

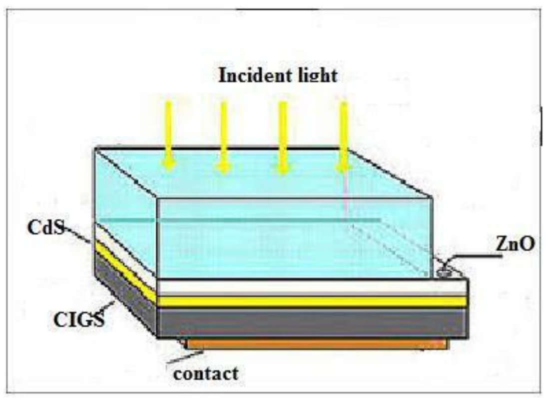


Figure 1: Cross section View of thin film solar cell

A. Working Principle

A Solar cell in its basic form consists of aPhotosensitive material in the form of a p-njunction which directly converts incident sunlightinto electricity[2].Solar cell characteristics depend on Si cell size like amorphous substrate is used or Poly-Silicon. The basic performance parameters which will be discussed in 2.2 are also depending on type of solar cell. Therefore, a review is done to illustrate them in table 1.

Table 1: Different generations of SolarCell [3], [4], [5], [7]

Generations	***1st generation***	***2nd generation***	***3rd generation***
Cell technology	Crystalline silicon	Thin film	Organic solar cell
Material used	Mono-crystalline silicon Poly-crystalline silicon String ribbon	Amorphous silicon Cadmium telluride (CdTe) Copper indium gallium selenide (CIG/CIGs)	polymer
voltage rating(Vmp/Voc)	80% - 85%	72% - 78%	-
Temp-coefficients	Higher	Lower	-
I – V curve fill factor	73% - 82%	60% - 68 %	-
Module efficiency	13% - 19%	4% - 12%	6.1%
Application type	Residential/commercial/utility	Commercial/utility	Commercial/utility
Required area	Industry area	May require upto %50 more space for a given project size	-

II. Thin film solar cell [2]

The thin film solar cell require less semiconductor material and are easier to fabricate and integrate, light weight and flexible and less expensive than wafer based solar cell. TFSC are two types junction, 1st is homo junction, they include material like GaAs, InP etc. and another is hetero junction which include CdTe, CIS, CdTe is easy to deposit but it is toxic and CIS has high optical absorption coefficient. It has very good optical and electrical characteristics but having low band gap. Therefore, a slight variation in CIS is obtained by adding gallium gives CIGS having high band gap of gallium. Materials for multi junction solar cell are carefully chosen which absorb electromagnetic radiation over a wide spectrum thus increase efficiency.

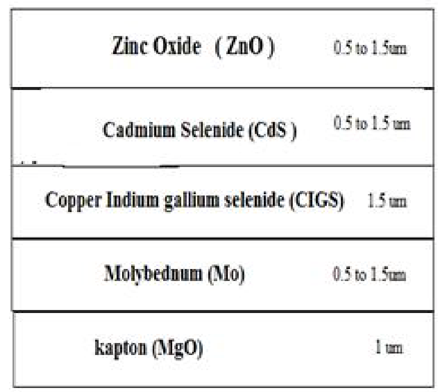


Figure 2: Layered architecture of thin film solar cell

A.Description of various layers is as follows: [1], [5], [6]

1. **Substrate (MgO):**It is basically used for high efficiency devices. It provides flexibility to the device. It can be replaced by kapton (Polymide film) which shows same electrical and optical properties.

2. **Back Contact (Mo):** Metal should have a higherwork function than that of semiconductor to form an ohmiccontact between them. Mo is highly anticorrosive and hence used as a back contact in chalcopyrite devices.

3.Absorber layer (CIGS):CIGS stands forCopper Indium Gallium Selenide. It is an alloy of 1-3-6 group of periodic table. These are used as absorber layer as they include a wide range of band gap and this layer behave as p type.CIGS exhibits nontoxic nature and exhibit excellent stability in electrical properties. The production cost for entire device is however increased due to the use of In and Ga materials.

4.Buffer layer (CdS): CdS layer with a band gapof 2.4 eV is used between ZnO and the CIGS (absorber layer) .CdS layer is usually prepared with the chemical bath deposition method and this layer behaves as n-type.

5. Window layer (ZnO): This layer is used forgood conductivity by allowing largest possible percentage of photons to reach to absorber layer. It also provides high transmittance in visiblelight. ZnO can be replaced with indium tin oxide (ITO), indium gallium oxide (IGO) and SnO_2. However in all these materials ZnO is considered as most competitive in cost and properties.

The buffer layer is an n-type wide energy gap material, which make a junction with the p-type absorber layer. The benefit of such structure is that the minority diffusion length of electron p-type semiconductor is much greater than that of holes in an n-type semiconductor.

B. Performance parameters of Thin film solar cells: [7]

1. Short- circuit current density (Jsc): It is usedto describe maximum current delivered by a solar cell. The maximum current that the solar cell can deliver strongly depends on the optical properties of the solar cell, such as absorption in the absorber layer and its reflection.

2.Open-circuit voltage (Voc): It is themaximumvoltage that a solar cell can deliver. Open circuit voltage corresponds to the forward bias voltage, at which the dark current J_o compensates the photocurrent. Voc depends on the photo-generated current density $J_{ph}$and can be calculated form given below equation.

$$\mathrm{Voc} = \left(\frac{\mathrm{KT}}{\mathrm{e}}\right) \ln\left(\frac{\mathrm{Jph}}{\mathrm{Jo}} + 1\right)$$

3. Fill Factor: The fill factor is the ratio betweenthe maximum power generated by a solar cellJ_{max} $V_{max,p}$ and the product of Voc with Jsc. The fill factor is between 0.70 and 0.85depending onthe material and structure of the device.

$$\mathrm{FF} = \frac{\mathrm{JmaxVmax,\ p}}{\mathrm{JscVoc}}$$

4. Conversion efficiency: The conversion efficiencyis calculated as the ratio between maximalgenerated power and the incident power. The efficiency depends on the product of V_{OC} and I_{SC}, therefore, an optimum energy band-gap material is taken for producing maximizing efficiency devices.

$$\eta = \frac{\mathrm{Pmax}}{\mathrm{Pin}}$$

$$\eta = \frac{\mathrm{JmpVmp}}{\mathrm{Pin}}$$

$$\eta = \frac{\mathrm{JscVocFF}}{\mathrm{Pin}}$$

C. Single junction and Dual junction Solar Cell: Athin layerof n and p region in solar cell is called single junction solar cell. Additionally, one more such type of p-n junction is dual junction and so on multiple junctions can be created. As we increase, the numbers of junctions, efficiency will increases.

Table 2: Characteristics of Single junction and dual junction Solar cell [1]

S.No	*Parameter*	*Single junction*	*Dual junction*
1.	Eg (eV)	1.27	1.27257
2	Voc (V)	0.735	0.738111
3	Isc (mA/cm^2)	30.2	39.9168
4	FF	77.73	78.2462
5	Efficiency (%)	18.3	23.0537

III. Fabrication Process flow of TFSC [1]

For the fabrication of Solar cell, some process sequences are there, which has to be followed:

1. MgO: Substrate deposition.
2. Mo deposition for back contact.
3. CIGS deposition absorber evaporation.
4. CdS deposition chemical deposition orevaporation.
5. ZnO:Al deposition front contact sputtering. Where we used DC microwave sputtering and RF microwave sputtering with CVD process.

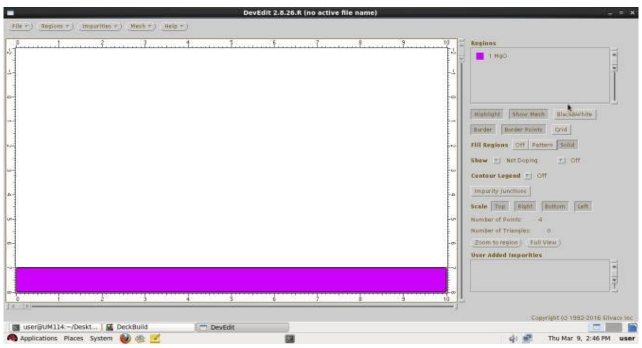
IV.Experimentation[8] [9] [10]

A. Fabrication Process flow of single junction Solar cell: The detailed description of singlejunction solarcell with layered materials, their properties and dimensions are discussed earlier. On the basis of these parameters, a simple fabrication process flow of single junction solar cell is shown below:

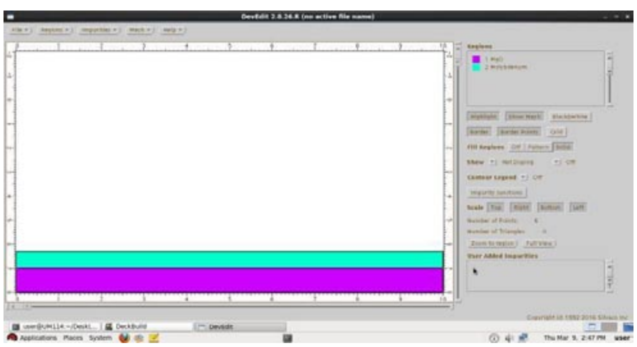
Table 3: Simulation parameters used in Modeling of TFSC.

Parameters	*ZnO*	*CdS*	*CIGS*
$\mu_n(cm^2/Vs)$	50	10	300
$\mu_p(cm^2/Vs)$	5	1	30
Eg(eV)	3.3	2.4	1.2
Thickness (nm)	800	1000	1500

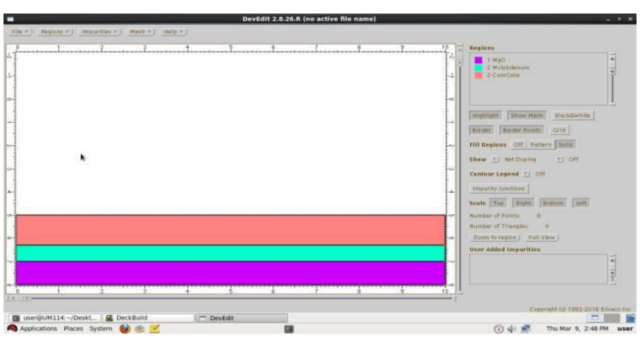
Step 1: Deposition of MgO



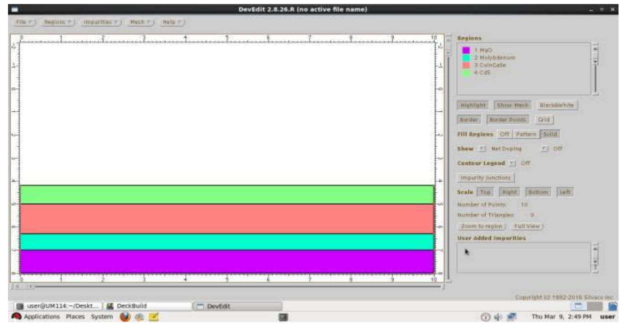
Step 2: Deposition of Molybdenum



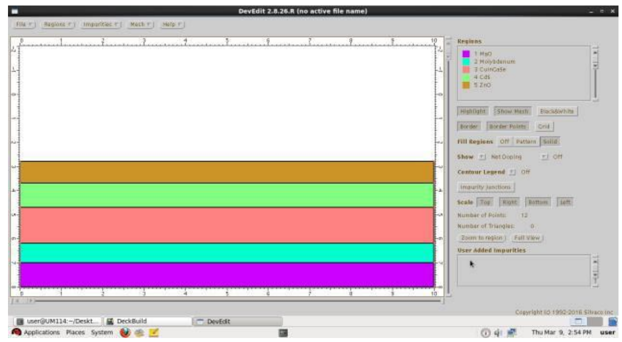
Step 3: Deposition of CIGS



Step 4: Deposition of CdS



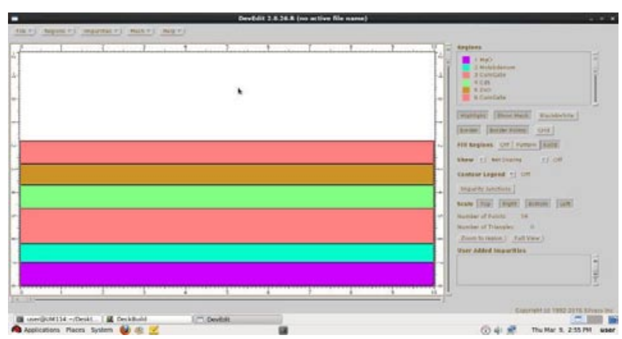
Step 5: Deposition of ZnO



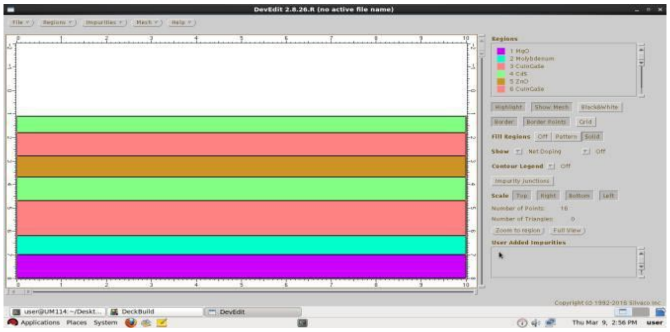
Above figure shows the final single junction thin film solar cell in which a single p-n junction is lying in between CIGS-CdS.

2. **Fabrication process flow of dual junction solar cell**:In this process, deposition of CIGS followed by deposition of ZnO, CdS, CIGS, Mo, MgO substrate. Show in following figure.

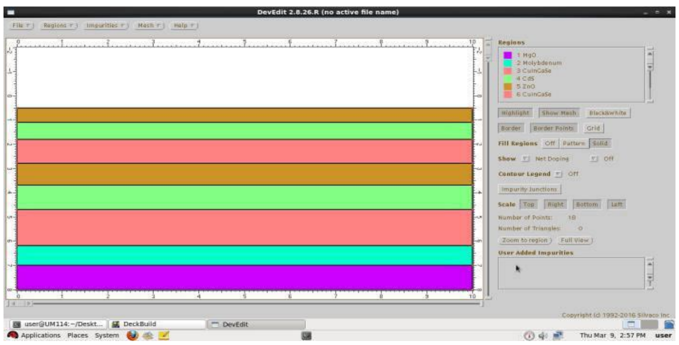
Step 6: Deposition of CIGS



Step 7: Deposition of CdS



Step 8: Deposition of ZnO



The above figure shows the final TFSC dual junction. As similar to single junction solar cell, two junctions are lying in between two CIGS-CdS layer consequently.

Conclusions:

This paper investigated a novelapproach for modeling of fabrication method in thin film single and dual junction solar cell. This innovation makesfabrication process easier and simpler to understand. We also study some materialistic properties for TFSC which help in further enhancement of efficiency, reduction in cost and so on manufacturing time. We also conclude that as number of junction in solar cell increases, efficiency increases. But there are several limitations on performance of solar cell as we increase junctions.

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