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Application Scope of ZnSe-In_2S_2 as a Dual Buffer Layer as a Substitute of CdS Buffer Layer in CIGS Based Solar Cell

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Abstract:- Copper indium gallium selenide (CIGS) absorber based solar cell generally use CdS as a buffer layer. In large scale utilization of this kind of solar cell there is a debate on the CDS which comprises with toxic Cd. In this research different non-toxic materials have been studied observing the suitable energy band bending, potential of light insertion on the absorber layer and other electrical output parameters for optimum efficiency. From the research it has been revealed that out of single layer ZnS, ZnSe, ZnTe, SnO_2, In_2S_2 and double layerZnSe-In_2S_2,ZnS-CdS materials the double layer ZnSe-In_2S_2 has an excelled impact on the band alignment and shows an efficiency around the conventional single layer CdS based CIGS solar cells, ~21%. Hence this double layer ZnSe-In_2S_2 can be an alternative of the toxic Cd based CdS in CIGS solar cells.

Keywords—Photoconversion efficiency, toxicity, dual buffer layer, band alignment, Thin film solar cells (TFSC).

I. INTRODUCTION

CIGS solar cells are well known for its high photoconversion efficiency as around ~22.8% [1,2,3] among the solar cells has been produced since the very beginning. To make it more efficient and more environment friendly scientists are testing different materials for buffer layer to find the optimum one [3,4,5,6]. Different variation on buffer layer, different material, thickness variations are done in terms of development of CIGS solar cell [2,7]. Along with the buffer layer absorber layer has been also tested with different thickness to have an optimum result [8]. Due to high positive impact on energy demand CIGS solar cells has a negative side when it is used with CdS as buffer layer for its toxicity. A very bad effect on health can happen if human body exposure to Cd. Cd can even cause, Diarrhea, stomach pains and severe vomiting, Bone fracture, Reproductive failure and possibly even infertility. Damage to the central nervous system and damage to the immune system is also possible. Which can lead to Psychological disorders and possibly DNA damage or cancer development. Many researches have been done to have a structure of CIGS solar cell without toxic Cd [9], many has found alternative solution and research is going on. Double layer buffer is also been tested and found that compared to single layer dual buffer layers shows batter results [5]. In this work, we have proposed a ZnSe-In_2S_2 based double buffer CIGS solar cell using WxAMPS tool. Proposed model shows a higher conversion efficiency similar to the CdS.

II. RESEARCH METHODOLOGY

In this section, steps of the research procedure have been described. Initially, a material as suitable alternatives for CdS has selected to start the research work. Some preliminary value sets for the simulation parameters to have the optimum results. The impact on band alignment has investigated of different buffer layer so a suitable buffer layer can be selected. Among various single layers like ZnS, ZnSe, In2S2, ZnTe, SnO2; ZnSe shows a higher open circuit voltage and In2S2 shows higher short circuit current but overall conversion efficiency is still less then CdS. To solve the problem a combination of Znse/In2S2 has been proposed and it's optical and electrical properties are observed.

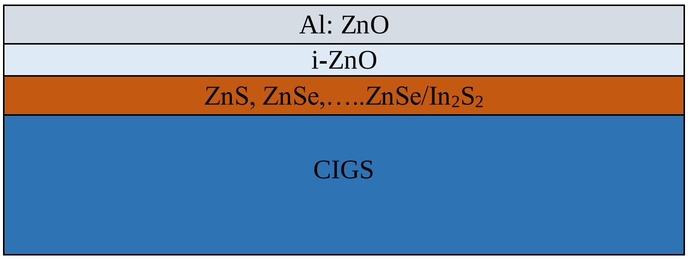

Fig. 1. Cell Structure of Proposed model

Fig.1 shows the structure for CIGS solar cell with different buffer layers. Table (1) shows the electrical and optical input parameters of different buffer layer which we use to find the comparative study to find the suitable buffer layer for CIGS based thin film solar cell instead of CdS. WxAMPS has been used to simulate the proposed model. As this software is very user-friendly and easy to use, there are many advantages to using this software. In this tool to make sure the refraction and absorption of light in all the layers and to find out the transmittance among the layers Transfer matrix method has been used, this tool also uses Band to Band Tunneling, Trap- Assisted Tunneling (TAT), Intra Band Tunneling to simulate properly.

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TABLE I. INPUT PARAMETERS FOR DIFFERENT BUFFER LAYERS

Parameters	Al: ZnO	i-ZnO	CdS
Permittivity	9	9	10
Eg (eV)	3.3	3.3	2.4
Affinity (eV)	4.4	4.4	4.2
Nc (cm^{-3})	2.20E+18	2.20E+18	2.20E+18
Nv (cm^{-3})	1.80E+19	1.80E+19	1.80E+19
Un (cm^2/v/s)	100	100	100
Up (cm^2/v/s)	25	30	30
Nd (cm^{-3})	1.00E+18	0	1.00E+18
Na (cm^{-3})	0	0	0

Parameters	ZnS	ZnSe	In2S2
Permittivity	10	10	13.5
Eg (eV)	3.5	2.9	2.8
Affinity (eV)	4.5	4.1	4.7
Nc (cm^{-3})	1.50E+18	1.50E+18	1.80E+19
Nv (cm^{-3})	1.80E+18	1.90E+19	4.00E+13
Un (cm^2/v/s)	50	50	400
Up (cm^2/v/s)	20	20	210
Nd (cm^{-3})	1.00E+17	5.50E+07	1.00E+18
Na (cm^{-3})	0	0	1.00E+01

Parameters	CIGS	ZnTe	SnO2
Permittivity	13.6	9.4	9
Eg (eV)	1.7	2.15	3.6
Affinity (eV)	4.5	3.25	4
Nc (cm^{-3})	2.20E+18	1.5E+18	1.5E+18
Nv (cm^{-3})	1.80E+19	1.90E+19	1.80E+19
Un (cm^2/v/s)	100	820	100
Up (cm^2/v/s)	30	40	30
Nd (cm^{-3})	0	1.00E+18	1.00E+18
Na (cm^{-3})	2.00E+16	0	0.00E+00

III. RESULTS

Our research result consists of three parts, first with CdS as buffer layer so we can have a reference standard to compare with, secondly with a single buffer layer which will represent single buffere as alternatives of CdS and finally proposed dual buffer layer. CdS as buffer layer in CIGS solar cell shows high conversion efficiency, that can be determined from fig.2(a), which shows the band diagram for CdS buffer layer.

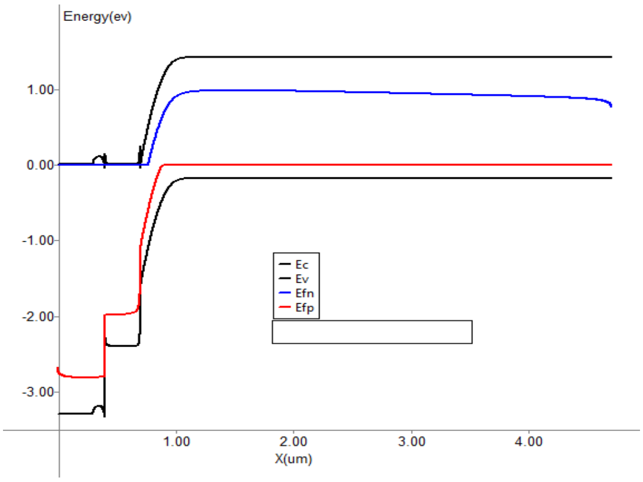

Fig. 2(a). Band Diagram for CdS

A uniform electric field is present in the band alignment which insure the separation of electron hole pair and lead to a high photo-conversion efficiency. As uniform band alignment solar spectrum will be absorbed within a thin layer. ZnSe has been tested as an alternative of CdS, but electric field for ZnSe does not show the uniform property as CdS as a results even with a high open circuit voltage conversion efficiency still way less than CdS. Fig.2(b) shows the band diagram for ZnSe which clear the flow of band alignment that leads to a weak electron hole pair separation power that couses lower efficiency.

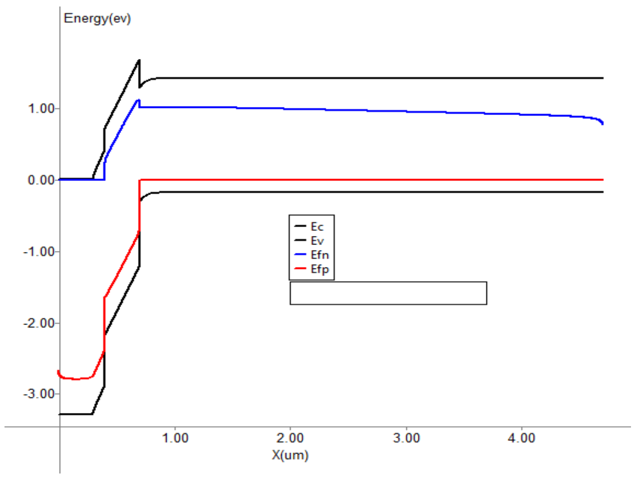

Fig. 2(b). Band Diagram for Znse

Finally, in fig.3 depicts the band alignment of proposed model of ZnSe-In_2S_2 has a uniform band alignment as a result it produces a strong electric field which ensure the separation of electron hole pair and reduce the rate of recombination may cause for due to weak electrical field.

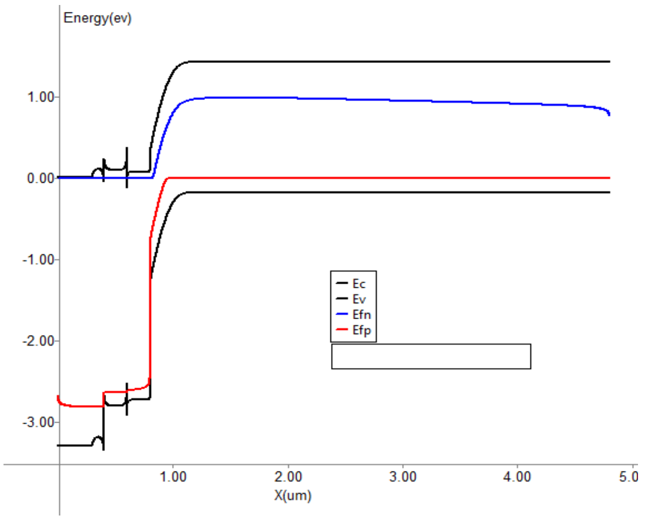

Fig. 3. Band Diagram for Proposed model

Fig.4(a) and fig.4(b) represent the comparative study of IV-vurve and the power vs voltage curve respectively for the different buffer layer including single and dable layers. ZnSe-In_2S_2 shows a promising result which have the almost same value I_{sc} and V_{oc} as CdStable(2), comparıng to the other single layers. Maximum power is also higher in proposed dual buffer layer among the tested layers. There is another possitive site of the proposed buffer layer is that the fill factor is lower than CdS (**77.14** % for proposed model and **80.51**% for CdS) which indicates that ther are more potential in ZnSe-In_2S_2 thanCdS and in future, a higher efficiency can be attained by increasing the I_{sc} and V_{oc} by increasing the fill factor with advance modeling.

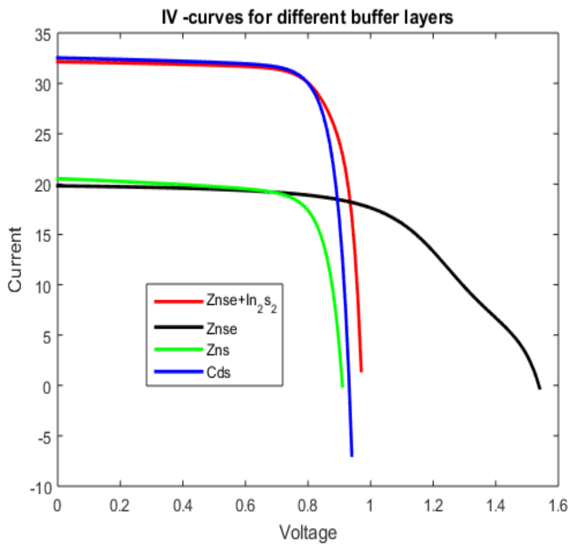

Fig. 4(a). Comparative Current vs Voltage curve

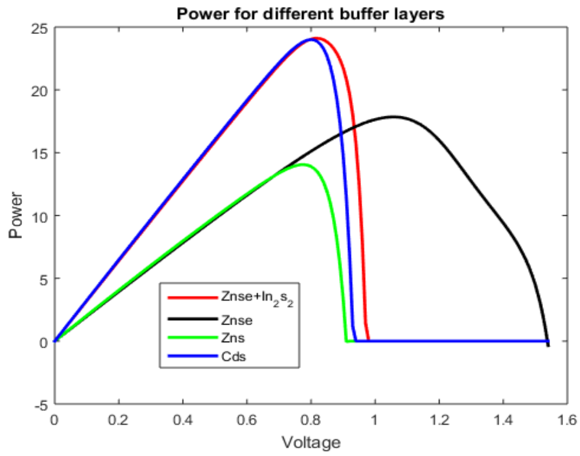

Fig. 4(b). Comparative Power vs Voltage curve

Summary of comparative results for different buffer layer along with CdS is discused in table (2), which included I_{sc}, V_{oc}, FF, and quantum efficiency. Similiar result in efficiency can be observed in both CDS and ZnSe-In_2S_2 and a lower value in fill facator for the proposed buffer layer as stated earlier.

TABLE II. COMPARATIVE RESULTS FOR DIFFERENT BUFFER LAYERS

Buffer layer	**Open circuit voltage (V)**	**Short circuit current (mA/cm^2)**	**Fill factor (%)**	**Efficiency (%)**
CdS	0.9316 V	32.52 mA/cm2	**80.51%**	**24.0015%**
ZnS	0.09099V	20.53 mA/cm2	75.017 %	14.04 %
ZnSe	1.537 V	19.82 mA/cm2	58.55 %	17.84 %
In_2S_2	0.9390 V	23.15 mA/cm2	74.65 %	13.22 %
ZnSe-In_2S_2	0.971 V	32.21 mA/cm2	**77.14%**	**24.1093%**

IV. CONCLUSION

A numerical and Graphical representation of CIGS cell structure has been investigated, which include ZnSe-In2S2 as dual buffer layers and pacify the problem of toxicity which occur for CdS in CIGS solar cell. Parameters gathering for materials was a challenge which has been fill-up from various journals and articles. An error may occur which has been estimated around ±5 due to some material value has been collected from different graphs and table which may not be perfectly accurate. Different buffer layers have been tested for finding the optimum results and observe that proposed dual buffer layers structure gives the almost same performance as CIGS with CdS layer. That drives to a conclusion that in future we can depend on these dual buffer layers as an alternative of toxic Cd based CdS in CIGS solar cell film until a new solution comes along. For future work, An antireflection coating will reduce the reflection hence increase the efficiency. A molybdenum substrate will

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increase durability and increase the barrier height for the dark current will reduce the recombination.

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