Investigation of ZnO thin film characteristics Fabricated as Buffer Layer for CIGS Thin-Film Solar Cell

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***Abstract*—In this study, investigation of the ZnO thin film characteristics deposited in between transparent conductive oxide and the CdS films layers in a CIGS solar cell (AZO/ZnO/CdS/CIGS/Mo),of various thicknesses have been deposited by the solution-based fabrication technique to get better performance of CIGS thin-film solar cells. The exchange efficiency of CIGS solar cell depends on ZnO thin film. There is significant work and progresses have seen in photovoltaic (PV) for alteration of solar energy into electrical energy and its storage. It had observed Shockley–Queisser (SQ) limit as a setback for the simple pn-junction solar cell. Though most of the practical solar cells suffer from band interface mismatch, energy defects, radiative, non-radiative recombination losses and so could not attain the SQ limit of 34% efficiency. While advances in modeling of materials and technological developments results into multiple junctions, intermediate band, photon up and down conversion (PUC) solar cells which have shown great potential to overcome the SQ limit and could achieve up to 88% efficiency. In this paper most of the contributing parameters of thin film solar cell has been emphasized.**

***Index Terms*—Thin-film, Photo Voltaic, Efficiency, Shockley–Queisser (SQ), Conduction Band Offset (CBO), CIGS solar cell.**

I. INTRODUCTION

II–VI semiconductor compound is ZnO having wide band gap around 3.3eV and having properties like high-quality precision, elevated electron mobility, and well-built room-temperature. ZnO has been considered outstanding to its admirable properties like optical, electrical, and structural, which be appropriate in favor of countless applications for eg. display panels,solar cells, and SAW devices. Aluminum doped ZnO thin film are utilize for window layers in $CuIn_XGa_{1-X}Se_2$(CIGS) solar cells. CIGS is a striking substance used for solution process thin film solar cell since its budding used for large-area and economical production. The fabrication of CIGS thin films have been established by a variety of approaches. The CIGS band gap energy controlled through unreliable the composition of Ga in the thin film. The CIGS solar cell optical and electrical properties has been studied by depositing ZnO film among the TCO film and CdS film recover the routine of CIGS thin film solar cell. The ZnO film protect the fundamental thin film CdS and CIGS film adjacent to break particles having high energies throughout the authentication dispensation for the Al-doped ZnO (AZO) film as attractive granule expansion. It avoid escape current in solar cell. In this revision, it has been investigated appropriate structural, electrical, and optical properties of ZnO thin film by means of dissimilar thicknesses of CIGS solar cells. The optimistic circumstances of ZnO thin film in between CdS and Al-doped ZnO film studied, and the association of the presentation parameter of CIGS thin-film solar cell by means of ZnO film depending on width has been considered, which definite the ZnO film width is the factors distressing the adaptation efficiency of CIGS solar cell.

II. EXPERIMENTALDETAILS

For synthesis of the CIGS nanoparticles, 0.6 moles of copper (II) chloride, 0.4 moles of Sodium tri acetoxyborohydride, Gallium nitrate,· 0.18 moles of Water of crystallization and selenium powder of 1.2 moles were mixed with ethyleneglycol and hydrazinemonohydrate 98%.The mixture be stimulated by ultrasonic generator intended for 3 hours by 110 C. The combination was centrifuged and washed through deionized irrigate quite a lot of times and dehydrated at room temperature. The result was isolated in hydrazine hydrate toward coating CIGS as absorber layer. later than the CIGS film deposition done using pin coating technique, the thin film was heated with Se powder below Ar into the heating system intended for 30 min under 500C. The CIGS is coated lying on the Mo coated soda lime glass with the thickness around 500nm and area was 2 cm×2 cm through a spin coating technique, after that the samples be dried out around 1 hour on 300C on the hot plate.The CIGS absorber film of around 9 µm-thickness has been deposited by spin-coating process larger than numerous samples. A CdS film of around 50 nm thickness has been deposited using chemical bath deposition technique, after that, ZnO thin film has been deposited through magnetron-sputtering organization. The migration strain of sputtering chamber was maintain about 1×10^{-5} torr using turbo molecular pump. To attain thin films of ZnO through dissimilar thickness,has been prepared on samples with changeable the deposition period. The complete investigational circumstances used by the study have revealed in Table I.

Table I. investigational Conditions.	
Target	ZnO (99.99%)
Target-substrate distance	50mm
Substrate temperature	RT
Working pressure	5×10^{-3}torr
R F power	100W
Film thickness	40,80,120nm

III. RESULTS AND DISCUSSION

Figure 1(a) represents the X-ray diffraction patterns of ZnO film for dissimilar thicknesses. As given in Fig 1(a), a ZnO film represents high-quality (002) superior orientation apart from the film thicknesses. At the preliminary authentication stage, nucleus with a variety of orientations has formed on the substrate. Every nucleus compete en route intended for develop except only those nuclei have the greatest rate for growth be able to remain and continue to exist.11,20 As ZnO films thickness has been increased, the concentration of peak 002 films are increased in totaling to the peaks become sharp suitable for enhanced crystalline of the films. Figure 1(b) shows the difference in ZnO film grain size. The grain size has compute throughout the full width at half maximum (FWHM) assessment according to Scherer's principle, 13 experimental to depend on thickness of the film. The result is reliable by means of other research paper.14, 15 Films with different thicknesses are create by changeable sputtering period. At the first deposition phase, there are many nuclei on substrate which produced tiny crystalline islands. as soon as the thin film has deposit for little point in time, this is over again produced tiny crystalline islands. When thin films have been deposited for a small period of time, the little crystallites cannot grow in to larger crystallites on the substrate. so, thin films must contain tiny crystallites as compared to thick thin films. Consequently, thin film crystallinity is enhanced with crystallite dimension become large through increasing thin film thickness.1415.Figure 2 represents FESEM images be in use to examine surface morphology of thin film ZnO among dissimilar thickness, that authenticate relationship in between grain size and thickness of ZnO thin film. This consequence shows the exterior plane of thin film having granular, grain size and morphology of the thin film having affinity to increase through thickness of thin film. The results are dependable by means of XRD results.

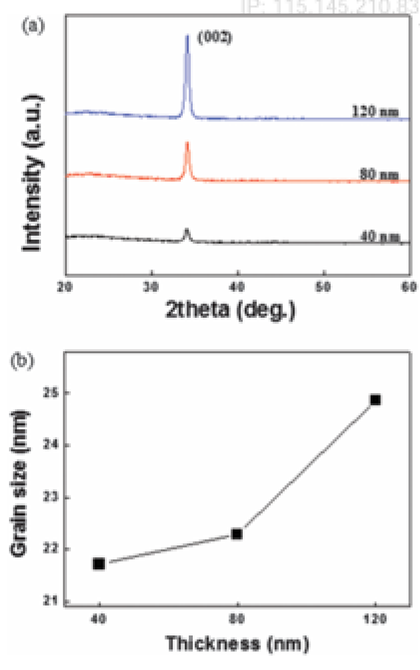

Figure 1.(a)Different patterns of ZnO films using X-ray diffraction for various thickness, (b)Variation pattern of grain sizes for different ZnO Thickness

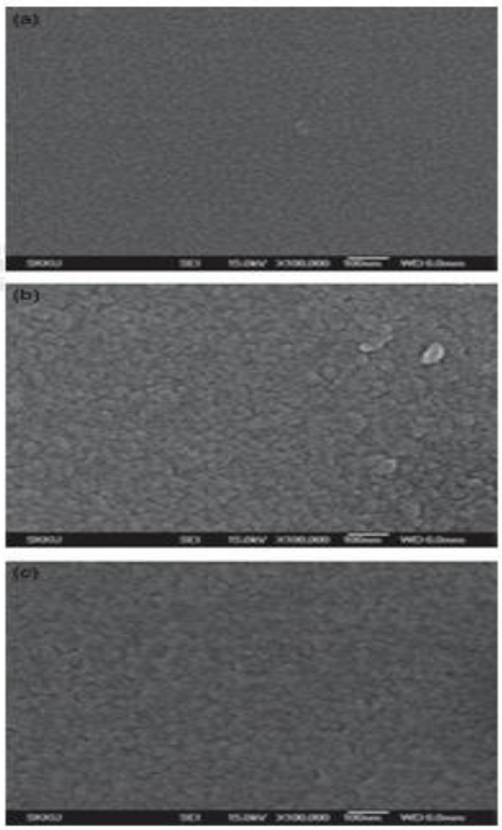

Figure 2. Surface morphology FESEM images for thicknesses of ZnO film (i) 40 nm, (ii) 80 nm, (iii) 120 nm

Thicknesses are established all the way through dimensions of carrier concentration, charge mobility, and thin film resistivity represented in Figure 3. The all samples have related carrier concentration, though, ZnO film thickness increase among the mobility. As given away in Figure 1.The thin film crystallinity and the grain size increases by way of thickness of ZnO film. This indicates the density of grain-boundary decreases through improved grain size for thin film. therefore, the crystallinity has been improved and decrease density of grain-boundary that increases the mobility due to concentrated diffusion by grain boundaries with increase in carrier lifetime.16,17 Figure3(b) show dissimilarity in resistivity through growing thickness of ZnO film. ZnO film thickness amplifies 40nm to 120 nm. Resistivity decrease starting 12.9 just before 3.04 Ω cm.The resistivity variation is appropriate to change in concentration of carrier with and thin film mobility. The resistivity depends on the carrier mobility and concentration as shown in the following formula, $\rho=1/(N\mu e)$,here ρ represents resistivity, carrier concentration represented by N, mobility is μ, and electron charge is e. The results disclose that resistivity thin films mostly exaggerated in the mobility fairly as compare to concentration of charge carriers since it is experiential as approximately invariable apart from of the thickness of film given in Figure 3(a).

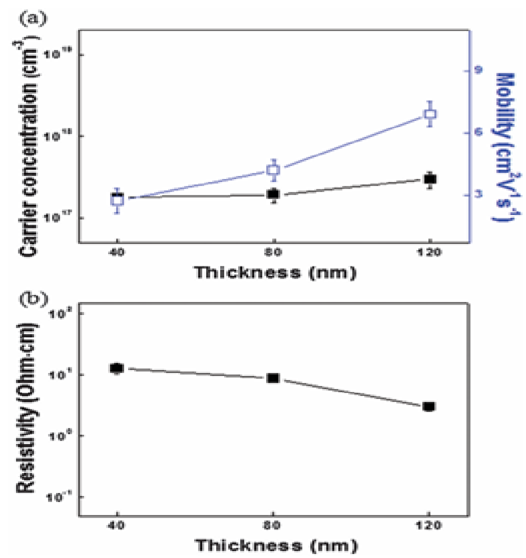

Figure 3. ZnO thin films for different thickness (a) Concentration of charge carriers with mobility (b) resistivity as function of thickness

Figure 4 and Table II represents the optical transmittance spectra with standard values of transmittance in visible region meant for ZnO film having changeable thickness of film. The standard transmittance of thin film is larger than 83%. During UV region, the inclusion of thin film experimentally increases by means of film thickness. The transmittance of ZnO film credited to change in grain size, thickness and carrier concentration1617.

Table II. The ZnO thin film standard transmittance of dissimilar thickness for 380 nm to 780 nm visible range.

ZnO film thickness (nm)	Transmittance (%)
40	80.55
80	81.80
120	83.50

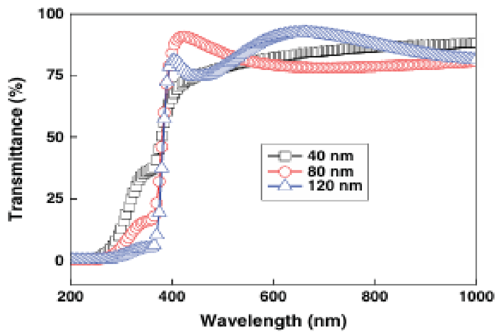

Figure 4. ZnO films Optical transmittance spectra

Surface morphology of the CIGS film deposited given in Figure 5, on top of substrate Mo/glass with nanocrystal based ink through solution-based development technique is tremendously irregular and having a lot of holes and crevice. CdS layer having thickness about 50 nm not completely wrap the CIGS surface layer. as a result,CIGS film crevices, are shaped previous to the electrode of AZO, for direct configuration of force trail cause straight contact sandwiched in between the layers of CIGS/Mo and AZO.

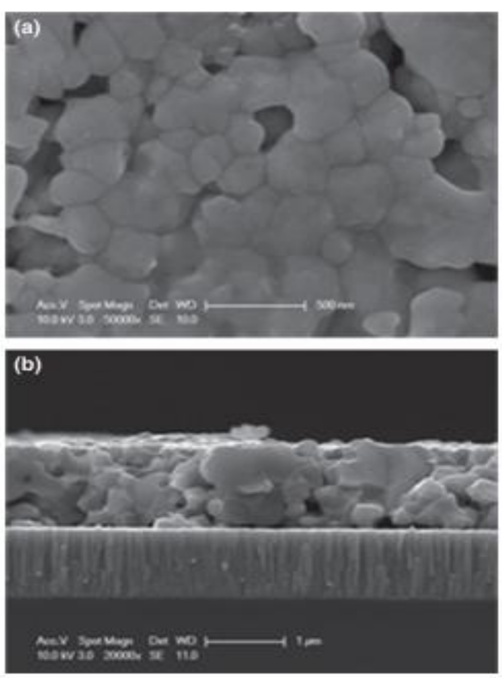

Figure5. FESEM images for CIGS thin film (a) per dynamic region exclusive of in the shade area surface morphology and (b) cross section morphology.

Table III. Performance parameters of thicknesses variation ZnO film CIGS solar cells.

Thickness	CE(%)	V_{OC}(V)	J_{SC}(mA/cm^2)	Fill Factor (%)
W/O ZnO	0.35	0.245	5.62	26.98
40 nm	0.41	0.249	6.29	26.60
80 nm	1.48	0.265	18.75	30.35
120 nm	1.29	0.268	17.09	28.29

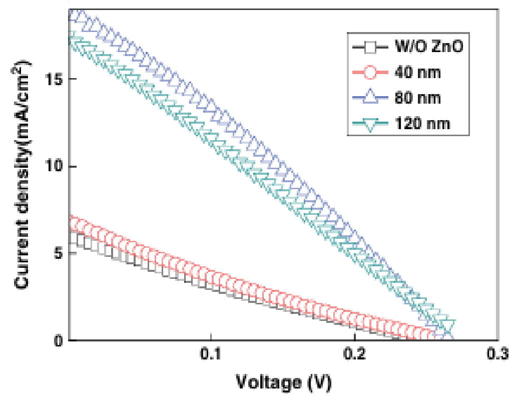

Figure 6. CIGS solar cells J–V characteristics for ZnO film thicknesses. The apparatus be scribed into miniature area strategy around 0.26cm^2 with alteration efficiencys

Normally, the CdS layer having thickness 50 nm deposit on uneven CIGS surface might be converted into non uniform leaving a little remote region somewhere CdS layer don't wrap CIGS surface. The affiliation among presentation with thickness of ZnO layer of CIGS solar cell given in Figure 6 with Table III., CIGS solar cell have obtained its maximum efficiency with ZnO film having thickness about 80 nm. J–V Characteristics shown in Figure 6 of CIGS solar cells ZnO film is greater than 40 nm, in this open-circuit voltage (Voc) become approximately steady. Dissimilarity, for thickness 80 nm, Voc decrease because of force path in solar cell. This consequence the direct drop a line among the CIGS and AZO layer ensuing large band gap change and as a result with hammering of open circuit voltage. Short-circuit current density (Jsc) increases as compare through without ZnO film and among ZnO film less than 80 nm since enhanced mobility and advanced transmittance with visible area. Short-circuit current density (Jsc) decrease evenly with decrease in thickness of ZnO film greater than 80 nm outstanding to chain resistance of film. CIGS solar cell analogous performance has been experiential and fill factor is exaggerated through series and parallel resistance. When ZnO film width improved up and about 80 nm, it amplified fill factor of the cell due to parallel path configuration is prohibited. on the other hand, the fill factor decrease evenly as thickness of ZnO film has greater than before 120 nm with increase in solar cell series resistance.

IV. CONCLUSION

The CIGS solar cell performance have been investigated with various thickness of the ZnO film. The ZnO films have studied various properties such as electrical and optical and structural that shows that thin film thickness affect solar cell efficiency and parameters. The crystallinity and grain size have improved with increased thickness of ZnO films. a variety of parameters of performance Open circuit voltage (Voc), the short-circuit current density (Jsc), and fill factor varies by dissimilar ZnO thickness of films. In this work the short-circuit current density (Jsc) largely depend lying on ZnO thickness. For ZnO thin film thickness 80 nm, solar cell maximum power adaptation efficiency has been achieve by Jsc 18.73 mA/cm2. The results indicate the result of shunt path created connecting CdS/CIGS and AZO concentrated through ZnO layer on CdS which is depend on thin film thickness.

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