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Various Metal Sandwich Layer Oriented Efficiency Enhancement Superiority on $CuInGaSe_2$ Thin Film Solar Cells*

R. Kabilan[1], R. Ravi[2#], A. Antony Christian Raja[3], T. Prem Kumar[4#]

[1]Department of Electronics and Communication Engineering, Francis Xavier Engineering College, Tirunelveli, Tamilnadu, India
[2]Department of Computer Science and Engineering, Francis Xavier Engineering College, Tirunelveli, Tamilnadu, India
[3]Department of Physics, Francis Xavier Engineering College, Tirunelveli, Tamilnadu, India
[4]Physics Department, S.N. College, Perungudi, Madurai, Tamilnadu, India
Email: #fxhodcse@gmail.com, #premphysics1@gmail.com

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Abstract

The good quality $CuInGaSe_2$ (CIGS) thin film solar cells were fabricated on molybdenum metal coated soda lime glass substrate. Three-stage co-evaporation method was utilized for the fabrication of high quality p-type CIGS thin film absorber layer. Further, n-type CdS layer, high resistive intrinsic ZnO layer and transparent conducting AlZnO layers were fabricated by CBD method and vacuum sputtering methods. We made three various top metal sandwich grid patterns, *i.e.* Al, Al/Cu and Cu/Al which were utilized to investigate the metal sandwich layer oriented efficiency enhancement superiority on $CuInGaSe_2$ thin film solar cells. The investigated specific CIGS solar cell device efficiency with respect to various top metal grid sandwich patterns is presented and discussed.

Keywords

CIGS Solar Cells, Metal Sandwich, Thin Film, Efficiency, CBD Method, Sputtering Method, Co-Evaporation Method, e-Beam Evaporation

1. Introduction

High energy photo conversion efficiency of $CuInGaSe_2$ (CIGS) solar cell devices has been largely issued so far. The CIGS devices have proved a superior laboratory scale power conversion efficiency $\eta > 19\%$ [1] [2] [3] [4] [5] and a successful installation of plant scale with megawatt level power conversion for the past

*All authors are equally contributed.
#Both Corresponding Authors are Equally Contributed.

decades [6] [7]. However, an in-depth research is still ongoing to reach the theoretical efficiency limitation using many ways, such as controlling the In and Ga ratio [8]-[14], suitable n-type buffer layer modifications [15] [16] [17] [18], metal grid thickness, p-type layer thickness modifications etc. Still CIGS solar cell based research and development is ongoing because of its high efficiency output even in large module level. The main advantage of CIGS thin film absorber layer is its larger granular size. More CIGS solar cell grains got agglomerated and it formed the micro meter size large CIGS thin film crystals at high temperature (over 400˚C). Top and bottom metal grid pattern also played very important role for efficiency enhancement, because more active charge carrier collection and all of outcome participated charge carriers successive recombination mainly depend on the chosen bottom and top metal grid pattern, so that in the present research work, we concentrated some different types of top metal sandwich grid pattern for the possible CIGS solar cell efficiency enhancement.

2. Experiment

Prior to deposition the Mo deposited soda lime glass substrates were cleaned using ultra pure water filled ultrasonic cleaner. Further the cleaned Mo substrate were dried in air atmosphere and further cleaned by Nitrogen gas. Then a good quality $CuInGaSe_2$ (CIGS) thin film solar cells were fabricated on Molybdenum (Mo) metal coated soda lime glass substrate using a well known three stage co-evaporation method. A 50 nm thick n-type Cadmium sulfide (n-CdS) layer was fabricated using Chemical bath deposition (CBD) method. Further a 50 nm thick high resistance intrinsic ZnO (i-ZnO) layer and transparent Aluminium doped ZnO (AlZnO) thin film layers were fabricated through high vacuum co-sputtering method under predetermined experimental conditions. For completing CIGS solar cell device a 1 μm thick three various metal grid patterns such as Al, Cu/Al and Al/Cu metal grid were fabricated. Except Al, Cu/Al and Al/Cu metal sandwich grid pattern all other thin film layers were fabricated with the help of previously reported literature. Top metal grid pattern were fabricated using electron beam evaporation method. The evaporation rates was fixed at 20 Å/Sec and at first the Cu metal crucible was melted after that Al metal crucible melted and then both crucibles cool down to get uniform molten state metal. The molten state metal reheated to make uniform evaporation throughout whole crucible. A well designed stainless steel mask pattern was utilized to get more CIGS solar cell active area. Our fabricated both Al metal grid, Cu/Al and Al/Cu metal grids are very thin and denser also relatively hard. Our metal and metal sandwich grid pattern strongly with stand even several times hard pin probing happened. For these three various metal sandwich depositions we utilized high thermal stable carbon crucible. The investigated results on
SLG/Mo/p-CIGS/n-CdS/i-ZnO/AlZnO/Al and
SLG/Mo/p-CIGS/n-CdS/i-ZnO/AlZnO/Cu/Al and
SLG/Mo/p-CIGS/n-CdS/i-ZnO/AlZnO/Al/Cu solar cell devices were presented

and discussed in the present work.

3. Results and Discussion

Figure 1(a)-(c) shows the complete CIGS solar cell structure with various top grid metal sandwich pattern. Here top Al metal grid pattern thickness is 1 µm and this solar cell efficiency was measured under 1 sun irradiation condition using 3A class Solar Simulator. Before solar cell measurement the 1 sun solar lamp radiation condition was standardized using both silicon and III-V standard reference solar cells. Our fabricated total mini lab module CIGS solar cell device area was 100 cm^2. Further CIGS solar cell isolated active area was 0.45 cm^2 and the total area of each isolated CIGS solar cell was 0.48 cm^2. CIGS solar cell active area of 0.45 cm^2 was taken for all the three measurement. Figure 2 shows the 1 µm Al metal grid pattern based CIGS solar cell current-voltage (I-V) output photo conversion efficiency curve. The measured open circuit voltage (Voc = 0.505 Volts), short circuit current density (Jsc = 35.5 mA/cm^2), Fill Factor (FF = 57.9) and photo conversion efficiency (η = 10.4%). Figure 3 shows the 200 nm Cu/800 nm Al metal sandwich grid pattern based CIGS solar cell current-voltage (I-V) output photo conversion efficiency curve. The measured open circuit voltage (Voc = 0.555 Volts), short circuit current density (Jsc = 35.6 mA/cm^2), Fill Factor (FF = 57.3) and photo conversion efficiency (η = 11.3%). Figure 4 shows the 200 nm Al/800nm Cu metal sandwich grid pattern based CIGS solar cell current-voltage (I-V) measurement output and photo conversion efficiency curve. The measured open circuit voltage (Voc = 0.555 Volts), short circuit current density (Jsc = 37.2 mA/cm^2), Fill Factor (FF = 60.7) and photo conversion efficiency (η = 12.5%).

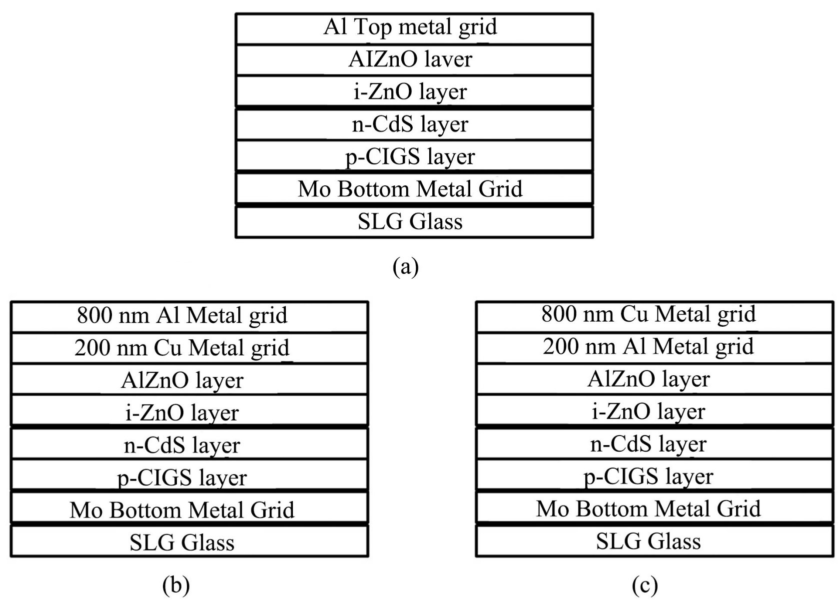

Figure 1. (a) (b) (c) the complete CIGS solar cell structure with various top grid metal sandwich patterns.

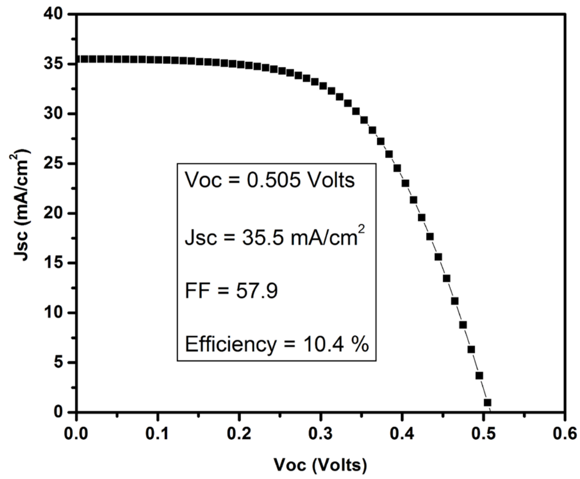

Figure 2. The 1 µm Al metal grid pattern based CIGS solar cell current-voltage (I-V) output photo conversion efficiency curve.

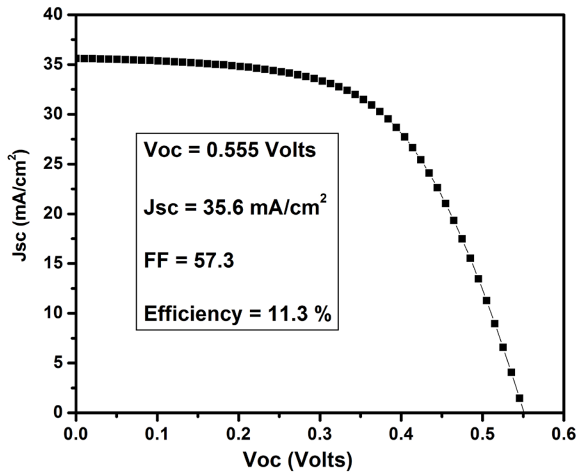

Figure 3. The 200 nm Cu/800nm Al metal sandwich grid pattern based CIGS solar cell current-voltage (I-V) output photo conversion efficiency curve.

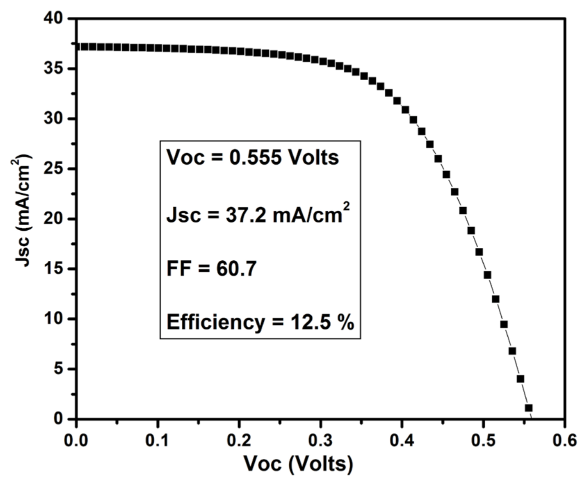

Figure 4. The 200 nm Al/800nm Cu metal sandwich grid pattern based CIGS solar cell current-voltage (I-V) measurement output and photo conversion efficiency curve.

4. Conclusion

We compared the three various top metal grid sandwich based CIGS solar cell and one can easily understand the 200 nm Cu/800nm Al showed 1.5% more efficiency than other two top metal grid pattern based CIGS solar cells device. This 1.5% efficiency improvement is reasonable result for continuing various metal sandwich grid pattern based CIGS, CZTS and other thin film based solar cells device research and development.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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