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POWER CONVERSION EFFICIENCY IN THIN FILM SOLAR CELL: A REVIEW

HO SOONMIN[*]

Centre for Green Chemistry and Applied Chemistry, Faculty of Science, Technology, Engineering and Mathematics, INTI International University, PUTRA NILAI, 71800, MALAYSIA

ABSTRACT

This review paper describes the preparation of thin films using various deposition methods such as vacuum based method and solution based deposition technique. The obtained thin films could be applied in solar cell due to many advantages including direct band gap between 1-2 eV and high absorption coefficient value. In this work, the construction and performance behaviors of solar cell were fabricated and discussed.

Key words: Thin films, Dye sensitized solar cells, Semiconductor, Band gap, Power conversion efficiency.

INTRODUCTION

Solar cell is an electrical device that can use sunlight to produce electricity. As we know that, the thin film solar cell has been more economical[1-5] than first generation conventional crystalline silicon technology. Additionally, they display many advantages including flexible, lower in weight and have less drag. This type of solar cell is grouped into second generation photovoltaic cells and generally the thickness of the films varies from nanometer to micrometers.

Up-to-date, thin films have been prepared using various deposition techniques as reported by many researchers. Generally, we could obtain high power conversion efficiency for the films prepared using expensive vacuum based deposition method. However, in order to lower the cost of solar cell fabrication, the solution-based deposition method was selected to prepare absorber materials. In this work, power conversion efficiency of fabricated solar

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[*]Author for correspondence; E-mail: soonmin.ho@newinti.edu.my; Ph.: + 6067982000

cell was tested and discussed. This test is defined as the ratio of power produced by the fabricated solar cell to the incident sunlight energy into the cell per time.

Literature survey

Potlog et al.[6] presented the photovoltaic characteristics of ZnSe/CdTe, CdS/CdTe/ and ZnTe/CdTe thin films heterojunction solar cell. These cells were produced by close space sublimation on transparent conductive oxide-coated glass. The test was carried out at the room temperature under illumination of 100 mW/cm^2. The results indicate the conversion efficient about 4.7%, 9.9% and 1.3% for ZnSe/CdTe, CdS/CdTe/ and ZnTe/CdTe thin films heterojunction solar cell, respectively.

Ayaka et al.[7] reported the Cu_2SnS_3 films using co-evaporation deposition technique and under annealing process. Then, solar cells were fabricated and efficiency was evaluated under various copper to tin compositional ratios. They found that the films prepared with a slightly tin rich composition show the largest grain size as indicated in scanning electron microscopy analysis. Lastly, they claim that power conversion efficiency of 4.29% could be obtained in the solar cell fabricated with Cu/Sn ratios of 1.87.

The influence of film thickness on the performance of copper indium gallium selenide (CIGS) solar cell was studied by Shamim et al.[8] They conclude that the efficiency is increasing with the thickness of absorber layer. Furthermore, they explain that the as the thickness increases, the recombination probability of the photon generated carriers with back contact is reduced. The efficiency of 19.75% for ZnO: Al/i-ZnO/CdS/CIGS based thin films solar cells have been observed in their research results. On the other hand, Walker et al.[9] prepared copper indium gallium diselenium using vacuum deposition technique. They point out that efficiency of films is low in the absence of secondary copper selenide phase. Meanwhile, the production of 4.3% total area power conversion efficiency was obtained in the presence of cupric selenide nanoparticles.

The Cu_2S and CdS films were synthesized using spin coating technique by Rohit[10]. The UV-Visible spectroscopy measurements were investigated to find the band gap value for Cu_2S (2.65 eV) and CdS (4.4 eV), respectively. Lastly, he revealed that the efficiency of thin films approached around 10.9%.

Many researchers find that there are some problems happened in cadmium telluride thin films such as stability and degradation in efficiency. Wagah et al.[11] described the preparation of cadmium sulfide and cadmium telluride thin films using thermal evaporation method. Following that, CdS/CdTe solar cell was designed and tested. In their experiment, they reported that the tunnel diode of CdTe/CdS was deposited in the back of the cell, finally energy conversion efficiency was improved by more than 7%.

Tin sulphide thin films can absorb visible light strongly and they have potential to be good absorber materials. Jaramillo et al.[12] have demonstrated new certified record power conversion efficiencies of 4.36 % and 3.88% by using atomic layer deposition and thermal evaporation method, respectively.

Zinc sulfide thin films were prepared from the chemical bath contained $ZnSO_4$, thiourea and ammonia as reported by Ji et al.[13] The photovoltaic behaviors of the AZO/ZnS/textured p-Si heterojunction solar cells were investigated under different annealing temperatures ranging from 150 to 300°C. They suggest that the best annealing temperature was 250°C. The power conversion efficiency improved from 0.89% to 3.66% as the annealing temperature was increased from 150 to 250°C.

The ITO/$CuInS_2$/Al_2O_3/$(CH_3NH_3)PbI_3$/Ag solar cell was fabricated for the first time by Chen et al.[14] The influence of the thickness of $CuInS_2$ films on the solar cell was studied. They reveal that too thick $CuInS_2$ films decrease the amount of light absorbed by the $(CH_3NH_3)PbI_3$ films. As results, degradation of short circuit current density (J_{sc}) and fill factor values could be observed. In the other case, the obtain films indicate the incident photon-to-electron conversion efficiency (IPCE) spectra response in the almost entire wavelength region from 370 to 1000 nm. Lastly, they claim that an optimum power conversion efficiency of up to 5.3% could be reached as shown in their experiment.

Goto et al.[15] analyzed the TCO/CdS/$CuinS_2$/$CuGaS_2$ thin films solar cell in their experiment. Firstly, the Ga-Cu stacked precursor layer with a copper to indium ratio of 1. Secondly, 240 nm films were vacuum evaporated onto Molybdenum coated soda lime glass substrate. Thirdly, the films were sulfurized in an argon and hydrogen sulfide mixture gas at 530°C. In the next step, $CuGaS_2$ layer was treated in KCN solution. The Cu-In stacked precursor layer was deposited on this surface. Finally, 13% efficiency cell was observed in their results.

Cu_2ZnSnS_4 thin films solar cells with 8.4% power conversion efficiency were successfully prepared using thermal evaporation by Shin et al.[16] In their experiment, 600 nm film was deposited at 150°C and subsequent short (5 mins), but high temperature (570°C). They are proud to announce that these are the highest efficiencies reported for the Cu_2ZnSnS_4 absorber using any deposition method. On the other hand, many scientists have successfully designed thin films solar cell according to their experiment results. The power conversion efficiency of these films are listed in Table 1.

Table 1: Power conversion efficiency for Cu_2ZnSnS_4 thin film solar cells

Researcher (s)	Power conversion efficiency (%)
Kazuo et al.[17]	5.74
Hironori et al.[18]	2.62
Wang et al.[19]	6.8
Schubert et al.[20]	4.1
Chet et al.[21]	0.23
Jonathan et al.[22]	3.2
Ennaoui et al.[23]	3.4
Sawanta et al.[24]	0.396
Tsukasa et al.[25]	6.03
Shinde et al.[26]	0.12

Currently, many scientists reported the preparation and characterization of binary and ternary thin films (Table 2) in solar cell application in their research findings.

Table 2: Binary and ternary chalcogenide thin films

Binary chalcogenide thin films
Zinc sulfide[27]
Bismuth sulfide[28]
Zinc selenide[29]
Indium sulfide[30]
Copper sulfide[31]

Cont…

Binary chalcogenide thin films
Cadmium sulfide[32]
Lead selenide[33]
Antimony sulfide[34]
Tin sulfide[35]
Lead sulphide[36]
Nickel sulfide[37]
Manganese sulfide[38]
Iron sulfide[39]
Ternary chalcogenide thin films
$Zn_xCd_{1-x}S$[40]
Cu_4SnS_4[41]
$ZnIn_2Se_4$[42]
$CuInSe_2$[43]
SbCuS[44]
$Ni_3Pb_2S_2$[45]
(Cd,Bi)S[46]
$Pb_{1-x}Fe_xS$[47]
$Pb_{1-x}Mn_xS$[48]
CdZnSe[49]
$AgInS_2$[50]

The general properties of thin films have been reported in published articles. The main drawback of thin film solar cells is lower power conversion efficiency. Because of these films are poorly crystalline, leading to poor charge carrier transport. Therefore, researchers suggest that device efficiencies of 3% are too low for commercialization and need to be improved.

CONCLUSION

Thin films have been prepared using expensive vacuum based method or cheaper solution based deposition technique. There are various chalcogenide thin films are being examined in order to produce good absorber materials in solar cell devices with very low production cost. In future, research and development have been carried out intensively in order to enhance power conversion efficiency of solar cell.

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