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A Review of Chalcogenide Thin Films for Solar Cell Applications

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Abstract

In this work, authors review the current state of research in chalcogenide thin films in order to study the use of films for the fabrication of cost-effective solar cells. As far as we know, various techniques have been employed to prepare thin films such as electro deposition, chemical bath deposition, flash evaporation, spray pyrolysis, successive ionic layer adsorption and reaction and so on. The obtained films showed that the band gap values are ranged from one to two eV which match to solar spectrum.

Keywords: Band Gap, Chemical Bath Deposition, Electro Deposition, Solar Cells, Thin Films

1. Introduction

The productions of various thin films have been studied for many years. This is due to the properties of these materials are suitable for application in solar cell, corrosion resistant coating, microelectronics, optics, magnetic, laser devices and gas sensor devices. Currently, the most used deposition methods to prepare these films are chemical bath deposition[1–15], electro deposition[16–23], flash evaporation[24–28], spray pyrolysis[29–31], successive ionic layer adsorption and reaction, magnetron sputtering[35–37], Metal organic chemical vapor deposition[38,39]. Keep in mind that all these deposition methods have advantages and disadvantages depending on the type of application intended for the films.

Nowadays, much effort has been made by many researchers to investigate the properties of thin films under various deposition conditions. Researchers work hard to control the size, morphology and crystallinity of the films in order to produce high quality thin films. In this review paper, we have focused only on two favorable properties which are used in solar cell such as band gap and power conversion efficiencies.

2. Results and Discussion

In last decades, the study of thin films has increased intensively because of the raw material can be obtained easily, cheaper and abundant. Generally, there are various thin films are considered as potential candidates for absorber materials of solar cells. It is because of band gap energy range of 1.0 to 2.0 eV (Table 1), high absorption coefficient and successfully produce uniform layer so that they can efficiently absorb light on almost any surface.

At present, most of the authors have reported the preparation and optimization of the thin films by using various physical and chemical deposition methods. Generally, thin films have been grown on the substrates from aqueous solutions. Following that, the obtained films were characterized using AFM, XRD, SEM, UV-Visible spectrophotometer, EDAX in terms of study the morphology, composition, structure, optical and electrical conductivity. Authors claimed that they can produce good quality

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Table 1. Band gap energy of various thin films

Thin films	Band gap	Reference
SnSe	1.25	Zainal et al.[40]
SnS	1.0	Hankare et al.[41]
PbSe	1-1.3	Okereke and Ekpunobi[42]
PbS	1.8	Oriaku and Osuwa[43]
NiSe	1.61	Hankare et al.[44]
CoS	1.13	Mane et al.[45]
CdSe	1.8	Gopakumar et al.[46]
CdTe	1.45	Laxman et al.[47]
Sb_2S_3	1.78	Nair et al.[48]
CdZnSe	1.7-2.3	Deo et al.[49]
PbMnS	1.5	Joshi et al.[50]
Ag-In-S	1.82	Lin et al.[51]
$Hg_xCd_{1-x}S$	1.76	Deshmukh et al.[52]
CdMnS	1.45-1.65	Oriaku et al.[53]
$CuInSe_2$	1.04	Bari et al.[54]
Ag_8SnS_6	1.28-1.39	Yeh and Cheng[55]
Cu_2ZnSnS_4	1.5	Subramaniam et al.[56]
Cu_2ZnSnS_4	1.55	Shinde et al.[57]
Cu_2ZnSnS_4	1.6	Kumar et al.[58]
Ag_2ZnSnS_4	1.2	Yeh and Cheng[55]

of thin films in the optimized experimental conditions for the solar cell applications but unfortunately, did not indicate the power conversion efficiency to readers. In other words, the power conversion efficiencies should be reported in their research findings and their paper as well before can be used in solar cells. Some examples are shown below.

Song and Lee prepared ZnxCd1-xS films using chemical bath deposition. The research findings indicated that the band gap and the pH of the solution decrease with increasing concentration of zinc acetate. $Cd_{0.5}Zn_{0.5}Se$ thin films were prepared by Kale et al. (2007) using chemical bath deposition method from aqueous solutions. The band gap and electrical resistivity were 2.35 eV and $10^7 \Omega$cm, respectively. The obtained films consisted of smaller and bigger particles because of the mixture of cubic and hexagonal CdSe and ZnSe phases as shown in XRD and AFM results.

The cadmium sulfide thin films grown at 80°C by chemical bath deposition method and electro deposition indicate poor crystallinity in XRD and SEM studies by Ileperuma et al. In addition, these films are n-type and the band gap values are close to 2.4 eV. Fernandez and Merino have reported for the first time the preparation of Sb-Se by electro deposition technique. They have successfully pointed out that the best conditions to produce

Sb_2Se_3 are using 0.04 M selenous acid and 0.1 M potassium antimonyl tartrate with a potential of -0.8 V for thirty five mi of deposition.

A study of the growth of $CuInS_2$ thin films by using electrodeposition method has been carried out by Asenjo et al. (2006). XRD studies revealed that $CuInS_2$ phase predominant for films after annealing at 200°C in nitrogen atmosphere. However, X-ray photoelectron spectroscopy indicated that the presence of $CuInS_2$ in their samples together with secondary phases such as In_2S_3, CuO/CuS and Cu_2O/Cu_2S compositions.

Cathodic electrodeposition in the presence of ethylenediaminetetraacetate as a chelating agent was used to prepare Cu_2S films deposited on titanium substrate by Anuar et al. (2002). The obtained results indicated that the films prepared are of p-type. Furthermore, the films prepared at -0.4 and -0.5 V have better photosensitivity. Electrodeposited cadmium indium telluride films have direct band gap of 1.1 eV and indicate cubic phase in XRD study by Kiran Jain (2003). According to SEM results, the films prepared at -0.54V show smooth and uniform surfaces with pinhole free appearance.

Todorov et al. (2006) have reported an atmospheric pressure deposition technique for preparing $CuInS_2$ films. The precursor films are obtained by a solution coating technique and then, are subjected to sulfurization treatment in their experiments. The sulfurized films are dense and adhered to the substrate based on SEM studies.

There are only a few reports of solar cell efficacy. Table 2 lists the original work that describe various thin films were prepared using different deposition methods for the accuracy measurement of solar cell efficiencies.

As shown in Table 2, the power conversion efficiencies for the various types of thin films are below 7%. We understand that the variable values are due to the several reasons such as deposition methods, the nature of precursors, growth conditions and deposition parameters. For example, the films grown at lower bath temperature may provide good conversion efficiencies if the post deposition treatment. Because of improve crystallinity of sample after surface treatment. In addition, these films seem to provide benefit for the compactness of the absorber layer, which would be preferentially for the smaller film thicknesses by avoiding pin holes.

Table 2. Power conversion efficacy for various thin films

Thin films	%	Method	Reference
$CdSe_{0.6}Te_{0.4}$	0.43	Chemical bath deposition	Shinde et al.[59]
$CdSe_{0.6}Te_{0.4}$	0.64	Electrodeposition	Shinde et al.[60]
SnS	1.3	Spray pyrolysis	Ramakrishna Reddy et al.[61]
$CdIn_2S_4$	2.94	electrodeposition	Kokate et al.[62]
CdS	0.06	Chemical bath deposition	Patil et al.[63]
CdTe	0.136	Chemical bath deposition	Patil et al.[63]
$CdS_{0.5}Te_{0.5}$	0.023	Chemical bath deposition	Patil et al.[63]
$MoBi_2Se_5$	0.281	arrested precipitation technique	Mane et al.[64]
$ZnS_{0.5}Se_{0.5}$	1.6	Close spaced evaporation	Subbaiah et al.[65]
$CuInSe_2$	3.1	Chemical bath deposition	Vidyadharan Pillai and Vijayakumar[66]
$SnS_{0.5}Se_{0.5}$	Less than 1	electrodeposition	Subramanian et al.[67]
$CuInS_2$	2.4	Photoelectrochemical & electrochemical anodic method	Berenguier and Lewerenz[68]

3. Conclusion

This review article pointed out those thin films could be used as lows-cost solar cells. Currently, several binary, ternary and quaternary thin films are studied for their potential for solar cell applications. The performance of thin films solar cells depend on the morphology, band gap and structure of films. In future works, more research activities should focus to how to improve the power conversion efficiency in chalcogenide thin films solar cells.

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