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REVIEW

A Review on Thin Films on Indium Tin Oxide Coated Glass Substrate

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Preparation and characterization of thin films on indium tin oxide were carried out by many researchers using chemical bath deposition and electro deposition technique. Thin films formation was confirmed by X-ray diffractometer. Meanwhile, compositional, morphological and optical properties of films were studied by means of energy dispersive X-ray, scanning electron microcopy, atomic force microscopy and UV-visible spectrophotometer, respectively.

Keywords: Thin film, Chemical bath deposition, Solar cells, Electro deposition.

INTRODUCTION

Indium tin oxide coated glass (ITO) is a very clear and transparent glass. It is an example of ternary compound and consists of a mixture of indium(III) oxide and tin oxide. It has been prepared using various techniques such as sputtering deposition, physical vapour deposition and electron beam evaporation. This compound has a good response time to conduct electricity and could be easily deposited as thin films. Currently, it is widely used in solar cells, plasma, electroluminescent, electro chromatic displays, touchscreen devices, flat panel TV, liquid crystal display and organic light emitting diode.

In this work, a critical analysis was done in order to prepare various types of thin films on indium tin oxide coated glass glass by chemical bath deposition (CBD) and electro deposition method. The obtained films were characterized using X-ray diffractometer (XRD), energy dispersive X-ray (EDX), scanning electron microcopy (SEM), atomic force microscopy (AFM) and UV-visible spectrophotometer.

The chemical bath deposition and electro deposition method have been recognized as the effective deposition methods for the production of the various types of thin films on the different types of substrates such as indium tin oxide coated glass or other metal plate. These techniques have many advantages such as low cost, low temperature process and simplicity. In these deposition techniques, the various properties such as grain size, film thickness, band gap, morphology, structure and optical properties can be controlled easily by the various deposition conditions.

Salazar *et al*. [1] have reported the preparation of chemical bath deposited CdS on indium tin oxide coated glass agitated by means of an electric tooth brush and their comparison under different conditions of agitation. They obtained films with a slow and constant rate deposition by oscillating only the substrate at 37 Hz during the experiment. Moreover, the chemical bath does not present colloidal precipitates after deposition, producing clean CdS films. Klochko *et al*. [2] have developed the synthesis route of CdS films using chemical bath deposition and continuously agitated by magnetic stirrer. In XRD studies, the impurity such as cadmium cyanamide phase and cadmium oxide appeared for the as-deposited film and annealed films, respectively. The influence of deposition time on the properties of chemical bath deposited CdS films was reported by Ordaz-Flores *et al*. [3]. They have found that the film thickness was increased from 7.5 to 13.7 nm as the deposition was increased from 20 to 50 min. The use of electro deposition method for the production of CdS films at 90 °C has been investigated by Dennison [4]. The obtained research findings reveal that an increase in film thickness as the pH decreases. Furthermore, lower pH value also promotes a low potential process which interferes with both controlled potential and controlled current CdS growth. Sisman *et al*. [5] studied the influence of deposition time on the absorption spectra of the electro deposited CdS films. They found that the absorption edges around 465 nm become more pronounced and shift to lower energy with increasing deposition time.

Chemical bath deposition of ZnS films has been investigated by Yamaguchi *et al*. [6] in the temperature range from

50 to 90 °C. They report that there is a continuous increase of the amount of the precipitate with bath temperature; meanwhile the rate of precipitation slowly decreases. The deposition of ZnS films from zinc nitrate solution was reported by Antony *et al*. [7] in the pH range from 10 to 10.6. They reveal that the obtained films have been found to possess a higher band gap, better transparency and surface morphology if compared to those prepared from zinc chloride solution. On the other hand, the structure and morphology of electrodeposited ZnS films were investigated by Kassim *et al*. [8]. As shown in AFM images, the grain size reduces as the potential becomes more negative. In the XRD studies, the number of ZnS peaks increased as the deposition time was increased from 15 to 30 min.

Chemical bath deposited indium sulphide films have demonstrated their potential to be used as absorber materials in solar cell application. Asenjo *et al*. [9] proposed that electronic properties of the In_2S_3 films are controlled by shallow tail states and a broad band centered at 1.5 eV. In_2S_3 films have been deposited using chemical bath deposition method onto glass and indium tin oxide coated glass substrates by Bansode *et al*. [10]. In the optical properties, the band gap value of 2.32-2.29 eV for the films deposited on indium tin oxide coated glass glass is less than the band gap value of 2.4-2.79 eV for the films deposited on glass. This is because of the porosity of surface morphology of indium sulfide films deposited on glass substrate.

The surface morphology of CuS films were investigated using AFM by Sangamesha *et al*. [11]. It is observed that the films are uniform and consist of spherical nano sizes particles which are well adhered to the substrate. The influence of deposition time on the properties of chemical bath deposited CuS films were reported by Anuar *et al*. [12]. In XRD studies, the number of peaks attributed to CuS increased as the deposition time was increased to 16 h. However, the band gap value was decreased from 2.9 to 2.45 eV as the deposition time was increased as shown in optical study.

Tin sulfide (SnS) films were electrodeposited on indium tin oxide coated glass substrate from aqueous solutions by Cheng *et al*. [13] under various experimental conditions such as bath temperature (30-50 °C), deposition potential (-0.7 to -1.1 V *versus* saturated calomel electrode) and EDTA concentration. They claim that, increase of the bath temperature improved the crystallinity of the films and made the band gap become smaller (from 1.48 to 1.24 eV). The electrodeposited SnS thin films at the potential of -0.95 V and -1 V were polycrystalline with orthorhombic structure and the Sn/S ratio was nearly 1:1 [14]. They also conclude that there is only SnS phase present in the films when the EDTA/Sn^{2+} is 1/1, mean-while, Sn_2S_3 phase could be observed when the EDTA/Sn^{2+} is less than 0.5 as indicated in X-ray photoelectron spectroscopy analysis [15].

Cadmium selemide (CdSe) films are well known as II-VI compound semiconductor, have been electrodeposited on indium tin oxide coated glass substrate by Shen *et al*. [16]. In EDX studies, nearly stoichiometric CdSe films with smaller size were obtained for the films deposited at potential of -0.7V if compared to other deposition potentials such as -0.65, -0.71 and -0.72 V *versus* saturated calomel electrode. The AFM and SEM analysis indicated that these films were smooth, compact and uniform. On the other hand, the effects of pH on the structure and morphology of CdSe films were also discussed by them. Atomic force microscopy images indicated that the films were uniform with grain sizes ranging from 80-150 nm in different pH solutions [17]. Thin films of electro deposited CdSe various sizes ranged from 7 to 8 nm have been prepared by Sarangi and Sahu [18]. The crystalline sizes were controlled by varying the current density and temperature of the solution.

The electrochemistry of electrodeposited $CuInSe_2$ films was investigated by Whang *et al*. [19]. The quality of films could be improved when the concentration of complexing agent less than 0.1 M. As shown in XRD patterns, the crystalline signals were less strong when then concentration of triethanol-amine more than 0.1 M. The effect of adding benzotriazole (BTA) as a complexing agent was studied by Beyhan *et al*. [20]. A smooth film formation with a good stoichiometry obtained under -0.55V *versus* SCE at pH 3 with 1 mM benzotriazole. However, the surface composition of the films prepared in the absence of benzotriazole was far from the preferred values. The $CuInSe_2$ films were deposited under various deposition times such as 5, 10, 15 and 20 min by Meglali *et al*. [21]. The XRD patterns indicate that the films prepared at 20 min present $CuInSe_2$ single phase. Whereas, the films prepared at other deposition times show the present of In_2Se_3 as secondary phase.

Nowadays, Cu_2ZnSnS_4 (CZTS) thin films are considered as promising materials for solar cells applications on a terra-watt scale. It is due to these materials have band gap energies ranging from 1 to 1.5 eV and also high absorption coefficient (more than 10000 cm^{-1}). Solar cells based on chemical bath deposited Cu_2ZnSnS_4 have been reported by Subramaniam *et al*. [22]. The power conversion efficiency is 1.34 % and the band gap obtained is 1.5 eV. CZTS films were obtained by electro deposition method by Jafarov *et al*. [23] at room temperature from a salt bath. The films were behaved as p-type semiconductor with band gap of 2 eV as shown in photoelectro-chemical characterization.

The biggest problem about indium tin oxide is the cost. Indium tin oxide coated glass is expensive because of the shortage of indium. As we know, indium is a rare mineral and much of the indium mineral reservations are located in China. In addition, China controls the exporting and marketing demand of this material due to the indium unique properties make it a critical component for many products. Therefore, researchers are looking for other substrates in order to replace indium tin oxide coated glass in their research activities. In recent times, there have been several substrates adopted for thin film deposition (Table-1) such as fluorine doped tin oxide, quartz, stainless steel, molybdenum soda lime glass, titanium, tin oxide and microscopy glass slide.

Conclusion

This paper reviews recent articles published in the subject of various thin films deposited onto indium tin oxide glass using chemical bath deposition and electro deposition method. The interests and challenges of the indium tin oxide glass were addressed by many researchers. Currently, more and more scientists work on the other substrates such as titanium, quartz, stainless steel, tin oxide, soda lime glass and fluorine doped tin oxide.

TABLE-1
VARIOUS SUBSTRATES USED FOR THE PREPARATION OF DIFFERENT THIN FILMS

Thin films	Ref.
Fluorine doped tin oxide	
Cd-Se-Te	[24]
ZnCuTe	[25]
Cd-In-Te	[26]
$FeSe_2$	[27]
MnS	[28]
ZnTe	[29]
Quartz	
(Cd,Zn)S	[30]
ZnS	[31]
CdS	[32]
Stainless steel	
$CdS_{1-x}Te_x$	[33]
CdSe	[34]
ZnSe	[35]
Cu-In-S	[36]
Molybdenum soda lime glass	
$CuInSe_2$	[37]
CdS	[38,39]
$CuInSe_2$	[40]
ZnS	[41]
Titanium	
$CdIn_2Se_4$	[42]
SnSe	[43]
CdTe	[44,45]
ZnSe	[46]
$CdSe_xTe_{1-x}$	[47]
Tin oxide	
$CuInS_2$	[48]
SnSe	[49]
ZnSe	[50]
CdZnTe	[51]
Microscopy glass slide	
CdSSe	[52]
CdS	[53-55]
ZnS	[56-58]
SnS	[59,60]
PbS	[61-64]
$Cd_{0.6}Hg_{0.4}Se$	[65]
FeS_2	[66]
$Ni_3Pb_2S_2$	[67]
$MgCdS_2$	[68]
NiSe	[69]
PbSe	[70]
NiS	[71]
Cu_2S	[72]

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