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Thermal Evaporation of Thin Films: Review

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Abstract: This work reviews recent articles published on the subject of thermally evaporated thin films. Deposition of binary, ternary and quaternary thin films has been successfully carried out by many researchers by using this technique. The properties of thin films were determined using different analysis methods such as X-ray diffraction, scanning electron microscopy and UV-Visible spectrophotometer.

Key words: Thin Films · Thermal Evaporation · Semiconductor · Solar Cells

INTRODUCTION

There are a number of reports on the preparation of thin films by various deposition techniques. For example: Bi_2Te_3[1], Sb_2Te_3[2], ZnS [3] and CdSe [4] films were prepared using metalorganic chemical vapour deposition; ZnS [5], ZnSe [6], Cu_2ZnSnS_4 [7] and CdS [8] were synthesized by sputter deposition; CuS [9], ZnS [10], Cd-In-S [11] and CdSe [12] were produced using spray pyrolysis; CuS [13], CdSe [14], SnS_2 [15] and Cd-Zn-S [16] films were prepared using successive ionic layer adsorption and reaction method; chemical bath deposition method was used to prepare PbS [17], $Ni_3Pb_2S_2$ [18], Cu_2ZnSnS_4 [19], Cu_3SnS_4 [20], Ni_4S_3 [21], CDs [22], ZnSe [23], Bi_2S_3 [24], CdTe [25], NiSe [26], CoS [27], Cu_2S [28], Cu_4SnS_4 [29] and Ag-Zn-Sn-S films [30]; electrodeposition method was employed to produce Sb_2Se_3 [31], ZnSe [32], PbTe [33], CuS [34], NiS [35], $SnS_{0.5}Se_{0.5}$ [36] and Cu_4SnS_4 films [37]. Generally, the deposition technique used in producing the thin films chiefly depends on the need for certain criteria. Furthermore, the deposition technique cost also become a crucial factor in determining the mass output of thin films in the market.

The aim of this work is to study the synthesis of thin films using thermal evaporation method. Most of the thin films are important materials for applications in various optoelectronic device and photovoltaic devices. The deposition conditions will be discussed and the results will be reported based on literature review. Thermal evaporation method has many advantages such as cost effective, simple and suitable for larger area deposition. In addition, very thin layer with smooth surface could be obtained using this deposition technique. The obtained films were characterized using various analysis methods such as X-ray diffraction, scanning electron microscopy, atomic force microscopy and UV-Visible spectrophotometer.

RESULTS AND DISCUSSION

ZnSe films have high potential for application in optoelectronic applications have been prepared by Chaliha *et al.* [38] using thermal evaporation method under various substrate temperatures from room temperature to 523 K. The obtained experimental findings show that the internal strain and dislocation density reduced with the increase of substrate temperature. However, the grain size which calculated using Scherrer formula was found to increase from 13 nm to 33 nm under this deposition conditions.

Indium sulphide films can be used as absorber material in the hetero junction of solar cell device structures. In_2S_3 films were deposited using thermal evaporation method on glass substrate by Timoumi *et al.* [39]. The obtained films show good crystallinity, homogeneity and adhesion. In addition, the optical transmission spectra for 1 µm thick In_2S_3 films show that these films display good transparency (70-80%) in the visible and infrared regions.

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ZnS films are an important II-VI material and were used as electroluminescent devices. The thermal evaporated ZnS films of 0.5 μm thickness have been deposited on glass substrate at various temperatures from 300 to 400 K by Rahul [40]. It is shown that the electrical resistivity reduced from 0.36 x 10^6 to 0.15 x 10^6Ωcm as the substrate temperature was increased from 300 to 400 K. However, other experimental results such as grain size and electrical conductivity have increased in der such deposition conditions.

CdSe films can be employed in the field of photo-catalysis and conversion of solar energy. By controlling the thickness of the CdSe films, flat morphology (67 nm thick film), mosaic like structure (170 nm thick film) and continuous thin films with smooth surface morphology (305 nm thick film) could be prepared as reported by Pal *et al.* [41] in SEM studies.

SnS films are important IV-VI semiconducting materials with a direct energy band gap of 1.3 eV. Tin sulphide films with thicknesses of 20-65 nm have been deposited on glass substrate using thermal evaporation by Cheng and Conibeer [42]. It can be seen that, an increase of the films thickness leads to the XRD peaks become stronger as shown in XRD patterns. They claimed that the obtained films were pinhole free, smooth and strongly adherent to the substrate surface. In addition, they observed that the color of films changes from pale yellow to brown with increasing film thickness.

Thin films of p-type SnSe were synthesized using thermal evaporation by Kumar et al [43]. The surface roughness increases with an increase in film thickness. In the AFM investigation, the smaller grains agglomerate together to produce larger particles, which result in the increased grain size of the films. In optical measurement, the higher transmittance of 150 nm thickness is because of the smoother surface observed by AFM measurement.

Several ternary and quaternary semiconductors are studied for their potential for thin films technology. Bi-Sb-S films have been deposited by thermal evaporation by Rajalakshmi et al [44]. The obtained films are non-stoichiometric and contain excessive bismuth as indicated in EDX analysis. The AFM investigation reveals that the films consist of uniform grains. The RMS roughness was calculated using the software. The results indicate that the RMS roughness is found to increase with reducing film thickness from 319 nm to 54 nm.

The morphology and film composition of the Ag_2SeTe films were studied for the first time by Vijayan *et al.* [45]. AFM images reveal that the grain size keeps on increasing with increasing film thickness. These experimental findings agree with the increase in the crystallite size which obtained from the XRD data. They conclude that the stoichiometry is slightly altered with thickness as shown in EDX analysis.

Cu_2SnSe_3 thin films have a potential for solar cell application and radiation detector. The thickness of thermal evaporated Cu_2SnSe_3 films have been measured using Ellipsometer by Yunos *et al.* [46]. They found that the crystallite size increases while lattice strain decreases with increasing annealing temperature from 100 to 500 °C.

$CuAlS_2$ thin films can be used in optoelectronic and solar cells. These films were produced using thermal evaporation by Moreh et al [47]. They reported that the grain size was 80.3, 115.2 and 149.1 nm for the 50, 100 and 200 nm of thickness as shown in XRD studies. On the other hand, there is increase in intensity with increase in films thickness, indicating that the crystallinity is quite close related to the film thickness.

Cu-Ag-In-Se thin films have been deposited by thermal evaporation by Gullu *et al.* [48]. The composition of the films was studied using EDX. They claimed that the decrease in the atomic percentage of Se could be detected as the annealing temperature increases. Also, the increase in grain size can be observed as the indication of improvement in crystallinity (as shown in XRD data) following to the annealing process. They also mentioned that the as-deposited films are amorphous in nature and it transforms to the polycrystalline phase as a result of annealing process.

Cu_2ZnSnS_4 thin films were deposited using thermal evaporation technique followed by annealing at 300 °C for 40 min under high purity nitrogen atmosphere. The morphological of annealed films show a smooth, densely packed and homogeneous surface as reported by Shi *et al.* [49]. The obtained films have a band gap of 1.55 eV with p-type conductivity. On the other hand, the fill factor and conversion efficacy for these films is 0.42 and 0.36%, respectively.

The $AgGa_{0.5}In_{0.5}Te_2$ thin films have been deposited using thermal evaporation by Karaagac and Parlak [50]. They suggest that the stoichiometric of the films changes with the annealing process as shown in EDX spectra. As-deposited films indicated Te-rich and Ag, Ga, In-deficient behaviors. However, the decreasing in the amount of Te and In can be seen in the annealed films. On the other hand, XRD patterns reveal that the single phase $AgGa_{0.5}In_{0.5}Te_2$ was detected at the anneal temperature of 300 °C. However, XRD patterns display that the co-existence of $AgGaTe_2$ and $AgGa_{0.5}In_{0.5}Te_2$ phases if the anneal temperature below 300 °C.

CONCLUSION

There are many scientists have reported the preparation of thin films using thermal evaporation method. This method offers many advantages such as simple technique, less substrate surface damage, high purity of films and cheap deposition method. The obtained experimental results indicated that they could be used in optoelectronic and solar cell applications.

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