Indium Sulfide Thin Films: a Substitute Buffer Layer For Solar Cells

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Abstract

Preparation of nanometer size materials in thin film form have attracted the attention because of their potential applications in the various fields of science and technology, including the diverse fields of electronics, optics, space science, aircraft science, defense and other industries. In this paper, our serious effort is to substitute the CdS buffer layer by other nontoxic materials prepared by a simple and cost effective deposition technique. Thin films of indium sulfide (In_2S_3) have been deposited on glass substrate using homemade chemical bath deposition (CBD) technique. The influence of deposition parameters on growth rate, structural and morphological properties of as-deposited thin films have been carried out using X-ray diffractometer and scanning electron microscope (SEM).

Keywords: In_2S_3, chemical bath deposition, thin films, buffer layer.

Introduction

Indium sulfide (In_2S_3) is an important material for optoelectronic and photovoltaic applications and is a promising candidate for many technological applications due to its stability, wider band gap and photoconductive behavior. This material is also having interesting photoluminescence properties, and hence finds large number of applications in optoelectronic devices. It can be used as an effective nontoxic substitute for cadmium sulfide (CdS) in CIGS based solar cells. This material not only eliminates toxic cadmium but also improve light transmission in the blue wavelength region on having band gap wider than that of CdS[1-3].

In_2S_3 thin films were prepared by variety of techniques such as; thermal evaporation technique[4], single source vacuum thermal evaporation method[5], plasma-assisted coevaporation (PACE)[6], chemical precipitation method[7,8], SILAR technique[9,10], photochemical deposition technique (PCD)[11], electro-synthesis[12], electrochemical deposition[13], spin coating method[14], etc. We used a simple, attractive and low cost homemade CBD technique for the preparation of thin films. It is a controllable chemical reaction at close to room temperature and the films can be deposited on different kinds, shapes and sizes of substrates.

Good quality In_2S_3 thin films have been prepared by CBD technique using thioacetamide, Indium Chloride and sodium citrate as reagents. In this work, we have studied the preparatory conditions for reproducible deposition of good quality In2S3 thin films. The structural and morphological properties are also reported in this work. The optical and electrical properties were under study.

Experimental details

All chemicals used in the experiments were of the highest purity grade available. Solution of 0.025M indium chloride and thioacetamide varied between 0.1M and 0.5M was prepared in proper amount of distilled water. Sodium citrate was added slowly to adjust the pH value. The solution was stirred and transferred to another container containing substrate. The resulting solution was kept at 70±5ºC for different deposition time to achieve required thickness. The substrate used is soda lime glass slide. Cleaning of substrate is important in deposition of thin films, cleaning steps and growth procedure is reported elsewhere[15,16].

The crystallographic structure of films was analyzed with a diffractometer (EXPERT-PRO) by using Cu-Kα lines (λ= 1.542Å). The average grain size in the deposited films was obtained from a Debye-Scherrer's formula. Surface morphology was examined by JEOL model JSM-6400 scanning electron microscope (SEM).

Results and discussion

Influence of preparatory parameters:

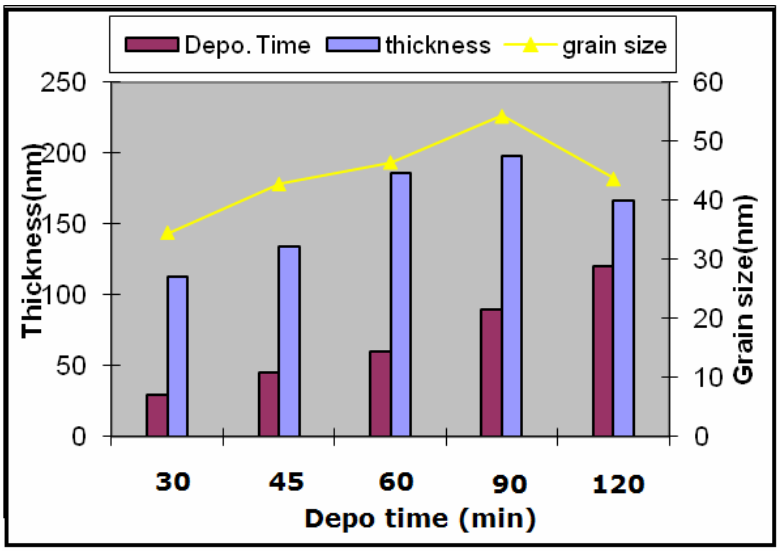

Fig. 1 Variation of film thickness, grain size with deposition time

The influence of some of the preparatory parameters such as deposition time, film thickness, deposition temperature on grain size, growth rate and the structural and morphological properties of In_2S_3 thin films have been investigated. Fig.1 shows the variation in film thickness and grain size with the deposition time. Two different regions were observed, an initial linear region and the final saturation

region. Initially the film thickness as well as grain size increases linearly it may due to the slow release of In^{3+} and S^{2-} ions in an acidic medium and their subsequent condensation on the substrates when the ionic product exceeded the solubility product. During the saturation region, the film thickness, grain size and obviously the growth rate decreases significantly as consequence of a reduction of the reagents concentration in the solution.

Structural and Morphological properties

The as-deposited In_2S_3 thin films have been characterized through X-ray diffraction measurements for the study of structural properties. Fig 2 shows the XRD pattern of In_2S_3 thin films for varying molar concentration at temperature 70±5ºC. It is observed that the thicker films with higher molar concentration of thioacetamide (TA) shows a reflection at 2θ=48.30° associated to the (2212) plane of the tetragonal β- In_2S_3 phase (JCPDS#25-0390).

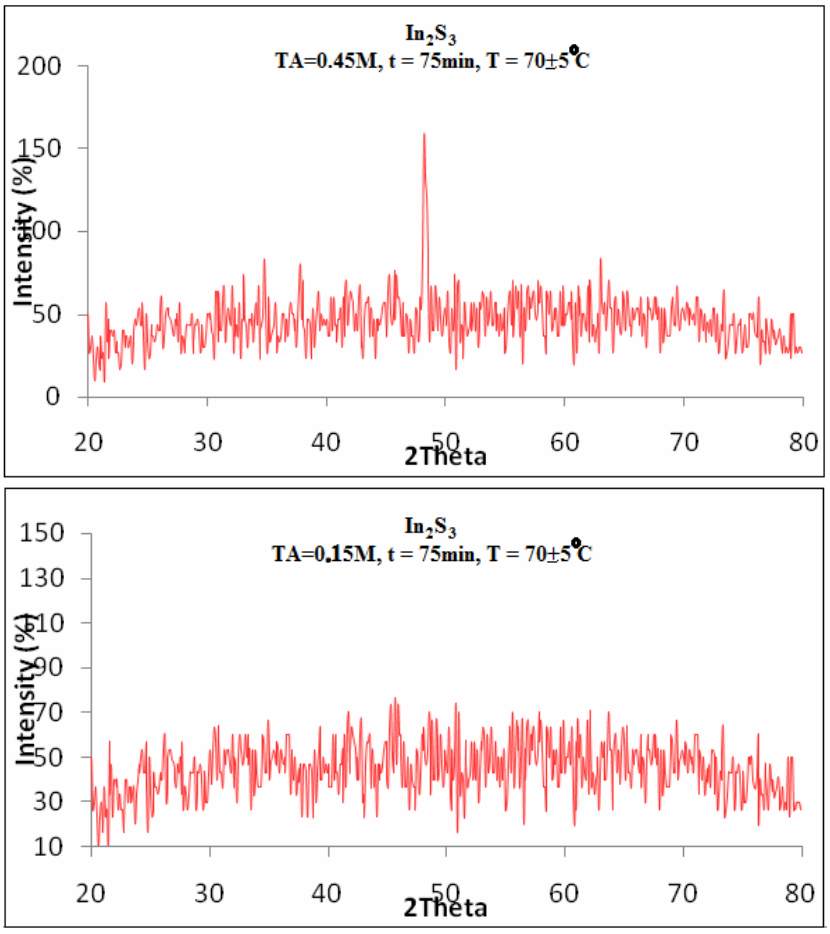

Fig. 2 shows the XRD pattern of In_2S_3 thin films (a) for TA= 0.15M and (b) for TA= 0.45M

The average size of grain (g) have been obtained from the XRD patterns using Debye-Scherrer's formula, [9-12]

$$g = K\lambda / \beta \cos\theta \qquad \ldots\ldots(1)$$

Where,

K = constant taken to be 0.94,

λ = wavelength of X-ray used (1.542Å),

β = FWHM of the peak and

θ = Bragg's angle.

The average grain size of the as-deposited In_2S_3 thin film is 45nm. It is observed that, initially the grain size increases with the film thickness but it decreases during the saturation region. The SEM image shows the roughness is more in saturation region. . The grain size obtained from SEM matches with the grain size obtained from XRD.

Conclusion

The homemade chemical bath deposition technique have been developed for the synthesis of various thin films. A good quality In_2S_3 thin films have been successfully deposited on glass substrate. The study demonstrates the role of preparatory parameters such as deposition time, film thickness, deposition temperature, etc. XRD study confirms that the films are of single tetragonal β phase. The result indicates the non toxic material developed is useful as buffer layer in solar cells and other opto-electronic applications.

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