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Influence of Bath Temperature on the Properties of In_2S_3 Films Grown by Chemical Bath Deposition

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Abstract

In_2S_3 films were deposited by chemical bath deposition (CBD) method on glass substrates using indium sulphate and thioacetamide (TA) as precursors and acetic acid as the complexing agent. The films were grown by varying the bath temperature (T_b) from 50^{o}C to 90^{o}C, keeping concentration of indium precursor at a constant value of 0.025 M and thioacetamide concentration at 0.1 M for a fixed deposition time of 60 min. X-ray diffraction (XRD) studies revealed that the deposited films were nanocrystalline in nature and showed the (311) peak as preferred orientation, exhibiting cubic structure. The Raman studies revealed that the grown layers were free from secondary phases. The scanning electron microscopy (SEM) studies indicated smooth morphology at lower temperatures that changed in to granular structure at higher temperatures. Energy dispersive X-ray analysis (EDAX) revealed a change of composition from sulfur deficient to sulfur rich at a bath temperature of 70^{o}C. The optical measurements showed that the films had a maximum transmittance of >85% in the visible region. The evaluated energy band of the layers varied in the range, 2.36 – 2.74 eV with the change of bath temperature. A detailed study of the results were presented and discussed.

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Keywords: In_2S_3 films; Chemical bath deposition; Composition; Structure; Optical properties

1. Introduction

Among several materials, indium sulphide (In_2S_3) is an important material for optoelectronic and photovoltaic applications due to its chemical stability, wider energy band gap, higher transmittance and controllable electrical characteristics [1,2]. In recent years, In_2S_3 has been proved to be a promising buffer layer in the fabrication of $Cu(In,Ga)Se_2$ thin film solar cells due to its low toxicity compared to CdS [3, 4].

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In_2S_3 is an n-type semiconductor that belongs to the III-VI group of compounds. Depending upon temperature and pressure, it exists in three crystallographic phases such as α, β and γ. Among these phases, β-In_2S_3 is the most stable phase at room temperature [5]. Preparation of In_2S_3 thin films has been carried out by different methods such as spray pyrolysis, vacuum deposition, electro deposition and chemical bath deposition (CBD) [6]. Among these methods, CBD is inexpensive, simple and convenient wet chemical method that has been previously used for deposition of a variety of metal chalcogenide thin films. Further, In_2S_3 film as a buffer layer in Cu(In,Ga)Se_2 based solar cells have demonstrated a solar conversion efficiency of 15.7%, nearer to that value of efficiency obtained by using CBD grown CdS as a buffer layer [7].

In most of the studies made on In_2S_3 thin films deposited by CBD process, indium trichloride ($InCl_3$) is used as the precursor for indium. However, these layers revealed presence of chlorine as one of the important impurities, which created many surface defects that ultimately degrade the efficiency of the cell [8]. To our knowledge, there has been only one report on the synthesis of In_2S_3 films using indium sulphate as indium source with limited analysis of the physical characteristics of the layers. In the present work, indium sulphate is used as indium source instead of $InCl_3$ to deposit the layers by CBD process in order to avoid chlorine content in the as-grown films. The structural, morphological and optical properties of the as-grown In_2S_3 films were investigated and discussed.

2. Experimental details

In the present work, In_2S_3 thin films were deposited using chemical bath deposition process, which is a simple wet chemical method that is suitable for large area deposition. Before deposition of experimental films, the glass substrates were cleaned with detergent, washed with distilled water, dried and vapor degreased using ethanol in an ultrasonic cleaner. The cleaned substrates were vertically immersed in a beaker containing aqueous solution of indium sulphate and thioacetamide. Acetic acid was used as the complexing agent. In_2S_3 thin films were grown by varying the bath temperature (T_b) from 50°C to 90°C and maintaining the indium concentration at a constant value of 0.025 M and thioacetamide concentration at 0.1 M for a fixed deposition time of 60 min. In the initial stage, the color of solution was lemon yellow that turned into bright yellow at the final stage of film deposition.

The chemical composition of the deposited films was determined by energy dispersive X-ray analysis (EDAX) using Inca Penta FET x3 energy analyzer. The structural properties of the grown films such as the preferred orientation, crystal structure and crystallite size were analyzed by X-ray diffraction (XRD) using Bruker D8 Advanced X-ray diffractometer. The Raman spectra were recorded at room temperature using Horiba Lab HR Raman Spectrometer to find out the various phases present in the experimental films. The surface morphology and grain size of the films was analyzed by using Carl Zeiss EVO MA 15 scanning electron microscope (SEM). The optical properties of the layers like the optical absorption coefficient and energy band gap were evaluated from the optical transmittance versus wavelength data obtained using Perkin Elmer Lambda 950 UV-Vis-NIR double beam spectrophotometer recorded at room temperature. The thickness of the films was calculated using Stylus method and found to be in the range, 85 - 90 nm.

3. Results and discussions

The visual appearance of the as-grown In_2S_3 films indicated that the layers were uniform, pin hole free and bright yellow in colour. Further, the scratch tape test revealed that the grown films were strongly adherent to the surface of the glass substrate.