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Effect of substrate temperature on structural, morphological, optical and electrical properties of $MnIn_2S_4$ thin films prepared by nebulizer spray pyrolysis technique

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ABSTRACT

Manganese indium sulphide ($MnIn_2S_4$) thin films were deposited using an aqueous solution of $MnCl_2$, $InCl_3$ and $(NH_2)_2CS$ in the molar ratio 1:2:4 by simple chemical spray pyrolysis technique. The thin film substrates were annealed in the temperature range between 250 and 350 °C to study their various physical properties. The structural properties as studied by X-ray diffraction showed that $MnIn_2S_4$ thin films have cubic spinel structure. The formation of cube and needle shaped grains was clearly observed from FE-SEM analysis. The energy dispersive spectrum (EDS) predicts the presence of Mn, In and S in the synthesized thin film. From the optical studies, it is analyzed that the maximum absorption co-efficient is in the order between 10^4 and 10^5 cm^{-1} and the maximum transmittance (75%) was noted in the visible and infrared regions. It is noted that, the band gap energy decreases (from 3.20 to 2.77 eV) with an increase of substrate temperature (from 250 to 350 °C). The observations from photoluminescence studies confirm the emission of blue, green, yellow and red bands which corresponds to the wavelength range 370–680 nm. Moreover, from the electrical studies, it is observed that, as the substrate temperature increases the conductivity also increases in the range $0.29–0.41 \times 10^{-4}\ \Omega^{-1}\ m^{-1}$. This confirms the highly semiconducting nature of the film. The thickness of the films was also measured and the values ranged between 537 nm (250 °C) to 483 nm (350 °C). This indicates that, as the substrate temperature increases, the thickness of the film decreases. From the present study, it is reported that the $MnIn_2S_4$ thin films are polycrystalline in nature and can be used as a suitable ternary semiconductor material for photovoltaic applications.

1. Introduction

$MnIn_2S_4$ is a ternary magnetic semiconductor that has a cubic spinel structure [1]. $MnIn_2S_4$ is formed by both direct and indirect transitions [2] and that finds applications in the fields of optoelectronic and functional devices [3–5]. This becomes possible due to the stability and wide band gap (2.0–3.7 eV) of indium sulphide [6]. Moreover, indium sulphide can act as a suitable and effective compound for replacing cadmium sulphide (CdS) in the making of solar cells [7–9]. For compounds such as $MnIn_2S_4$, indium sulphide can be used as a suitable binary base material [10]. There are various methods in which $MnIn_2S_4$ thin films can be grown, like that of the spray pyrolysis, chemical bath deposition, thermal evaporation, atomic layer chemical vapour deposition, sol-gel and reactive sputtering methods [11–16] Out of these, the spray pyrolysis method is a simple, eco-friendly method that consumes very less time for deposition on a substrate with minimum wastage of the base material [17,18]. It is a well known fact that the method of deposition, the various factors governing the process of deposition, the thickness of the film could greatly vary the physical property of the deposited thin films [9].

Information on structural and optical properties for the $MnIn_2S_4$ thin film was provided by Sharma et al. 2005 [1], but studies relating to electrical properties were not carried widely by researchers [7,19]. The current paper aims to discuss on surface morphology, chemical composition and electrical properties along with structural and optical properties of $MnIn_2S_4$ thin film at various substrate temperatures maintained at a constant spray time. The primary objective of this study is to grow a highly transparent thin film by spray pyrolysis method and to obtain maximum transmittance and electrical conductivity, which could find wide application in the field of semiconductor devices.

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