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Effect of Deposition Temperature on Structural and Optical Properties of Chemically Sprayed ZnS Thin Films

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Abstract

Zinc sulfide (ZnS) thin films have been successfully deposited via spray pyrolysis using an aqueous solution of thiourea and zinc acetate onto glass substrate. The effect of varying substrate temperature (150, 200,250 and 300°C) on structure and optical properties is presented. The films have been characterized by X- ray diffraction (XRD), UV-Vis-NIR spectrometry, photoluminescence (PL) spectroscopy and field emission scanning electron microscopy (FESEM). All the deposited ZnS films exhibit a cubic structure, while crystallinity and morphology are found to depend on spray temperature. PL analysis indicates the presence of violet and green emissions arising from Zn and S vacancies. The value of bandgap of ZnS films is found to decrease slightly with increasing substrate temperature; varying in the range 3.52–3.25eV, most probably associated with the formation of Zn(S,O) solid solution.

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1. Introduction

The exceptional and unique characteristics of Zinc sulfide (ZnS) make it among the most interesting semiconducting materials, in particular its nontoxicity and its high bandgap (~3.7 ev)[1]. Therefore, it has been considered as potential candidate in the fabrication of electronic devices, such as light-emitting diodes (LEDs)[2], field-effect transistors (FET)[3], gas sensors[4], thermal sensors[5], biosensors[6], and solar cells [7].Several methods have been proposed for the preparation of ZnS films, including pulsed laser deposition [8], chemical vapor deposition[9], atomic layer deposition (ALD), molecular beam epitaxy (MBE)[10], chemical bath deposition (CBD)[11],etc.

However, the above methods differ significantly in terms of film's quality and cost, which are considered the most important criteria for the fabrication of any devices. In addition, some synthesis methods require high cost and complex apparatus. In this regard, the aim of this research work consists on adopting an approach for the preparation of ZnS films at relatively low cost and using simple / easy operating apparatus, while exhibiting high film's quality. Therefore, spray pyrolysis has been identified as a very promising technique that has been successfully used for the deposition of ZnS films and other related materials.

This research paper is devoted to the synthesis of ZnS films by using spray pyrolysis, because of its simplicity and cost-effectiveness. In addition, the films are expected to have a better homogeneity, high crystallinity without further annealing after deposition and coverage of a relatively large area of the substrate. The study consists on investigating the effect of varying substrate temperature at relatively low range (150-300°C) on phase stability, crystallinity, surface morphology and topography as well as optical properties.

Nomenclature

ZnS	Zinc sulphide	**PL**	Photoluminescence spectroscopy
XRD	X-ray diffraction	**FESEM**	Field emission scanning electron microscopy
EDX	Electron dispersive x-ray spectrometer		

2. Experimental Part

During chemical spray pyrolysis, the solution was sprayed onto a hot glass substrate (prior to deposition, the substrates were subjected to cleaning).In this work, zinc acetate dehydrate ($Zn(CH_3COOH)_2.2H_2O$) and thiourea(CH_4N_2S) (R & M Chemical) precursors were used as source for Zn^{2+} and S^{2-}ions, respectively while deionized water was used as a solvent. The molar ratio Zn/S was fixed 1:1. The solution was sprayed with a steel needle at a spray rate of 4ml/min on to the glass substrate and the air was used as a carrier gas at a pressure of 3 bars. The substrate temperature was varied from 150 up to 300ºC using electronic temperature controller.

The crystal structure of ZnS thin films was characterized by X-ray diffraction (XRD) using X-ray Philips X,Pert diffractometer equipped with Cu-Kαradiation source (λ_{Cu}=1.5418 Å). Surface morphology of the deposited films were observed by field emission scanning electron microscopy (FESEM) using FEI Nova Nano SEM 450. The chemical composition (Zn/S ratio) was checked by electron dispersive spectroscopy (EDS). Optical properties were determined by recording absorbance spectra using Shimadzu UV-Vis 1800 double-beam UV-VIS spectrophotometer and photoluminescence spectroscopy using JobinYvon HR 800 UV equipped with He-Cd laser at325 nm excitation source.