Structural, Optical and Electrical Properties of PbS Thin Films Deposited by CBD at Different Bath pH

L. Beddek#1, M. Messaoudi#2, S. Guitouni#3, N. Attar#4, M.S. Aida#5

#1 Physics Department, Frères-Mentouri University
#2 Laboratoire de Couches Minces et Interfaces Faculté des Sciences, Constantine, Algeria
#3 Physics Department, Frères-Mentouri University
#4 Laboratoire de Couches Minces et Interfaces Faculté des Sciences, Constantine, Algeria
#5 Physics Department, Frères-Mentouri University

Abstract — PbS thin films were grown on glass substrates by chemical bath deposition (CBD). The precursor aqueous bath contained 1mole of lead nitrate, 1mole of Thiourea and complexing agents (triethanolamine (TEA) and NaOH). Bath temperature and deposition time were fixed at 60°C and 3 hours, respectively. However, the PH of bath was varied from 10.5 to 12.5. Structural properties of the deposited films were characterized by X-ray diffraction and Raman spectroscopy. The preferred direction was revealed to be along (111) and the PbS crystal structure was confirmed. Strains and grains sizes were also calculated. Optical studies showed that films thicknesses do not exceed 600nm. Energy band gap values of films decreases with increase in pH and reached a value ~ 0.4eV at pH equal 12.5. The small value of the energy band gap makes PbS one of the most interesting candidate for solar energy conversion near the infrared ray.

Keywords — CBD, PbS, pH, thin films, x-ray diffraction.

I. INTRODUCTION

During these last decades, thin films have been growing in importance in the field of technology and, in particular, in the semi-conductors industry. New properties, different from those observed in the bulk, appear in the films states [1]. Generally, those properties are linked to film thickness and preparation method [2, 3]. These properties can be controlled by varying the parameters of deposition. Lead sulfide (PbS) is a semiconductor arousing interest of researchers[4-8]. This material is belonging to IV-VI group with a narrow band gap (0.41eV) [9,10]. It is used in infrared optics as a material for temperature sensors and photodetectors [9, 11], and solar cells. Near infra red active solar cells based on PbS quantum dots and a conventional conjugated polymer Bi$_2$S$_3$/PbS heterojunction solar cells are fabricated by chemical bath deposition (CBD) [10]. Several other methods were used to synthesized PbS thin films such as spray pyrolysis (SP) [12], chemical vapor deposition (CVD) and vacuum evaporation [13]. CBD is the more interesting public deposition technique. It is known to be technically simple and necessitating few resources and cost [14]. A chemical bath deposition technique also offers the advantage of being able to deposit films on different kinds, shapes and sizes of substrates [15]. By CBD method the grains sizes can be controlled by varying experimental parameters. A lot of works on PbS thin films studied: the temperature effect on the PbS deposited films [16, 17], the deposition time dependence [7, 18], bath composition [8], morphology, optical and electrical properties of PbS thin films has been investigated [5]. The control of the bath pH is an important factor. Some attempts [4-6] are carried out to control this parameter to define accurately its influence on PbS thin films properties. The present study deals with the investigation of bath pH effect on PbS thin film properties.

II. EXPERIMENT DETAILS

Microscope glass slides (75 mm x25mm x2 mm) were used as substrates. Those ones were, firstly, washed with distilled water, immersed in methanol and cleaned ultrasonically for 20min. Then, they were cleaned again ultrasonically with distilled water for 20min and, finally, dried in air. The deposition was done in a reactive bath prepared in a 50mL beaker. The bath was composed of sulfur and lead precursors, 1M of thiourea [CH$_3$CSNH$_2$] and 0.1M of lead nitrate [Pb(NO$_3$_2)]. Triethanolamine (TEA) [N(CH$_2$OH)$_2$] was added as buffer solution to control the rate reaction. The PH solution was varied between 10.5 and 12.5 (10.5, 11, 11.5, 12, 12.5) by adding sodium hydroxide NaOH. Cleaned substrates were vertically dipped in the heated solution by external hot plate set at 60°C for 3hours. For the first 5min, the solution remained transparent, indicating the occurrence of decomposition reactions. After 5min, the solution became dark gray which indicates the PbS compound formation. The reaction process for forming lead sulfide films is considered as follows:

$$\text{Pb(NO}_3\text{)}_2 + 2\text{NaOH} \rightarrow \text{Pb(OH)}_2 + 2\text{NaNO}_3$$

$$\text{Pb(OH)}_2 + 4\text{NaOH} \rightarrow \text{Na}_2\text{Pb(OH)}_6$$