Sulfide precursor concentration and lead source effect on PbS thin films properties

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Lead sulfide (PbS) thin films were synthesized using chemical bath deposition (CBD). Bath solutions are formed of various concentrations of thiourea, sulfide source, ranged from 0.6 to 1.2 M and two different salts as Pb source (lead acetate and lead nitrate). From the growth mechanism, we inferred that PbS is formed through the ion by ion process when using acetate lead source, while, using nitrate source yields to films growth through the complex-decomposition process. Due to the difference in the involved growth process, lead acetate produces films with larger crystallite size (from 4 to 16 nm), smooth and dense films. However, lead nitrate produces rough films with smaller crystallite size (from 1 to 4 nm). Increasing the thiourea concentration results in crystallinity improvement when using lead acetate and, oppositely, in crystallinity degradation when using lead nitrate. Due to the quantum effect caused by the small crystallite sizes, the films optical gap is varied from 0.5 to 0.9 eV.

1. Introduction

Lead sulfide (PbS, galena) is a semiconducting material belonging to IV-VI group with a narrow band gap (0.41 eV) [1,2] and a large exciton Bohr radius of 18 nm, which permits a strong confinement effects visible, even for larger particles [3]. It has been a subject of considerable research activity due to its technological importance. PbS thin films have been used as a material for temperature and gas sensors, photodetectors in the infrared band (850–3100 nm), photoresistors [4–6], photovoltaic and photocatalysis applications [7].

Several techniques were used for thin films deposition such as spray pyrolysis (SP) [8], chemical vapor deposition (CVD), vacuum evaporation [9] SILAR [10] and chemical bath deposition (CBD) [2,11–14]. Among these techniques, CBD method is attracting, since it does not require sophisticated instrumentation. It is simple and cost-effective, suitable for large area deposition with good quality thin films [15]. Chemical bath deposition technique also offers the advantage of being able to deposit films on different kinds, shapes and sizes of substrates [16].

The correlation between the bath composition and physical properties of resulting film is still an open problem and a subject of investigations. Several authors have reported that small changes in the bath composition can lead to important changes in films properties [13]. In CBD method, the crystallites sizes can be controlled by varying experimental parameters. Most investigations on PbS thin films studied the temperature effect on films properties. Abbas et al. [17,18] have reported that deposition temperature besides thermal treatment influences strongly the films crystallites structure. However, the deposition time controls the films stoichiometry, microstructure and crystallinity [14,18]. The pH effect has also been investigated and found that it improves the films crystallinity [19]. The bath composition, the concentrations of sulfide and lead precursors, complexing agents and solvents were also studied [20,21]. While, to our knowledge, few investigations dealing with the lead source nature were carried. Hence, the lack of studies related to the precursor nature motivates the present work.

The main goal of the this paper is the investigation of lead source nature and sulfide precursor concentration effects on structural and optical properties of PbS thin films.

2. Experiment details

Microscope glass slide (75 × 25 × 2 mm) were used as substrates. First, substrates were washed with distilled water, immersed in methanol and cleaned ultrasonically for 20 min. Then,