Research Journal of Applied Sciences 2 (9): 931-934, 2007
ISSN: 1815-932X

Deposition Time Dependence on Absorptivity of Chemically Deposited Lead Lead Sulphide Thin Film

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Abstract: Lead Sulphide (PbS) thin films were deposited on glass substrates using chemical bath deposition technique. The prepared PbS samples were grouped into two: The ''as-grown'' and the ''annealed'' samples. We deposited our PbS samples, both as-grown and annealed, at various deposition time of 3, 4 and 5 (i.e 3, 4, 5 h for as-grown, 3, 4, 5 h samples annealed at 100°C, 3, 4, 5 h samples annealed at 150°C and 3, 4, 5 h samples annealed at 200°C. Absorbance of each sample was measured and recorded at various wavelengths using Visible/Ultra-violet Spectro-photometer model 6405. The result shows non-linear relationship between the deposition time and absorbance of chemically deposited PbS thin film. Absorptivity increases in the initial process of growth with deposition time but beyond a specific time, the absorbance decreases as deposition time increases. The optimum absorptivity of the PbS samples occurs at a specific deposition time after which the absorptivity decreases as deposition time increases. This optimum absorptivity is obtained between 220 and 250 min deposition time after which the absorptivity decreases with further increase in deposition time for all samples under investigation. Thus, the optical and electrical properties of PbS thin film are deposition time dependent.

Key words: Thin film, annealing, absorptivity, deposition time, electromagnetic radiation, substrate

INTRODUCTION

Thin film is a layer of material deposition whose thickness is of the order of a given wavelength of electromagnetic radiation. The layers of materials are coated on substrates, which could be plastics, glasses or metals to accomplish a desirable effect.

Electromagnetic radiation involves the energy transfer by electromagnetic waves. Radiant energy falling upon any surface may be partly absorbed, partly reflected and partly transmitted through the receiving body. Absorptivity is the fraction of incident radiation absorbed by the receiving body.

The significances of thin film can not be over emphasized among which are in the production of camera lenses, dichroic mirrors, solar cells, solar thermal system, photovoltaic power system, astronauts helmets etc.

Bode (1996) declared that Lead Sulphide has been used in infra-red detectors since mid 1940s and it was for this application that the chemical bath deposition technique for Lead Sulphide thin films known since 1910, was initially developed in the late 1940s.

Archbold (2005) discovered that the air annealed and $CdCl_2$ annealed films are very photo-sensitive and exhibit significantly faster photo-response times than the as-grown films.

Grecu (2004) disclosed that the evolution of optical characteristics of thin film (CdS) after annealing process was influenced by the deposition conditions.

Fajinmi (2001) showed that annealing of chemically deposited Lead Sulphide thin film modify its grain boundaries and consequently increase the grain size.

Ramaiah *et al.* (2001) reiterated that the Chemical Bath Deposition (CBD) is an "electroless" technique that is attractive as a simple and low cost method.

Nair *et al.* (1991) declared that the typical deposition process involved the immersion of glass substrate in alkaline. Lead thiourea solution yielded Lead Sulphide (PbS) thin films of various thickness 0.05μm and 0.14μm in about 2 h.

The essence of this research is to determine the effect of deposition time of thin film on the absorptivity. It is pertinent to know the effect since a low cost, less sophisticated technique is adopted. The

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effect would further help in determining the characteristic properties of PbS thin film.

Hence, in this research, the influence of deposition time on absorptivity of PbS sample is studied among many other deposition conditions such as bath composition, reagents concentrations, temperature, PH, etc.

MATERIALS AND METHODS

In this research, materials and equipment such as chemicals, beakers, PH meter, stirrer, spatula, chemical beam balance, thermometer, microscopic slide, glasscutter, oven and spectro-photometer were used.

Chemical bath deposition technique was employed in depositing Lead Sulphide thin film on the glass substrates. This was carried out at the Physics Laboratory of Ladoke Akintola University of Technology, Ogbomoso, Nigeria in 2006.

The solution for deposition of Lead Sulphide thin film on both surfaces of glass substrates (microscopic slide) were constituted from aqueous solution of 1.0 mole of Lead Acetate, 1.0 mole of Thiourea (TU) and 1.0 mole of Tri-Ethanol Amine (TEA). Sodium Hydroxide (NaOH) was added to the solution to give a PH value between 9 and 10 to the chemical bath.

The concentration of the reagents, PH (between 9 and 10) and temperature of 25°C were kept constant for all deposition time 3, 4 and 5 h.

The glass substrates were then immersed vertically on the wall of 50 mL beaker (the deposition bath) containing the solution.

The possible reactions can be represented by these chemical equations:

$$SC(NH_2)_2 + OH\ CH_2N_2 + H_2O + HS \quad (1)$$

$$2HS + 2OH\ 2H_2O + S_2 \quad (2)$$

$$Pb^{2+} + S^{2-}\ PbS \quad (3)$$

Spectro-photometer, model 6405 was used to measure the absorbance of each sample at various wavelengths within visible and ultra-violet region of electromagnetic spectrum.

RESULTS AND DISCUSSION

In the alkaline medium, the thiourea decomposes and releases S^{2-} ions, which precipitates Pb^{2+} ions. Thus, the Precipitated Lead Sulphide (PbS) was deposited on both surfaces of the glass substrates as thin film at various deposition times of 3, 4 and 5 h.

Table 1: Absorbance value with deposition time at varied wavelengths for as-grown PbS sample

Absorbance/ Deposition time	180 min	240 min	300 min
Abs at 400 nm	0.254	0.034	-0.047
Abs at 500 nm	0.235	0.031	-0.038
Abs at 600 nm	0.023	0.033	-0.044
Abs at 700 nm	0.022	0.025	-0.031
Abs at 800 nm	0.021	0.025	-0.020
Abs at 900 nm	0.012	0.029	-0.025
Abs at 1000 nm	0.003	0.024	-0.027

The absorbance values of all samples under consideration, the as-grown and annealed, at different deposition time of 3, 4 and 5 h were recorded.

The graphs of absorbance against deposition time for a specific sample batch (e.g. as-grown) at different deposition time are plotted.

Table 1 shows the variation of absorbance with deposition time for as-grown PbS sample at different wavelengths within Visible/Ultra-violet region. Maximum absorbance of 0.254 is obtained at 3h deposition time while the minimum of- 0.047 is obtained during 5h deposition time.

Figure 1 shows the variation of absorbance with deposition time for annealed PbS sample at 150°C. Just a little before 240 min deposition time, the absorbance becomes optimum for all samples considered between wavelength of 500 and 1000 nm after which absorbance decreases as deposition time further increases to 300 min. Also, for sample studied at 400 nm of wavelength, the absorbance is optimum nearly 180 min after which it reduces as deposition time increases.

Figure 2 shows the variation of absorbance with deposition time for annealed PbS samples at 200°C. This Fig. 2 shows the similar trend as Fig. 1. For all the samples at varied wavelengths between 400 and 1000 nm, the absorbance is optimum between 200 and 250 min deposition time after which there is decrease in absorptivity with increasing deposition time (Table 1).

It is observed from these figures that absorptivity increases up to an optimum at a specific deposition time and then decreases as the deposition time further increases.

The result obtained from this research shows non-linear relationship between deposition time and absorbance of chemically deposited PbS sample. That is, the absorbance initially increases with deposition time but later decreases as deposition time increases.

The obtained non- linear relationship, which was unexpected, is resulted from the principle that the constituent ions that have been condensed on glass substrates begin to wear out into the composition bath as the deposition time increases. Thus, the adhesive force

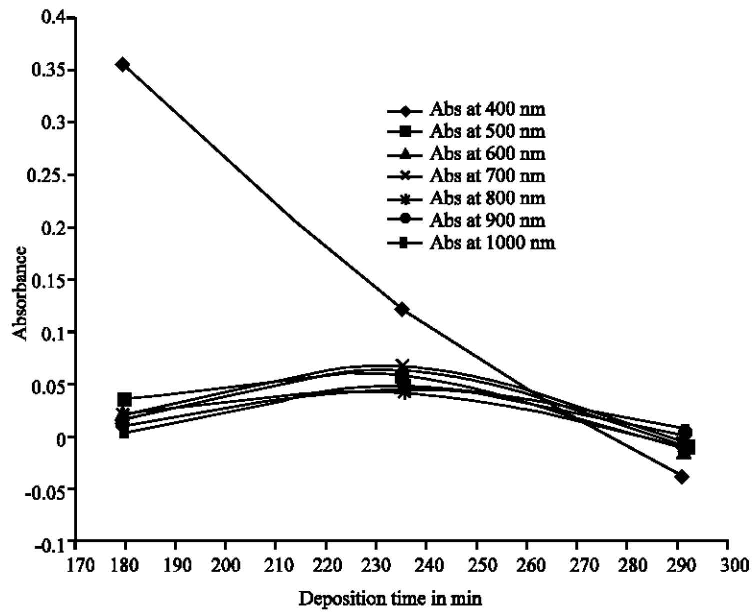

Fig. 1: Variation of absorbance with deposition time for annealed PbS samples at 150°C

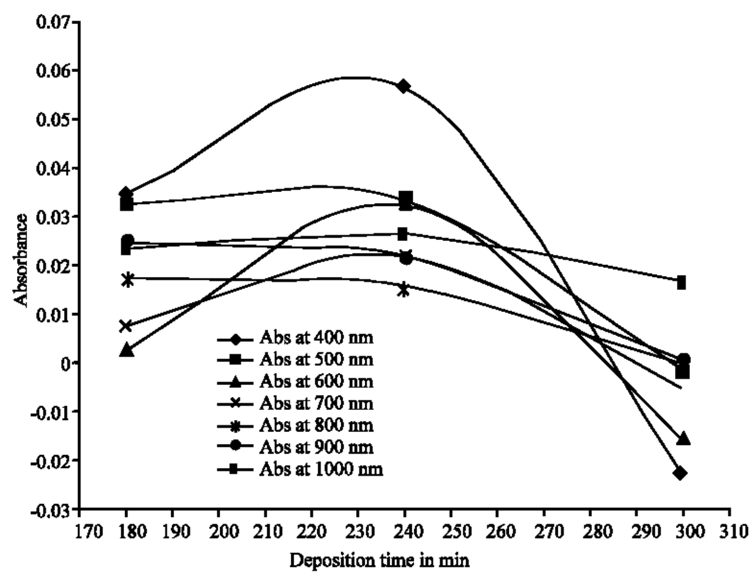

Fig. 2: Variation of absorbance with deposition time for annealed PbS samples at 200°C

between the constituent ions and the glass substrates weakens as deposition time further increases which later resulted into low absorptivity.

The slight deviation observed from our results most especially in Fig. 1 is as a result of non-uniform deposition of PbS on the glass substrates since the chemical bath deposition technique is easier, simple, lower in cost but less effective. The obtained result is consistent with the reports from Grecu *et al.* (2004) and Ubale *et al.* (2005).

CONCLUSION

Conclusively, increasing the deposition time of chemically deposited Lead Sulphide thin film beyond specific duration of deposition reduces its absorptivity. Thus, deposition time is among the deposition conditions, which strongly influence the film stoichiometry, microstructure and crystallinity. These characteristics (spectroscopic and non-spectroscopic) then determine the optical and electrical properties of PbS films.Thus, the properties of PbS thin film is deposition-time dependent.

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