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Effect of Deposition Time on Transmissivity of Chemically Deposited Lead Sulphide Thin Film

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Abstract: Chemical Bath Deposition (CBD) technique is employed in depositing prepared Lead Sulphide (PbS) as thin film on glass substrates at varied deposition time. The durations of our deposition are 180, 240 and 300 min. We annealed some prepared samples at 100, 150 and 200°C so as to modify their grain boundaries and the remaining samples were left, as they were prepared. The "*as prepared*" and "*annealed*" PbS samples are then studied. We measured and recorded the transmittance of each sample at various wavelengths between 400 and 1000 nm using Visible/Ultra-violet Spectro-photometer model, 6405. The effect of deposition time on transmissivity of Lead sulphide is observed. The result shows non-linear relationship between the deposition time and transmissivity of PbS sample. The deposition time of "*as prepared*" PbS samples increases as transmissivity increases up to an optimum point of transmissivity between 230 and 240 min after which the transmissivity nearly remains constant with further increase in deposition time. The annealed samples initially show increase in transmissiviy with an increasing deposition time but beyond a specific time, termed "*critical deposition time*", the transmittance decreases as deposition time increases. Thus, the optimum transmissivity of annealed PbS thin film occurs at this "*critical deposition time*" (between 235 and 245 min) beyond which the transmittance decreases with further increase in deposition time. Hence, the deposition time is then considered to have great influence on the transmissivity of chemically deposited Lead Sulphide (PbS) thin film and thus influence its electrical and optical characterization.

Key words: Transmittance, spectro-photometer, annealing, deposition time, wavelength, thin film

INTRODUCTION

Thin film is a layer of material, typically a few μm or less in thickness, directly deposited on glass, stainless steel, ceramic or other compatible substrate materials (Patel, 1999).

In this research, Lead Sulphide (PbS), which is coated as thin film on both surfaces of glass substrate by chemical bath deposition technique among many semiconductors, is studied.

Lead sulphide is a semiconductor with a direct band gap of about 0.40eV. A direct transition takes place when the lowest energy state in the conduction band has the same value of wave vector 'k' as the highest energy state in the valence band, otherwise an indirect transition occurs (Kittel, 1986).

Radiant energy falling upon any surface may be partly absorbed, partly reflected and partly transmitted through the receiving body. Thus, transmissivity is the fraction of incident radiation transmitted by the receiving body.

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 film known since 1910, was initially developed in the late 1940s (Bode, 1996).

The evolution of optical characteristics of thin film (CdS) after annealing process was influenced by the deposition conditions (Grecu *et al*., 2004).

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

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

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

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Ubale *et al*. (2005) declared that taking a substrate out of bath at regular interval of 2 h optimize the deposition time of ZnS. He observed that the film thickness increases up to 20 h deposition time and then remains nearly constant.

In this study, we report the influence of deposition time on the transmissivity of PbS thin film among many other deposition conditions such as bath composition, reagents concentrations, temperature and PH value etc.

MATERIALS AND METHODS

A very attractive method for producing PbS thin films due to possibility of large area deposition of some sulphides is the so-called Chemical Bath Deposition (CBD) method. This deposition method was carried out at Physics Laboratory of Ladoke Akintola University of Technology, Ogbomoso, Nigeria in 2006.

Chemicals, PH meter, thermometer, Spectro-photometer, Chemical beam balance were utilized in the course of deposition.

Thiourea is used as a sulphide ion source and Lead acetate as Lead ion source. Thus, PbS thin films are prepared by the decomposition of thiourea in an alkaline solution containing a Lead salt and a suitable complexing agent. The deposition process is based on the slow release of Pb^{2+} and S^{2-} ions in solution, which condensed on the substrate. The deposition of PbS occurs when the ionic product of Pb^{2+} and S^{2-} exceeds the solubility product of PbS.

The solution for deposition of Lead Sulphide thin film on both surfaces of glass substrate (microscopic slide) were constituted from aqueous solution of 1.0 mole of Lead Acetate, 1.0 mole Thiourea (TU) and 1,0 mole Tri-Ethanol Amine (TEA). Sodium Hydroxide (NaOH) was added to the chemical bath and temperature of 25°C were kept constant for all deposition time.

Depositions were done for 180, 240 and 300 min. Transmittance of each sample, at various wavelengths within visible and ultra-violet region of electromagnetic spectrum is measured using spectro-photometer, model 6405.

RESULTS AND DISCUSSION

The formation of PbS thin film involves the following chemical reactions:

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

$$2HS + 2OH \longrightarrow 2H_2O + S_2$$

$$Pb_2 + S_2 \longrightarrow PbS$$

We measured and recorded the transmittance of each sample of both "*as prepared*" and "*annealed*" that were deposited at varied time of 180, 240 and 300 min.

The variations of transmittance with deposition time for all samples at different wavelengths from 400-1000 nm are studied.

Table 1 reveals the transmittance of "*as prepared*" PbS sample at different wavelengths within visible and Ultra-violet region. At the wavelength of 400 nm, transmittance is 20.90% for "*as prepared*" PbS deposited for 180 min which then increases to 50.0% at 300 min. Just beyond 600 nm, the transmittance slightly decreases or nearly remains constant for deposition time between 180 and 300 min.

Figure 1 shows the graph of transmittance at varied wavelengths against the deposition time for Lead Sulphide annealed at 100°C.

The optimum transmittance of 69.50% is obtained at 240 min deposition time while the minimum transmittance of 17.40% is obtained at 300 min deposition time. In this Fig. 1, it is observed that the transmittance initially increases with deposition time to an optimum point after which it begins to decrease with increasing deposition time.

Figure 2 shows the variation of transmittance at varied wavelengths with the deposition time for Lead Sulphide annealed at 150°C. The optimum transmittance of 58.20% is obtained 240 min deposition time while the minimum transmittance of 15.20% is obtained at 180 min deposition time. The nature of this Figure shows similar trend with Fig. 1 in which transmittance initially increases with deposition time to an optimum point after which it begins to decrease with increasing deposition time.

Figure 3 also shows the variation of transmittance at varied wavelengths with deposition time for PbS thin film annealed at 200°C. The optimum transmittance of 48.90% is obtained at 240 min deposition time while the minimum transmittance as low as 2.30% is obtained at 300 min deposition time. The figure precisely shows similar trend as in Fig. 1.

We conclude from these figures that there is a specific deposition time termed "*critical deposition time*"

Table 1: Transmittance of "*as prepared*" PbS sample at varied deposition time

Time (min.)	Tr. At 400 nm (%)	Tr. At 500 nm (%)	Tr. At 600 nm (%)	Tr. At 700 nm (%)	Tr. At 800 nm (%)	Tr. At 900 nm (%)	Tr. At 1000 nm (%)
180	20.90	18.30	16.30	15.40	10.90	15.70	16.10
240	41.00	37.10	32.10	29.40	27.20	24.60	23.60
300	50.00	43.70	33.60	28.10	24.20	22.70	21.60

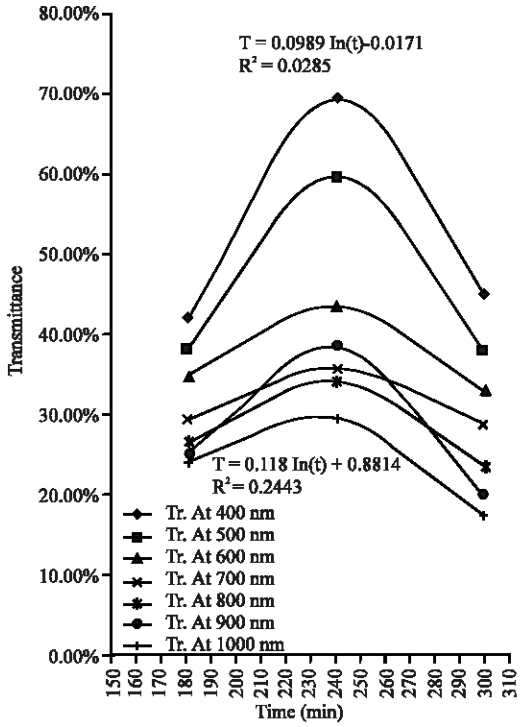

Fig. 1: Graph of Transmittance against deposition time of PbS sample annealed at 100°C

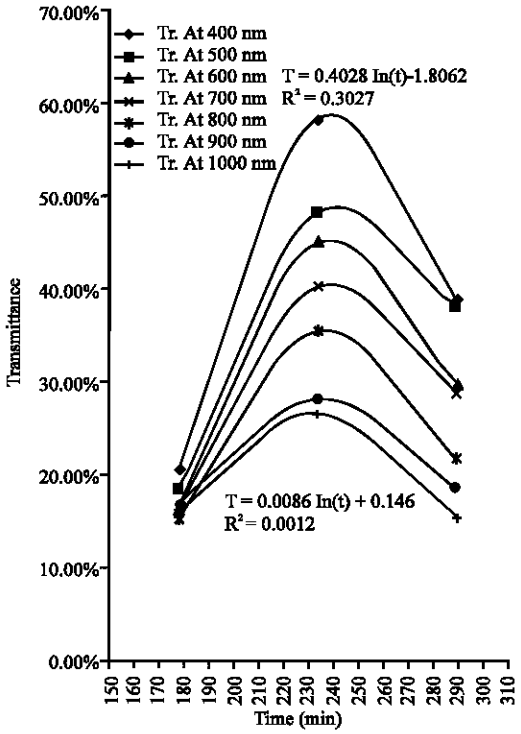

Fig .2: Graph of Transmittance against deposition time of PbS sample annealed at 150°C

at which the transmittance is optimum and beyond this deposition time, the transmittance decreases with further increase in deposition time.

Hence, this shows non-linear relationship between the deposition time and transmittance of chemically deposited Lead Sulphide thin film. That is, the transmittance initially increases with deposition time to an optimum but later decreases as deposition time increases.

The logarithm of the relationship between transmittance and deposition time is obtained as:

$$T = A \log (t) + B$$

Where:

T = Transmittance in %.
t = Deposition time in seconds.
A and B = Constants as a result of specific wavelength of the spectrum.

At critical deposition time

$$T_{max} = A \log (t_c) + B$$

Where:

$T_{max.}$ = Optimum transmittance
t_c = Critical deposition time

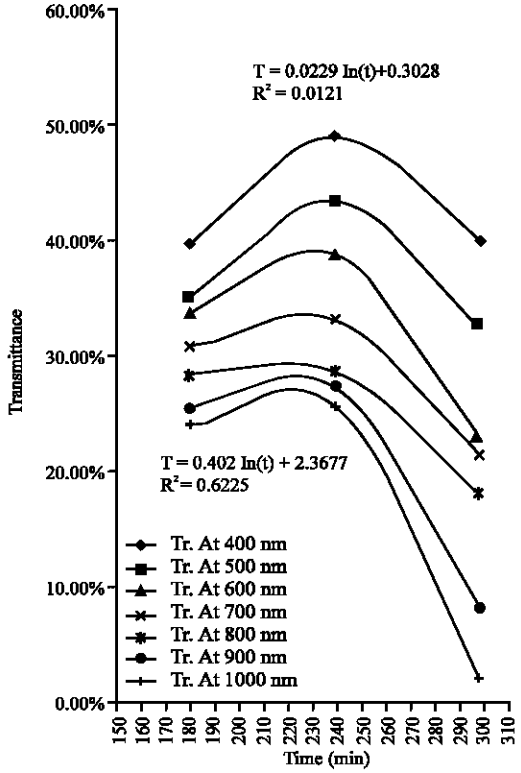

Fig .3: Graph of Transmittance against deposition time of PbS sample annealed at 200°C

One would have expected increasing thickness of PbS thin film as the deposition time increases, so as to yield contineuous increase in transmissivity but reverse is the case. This is assumed to result from the principle that the constituent's ions that have been condensed on both surfaces of glass substances after a specific deposition time begin to wear out into the composition bath even as the deposition further increases. Hence, the adhesive force, which is the force of attraction between constituent ions and the glass substrates, weakens as deposition time further increases which obviously resulted into the lowering transmissivity. This result is consistent with report from Ubale *et al*. (2005) who study the variation of thin film thickness with deposition time.

CONCLUSION

The PbS thin films have been chemically deposited on both surfaces of glass substrates from an aqueous alkaline bath. The transmittance of each sample under investigation at varied wavelengths between 400 and 1000 nm with deposition time is recorded and studied.

The transmissivity initially increases with deposition time up to an optimum point (*critical deposition time*) beyond which it decreases with increasing deposition time. Deposition time is then considered to have strong effect on transmissivity of chemically deposited PbS thin films and also as one of the deposition conditions which strongly influence the film stoichiometry, microstructure and crystallinity. This establishes the deposition time dependent of the optical and electrical properties of PbS thin film.

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