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Short Communication

Effect of Film Thickness on the Transmittivity of Chemical Bath Synthesized PbS Thin Film

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Abstract

Thin films of PbS were deposited at room temperature on glass substrates immersed in a bath mixture containing aqueous solutions of lead nitrate [Pb(NO$_3$)]$_2$, and thiourea (SC(NH$_2$)$_2$), using EDTA disodium salt as a complexing agent and ammonia solution as a pH adjuster at 300K. Optical and surface morphology of the films were investigated using a Janway 6405 UV/ Visible spectrophotometer and an Olympus optical microscope. The optical microscopy image showed that this film has uniform, small crystal size and covered the entire substrate surface completely. The films also have high transmittance in the visible/ near infrared region of the electromagnetic spectrum. We also established that increase in the film thickness in the chemical bath deposition of PbS thin film reduces the transmittance of the film.

Keywords: Transmittance, PbS thin films, chemical bath deposition technique, complexing agent.

Introduction

Thin film technology has attracted much attention because of its unique size dependent properties and applications in optoelectronic devices, solar cells, sensors, and laser materials. In the past few decades, several technique have been adopted for thin film deposition such as Sol –gel[1] ionized Cluster Beam Deposition[2,3] dc reactive magnetron, Sputtering[4], pulsed laser deposition[5], chemical bath deposition[6]. Chemical bath deposition technique is currently attracting a great deal of attention as the technique is relatively cost effective, has minimum material wastage, does not need sophisticated instrument and can be applied in large area deposition at low temperature. It is well studied and produces films that have comparable structural and opto-electronic properties to those produced using other sophisticated thin film deposition technique. The chemical bath deposition method uses a controlled chemical reaction to deposit a thin film. In the typical experimental approach, the substrates are immersed in solution containing the chalcogenide source, metal ion, and complexing agent. The preparation and characterization of thin films by chemical bath deposition have been reported by many researchers. For example[7], deposited CuO thin film[8], deposited BaSe thin film[9], deposited PbSe thin film.

The present work report the influence of thickness on the transmittivity of chemical bath synthesized PbS thin films at 300K bath temperature. The chemical bath contains lead nitrate and thiourea (SC(NH$_2$)$_2$), which provide Pb^{2+} and S^{2-} ions, respectively, while EDTA acted as a complexing agent.

Material and Methods

Thin films of PbS were deposited at room temperature on glass substrates immersed in a bath containing lead nitrate [Pb(NO$_3$)]$_2$, and thiourea (SC(NH$_2$)$_2$), using EDTA disodium salt as a complexing agent and ammonia solution as a pH adjuster at 300K. Thiourea is used as our sulphide ion source and lead nitrate as our lead ion source. Deposition time as a parameter was optimized and the growth of PbS was determined with respect to it. In this experiment, five reaction baths (50mls beaker) were used. 5mls of lead nitrate was measured into a 50ml beaker using burette; 5mls of E.D.T.A, was then added. On addition of E.D.T.A, the solution remained clear. Thiourea was now added to the solution, it turned milky and on addition of 5mls of ammonia solution turned brown. The mixture was then topped to 50mls level by addition of distilled water and stirred gently to ensure uniformity of the mixture. The experiment was performed at a pH of 10.8 and at 300K. A glass substrate was then dipped vertically into all of the five reaction baths with the aid of a synthetic form cover, which also acted as a lid for the reaction baths. Each bath was allowed to stand for various time intervals as shown in table 1, after which they were removed and dried in air.

The reaction mechanism is of the form:

$$Pb(NO_3)_2 + EDTA \rightleftarrows (Pb(EDTA)^{2+} + 2NO_3^{2-}$$
$$(Pb(EDTA]^{2+} \rightleftarrows Pb^{2+} + EDTA$$
$$(SC(NH_2)_2 + OH^- \rightleftarrows CH_2N_2 + H_20 + HS^-$$
$$HS^- + OH^- \rightleftarrows H_2O + S^{2-}$$
$$Pb^{2+} + S^{2-} \rightarrow PbS$$

The transmittance spectra of the fabricated films were obtained with a Janway 6405 UV/ Visible spectrophotometer. Surface morphology of the films was carried out using an Olympus optical microscope. Other solid state and optical properties of the films had been investigated in my earlier publication.

Result and Discussion

Figure 1 is a plot of thickness versus time. It shows an almost linear relationship with time of growth. At 1hour growth time, thickness was 0.296µm and at 5hours growth time, it was 1.176µm. Thickness increased linearly with deposition time.

Figure 2 shows the optical micrograph of the deposited PbS thin film. From the micrograph, it can be seen that the surface of the film has uniform, small crystal size and covered the entire substrate surface completely.

Figure 3 is a plot of transmittance of PbS thin film as a function of wavelength. The optical transmittance spectra of PbS films deposited onto a glass substrate were studied at 300K in the wavelength range of 300nm-1100nm. The optical transmittance spectra were obtained for the film deposited at different time intervals which lead to different film thicknesses. The curves show high transmittance (65- 80) % at wavelength range of (600- 1100)nm for the film with the lowest film thickness (0.296µm) and low transmittance (20 - 43)% at wavelength range of (600- 1100)nm for the film with the highest film thickness (1.176µm) The transmittance is low in the uv region for all the samples. In the visible region the transmittance is moderate. The transmittance is highest in the near infra-red region of the spectrum. A careful look at the curves shows that the transmittance tends to lower values as the film thickness increased. From this experiment one can infer that increase in the film thickness in the chemical bath deposition of PbS thin film reduces the transmittance of the film. Sample Pb1 with the lowest film thickness has a transmittance of approximately 80% at 1100nm, while sample Pb5 with the highest film thickness has a transmittance of approximately 43% at1100nm.

Table-1
Bath constituents for the deposition of lead Sulphide Thin Film

Slide NO.	Volume of complexing agent (EDTA) (mls)	Volume of thiourea (mls)	Volume of $Pb(NO_3)_2$ (mls)	Volume of ammonia (mls)	Time (hour)	Thickness (µm)
Pb_1	5.00	5.00	5.00	5.00	1.00	0.296
Pb_2	5.00	5.00	5.00	5.00	2.00	0.513
Pb_3	5.00	5.00	5.00	5.00	3.00	0.844
Pb_4	5.00	5.00	5.00	5.00	4.00	1.019
Pb_5	5.00	5.00	5.00	5.00	5.00	1.176

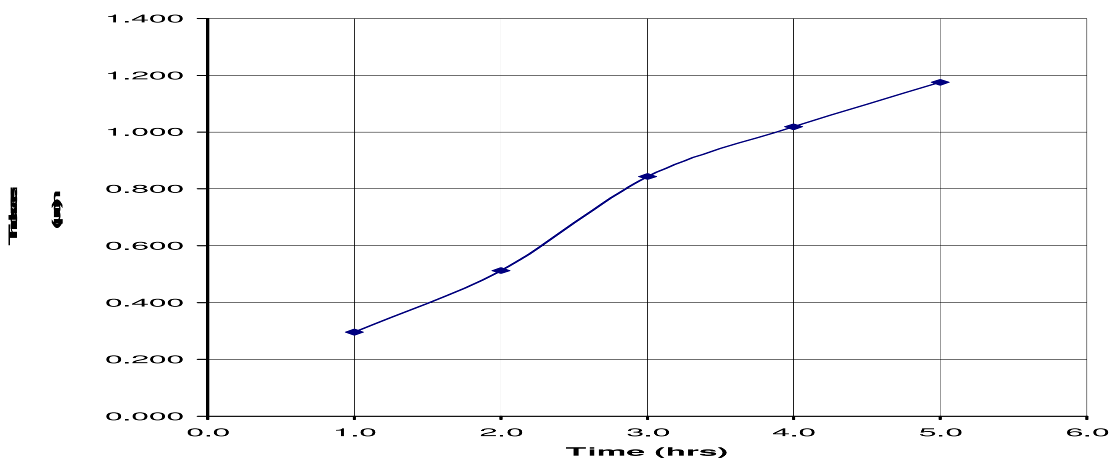

Figure-1
Plot of thickness versus time for PbS thin film

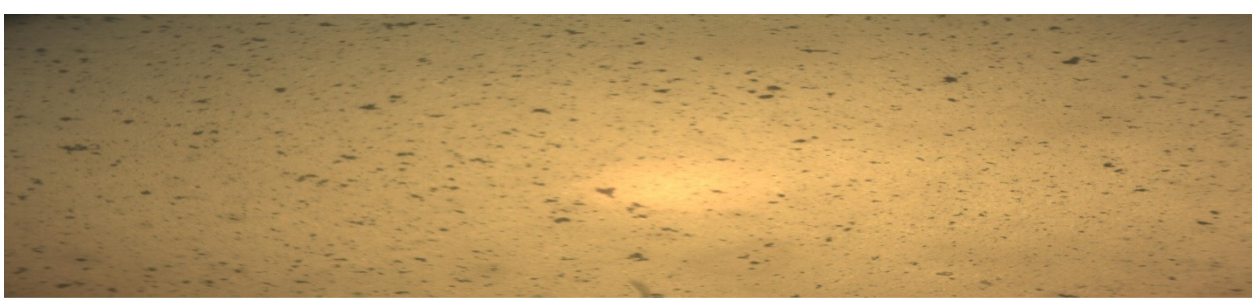

Figure-2
Optical Micrograph of PbS Thin Film

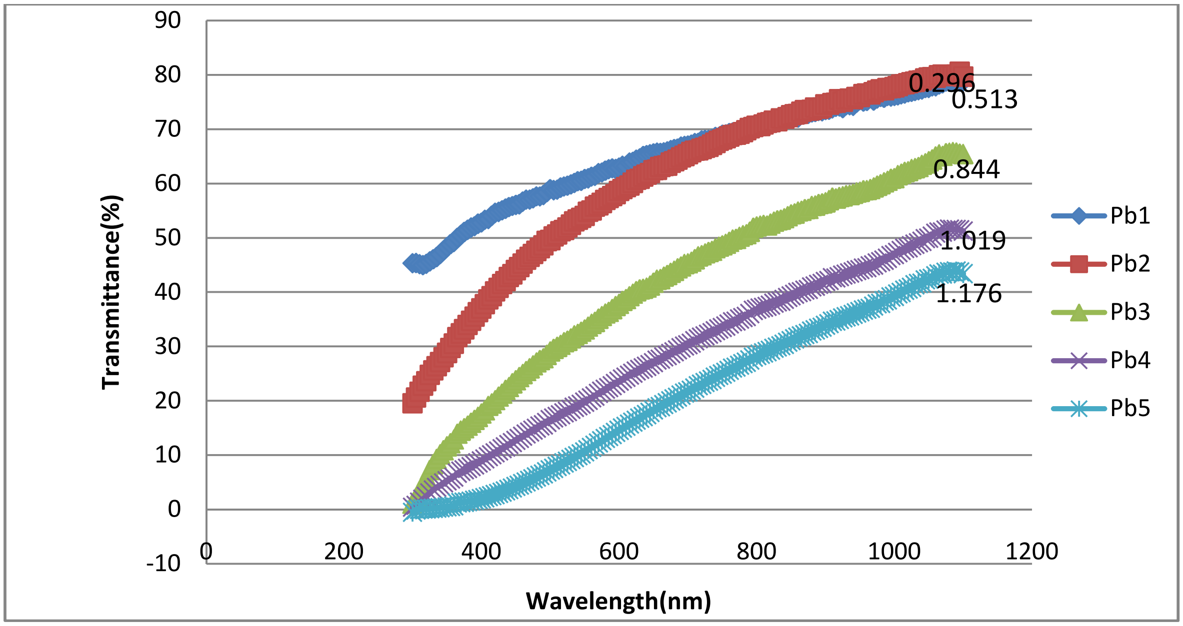

Figure-3
Spectral Transmittance of PbS films

Conclusion

PbS thin films have been chemically deposited on glass substrates from aqueous solutions of lead nitrate $[Pb(NO_3)]_2$, and thiourea $(SC(NH_2)_2)$, using EDTA disodium salt as a complexing agent and ammonia solution as a pH adjuster at 300K. The optical microscopy image showed that this film has uniform, small crystal size and covered the entire substrate surface completely. The films also have high transmittance in the visible/ near infrared region of the electromagnetic spectrum. This makes the films excellent glazing material for solar control in warm climate regions. The high transmittance also makes the films potential for use in manufacturing optical components, windows, mirrors, and lenses for high power IR laser. We also established that increase in the film thickness in chemical bath deposition of PbS thin film reduces the transmittance of the film.

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