

Optical Properties of a Synthesized PbS Thin Film Using Chemical Bath Method

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ABSTRACT The synthesis of PbS thin films was successfully carried out in the laboratory by neutralizing sulphide ions (S^{2-}) and lead ions (Pb^{2+}) from lead nitrate and thiourea compounds ($SC(NH_2)_2$) in crystalline form. The films were deposited on a glass substrate using the chemical bath method. The optical properties of the films, including absorbance, transmittance, reflectance, and refractive index, were investigated using a UV-visible spectrophotometer (model 6405) and a pH meter. The results showed a high absorbance of 1.105 a.u. in the visible region. The thickness of the films, which ranged from 0.71 μm to 3.34 μm , was found to have a near-linear dependence on the dip time. The study also revealed the following properties of the films: absorbance (0.02-1.105 a.u.), transmittance (0.9%-99%), reflectance (0.11%-98%), and energy band gap (1.6-2.70 eV) within the wavelength range of 400-1000 nm.

KEYWORDS: Aerosol Chemical Bath, Chemical Combinations, Optical Property.

I. INTRODUCTION

A thin film is a precipitate obtained from the chemical and physical processes taking place within the reactant components in a containing vessel. The precipitate will be seen coated or deposited on either glass, plastics or metal as substrate. Thin film of lead sulphides has been attracting researchers because of its wide range of application as antireflection coatings on window glasses, video screens camera lenses doors ,solar cell applications, temperature and humidity sensors, infrared detector optical and magnetic memories [1, 2]. The thin films are either crystalline or non crystalline developed on a substrate by physical or chemical methods[2]. There are several techniques required in the deposition of lead sulphide thin film such as electro-deposition, chemical vapour deposition [3], sputtering close-spaced vapour, chemical bath deposition CBD [4,5]. Among these techniques, chemical bath deposition method is simple, inexpensive, easy and convenient easy access to the materials and work can go on with or without power Optical properties of thin film generally have a direct impact on human vision especially the long sighted and short sighted patients. The construction of lenses to aid their vision is just the function of refractive indices of film used in treating glass which in turn de-pendent on reflectance of film used in glass [6]. Optical properties can be measured by spectroscopy including linear and non-linear optics. , conventional and non –conventional optical microscopy fibre optics for passive and active devices optical re-cording for CD/DVD and many more.[7] Lead sulphide (PbS) is an in-organic compound and occurs naturally as galena with the formula PbS. It is whitish-grey in colour, found as a member of semiconductors of groups IV – VI. It is a crystalline compound which has the same structure as sodium hydroxide (NaCl) (17). It means that lead sulphide has a face centered cubic lattice (fcc) and lattice constant is 5.94Å . Lead sulphide (PbS) is one of the semi-conductor materials that has a direct band gap in the range of 0.4eV – 1.98eV.

II. METHODOLOGY

A. EXPERIMENTAL PROCEDURE

The reagents used in this research are of an analytical grade. In this research, materials and equipment such as chemicals, beakers pH meter, stirrer, spatula, chemicals balance, thermometer, microscopic slides, electric furnace were used in the laboratory. A micro-scopic glass slide of dimension 25.4mm x 76.2mm and 1mm thick were used as substrate. The glass slides were decreased in concentrated nitric acid (HNO_3) for 48 hours, cleaned in cold water with detergent, rinsed with distilled water and dried in

air. The solution for deposition of lead sulphide thin film on both surfaces of glass substrates (microscopic glass slides) were constituted from aqueous solution of 1.0 mole tri-ethanol Amine (TEA) and 1 mole of sodium hydroxide (NaOH). The equivalent mass concentrations of solid reagents were measured using metter toledo (AB 0084) electric beam with four decimal places.

B. DEPOSITION OF LEAD SULPHIDE

The A very attractive method for producing PbS thin film is called chemical bath deposition (CBD) method. In this research the chemical bath deposition contains 37.9340g lead dissolved in 100ml of distilled water, 7.6120g of thiourea dissolved in 100ml of distilled water, 13.7325ml of Tri ethanol amine 100ml in distilled water; 4g of sodium hydroxide dissolved in 100ml of distilled water. The various solutions of the reagents are poured together in a chemical bath and stirred until the solid components of the solution dissolved completely before the substrates were immersed vertically using a peg and tied to a clamp on a retort stand. The temperature of the solution was at room temperature. Sodium hydroxide solution was added to increase the pH level of the solution to 9 which was measured by using a sum tex sp – 70/pH.MV/temperature The solution became cloudy, at first to dust brown and then dark brown. At this state a thick precipitate of lead sulphide had been formed. The grown samples were removed from the reaction bath, rinsed with distilled water and allowed to dry in air. During deposition, cations and anions in the solution reacted to become neutral atoms which either precipitated spontaneously or proceeds slowly. Fast precipitation implies that thin films could not be formed on the substrate immersed in the solution. However, on the addition of TEA, the reaction proceeded slowly for the thin film of neutral atom to be formed on the substrate. The complexing agents slowed down the precipitation action for formation of PbS. Sulphide ions were released by alkaline hydrolysis of thiourea, complexes absorbed onto the glass substrate when heterogeneous nucleation and growth took place by ionic ex-change reaction of Pb^{2+} ions. By the process of ion by - ion exchange, PbS was deposited on to the glass substrate in the form of uniform and adherent thin films. The equations of the reaction are shown below:

III. RESULTS AND DISCUSSION

Figure 1 shows the graph of thickness of PbS film against the deposition time. It is observed that the thickness increases with time. There is an approximately linear increase between 48hrs and 96hrs deposition time. This is in agreement with research by Ezenwa et al [10].

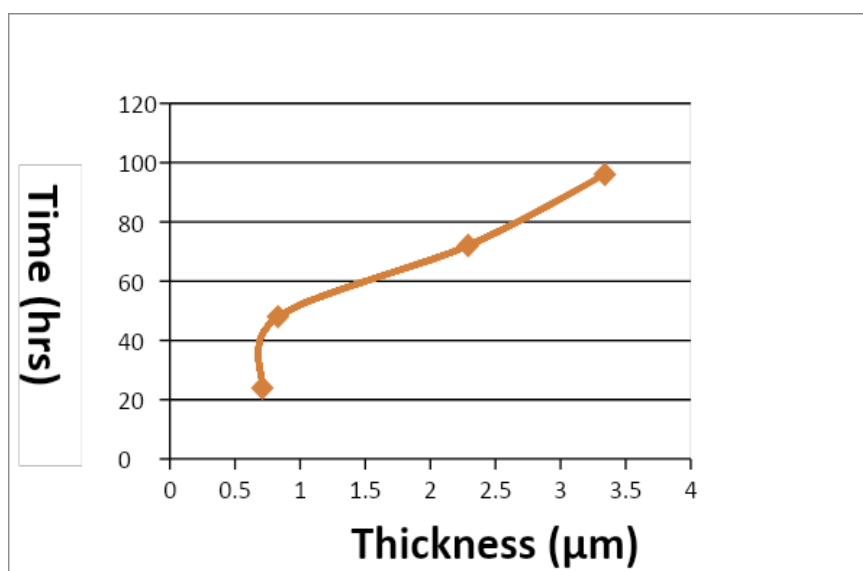


Figure 1. Thickness of PbS against Time

Figure 2 depicts the graphs from optical studies for the absorbance, transmittance and reflectance measurements carried out in the wavelength range from 400 to 1000nm. Figure 2a shows the absorbance of PbS variation with wavelength at different dip time of 24hrs, 48hrs, 72hrs, 96hrs for sample A, B, C and D respectively. The sample B which has a dip time of 48hrs was observed to have the highest peak of absorbance at 1.105a.u corresponding to wavelength of about 400 nm which is in the near infrared region. All the four samples have their peak at the same wavelength (400nm) which is in agreement with (Ezenwa and Ekpunobi, 2012; Ubale and Kulkarni, 2006) [10].

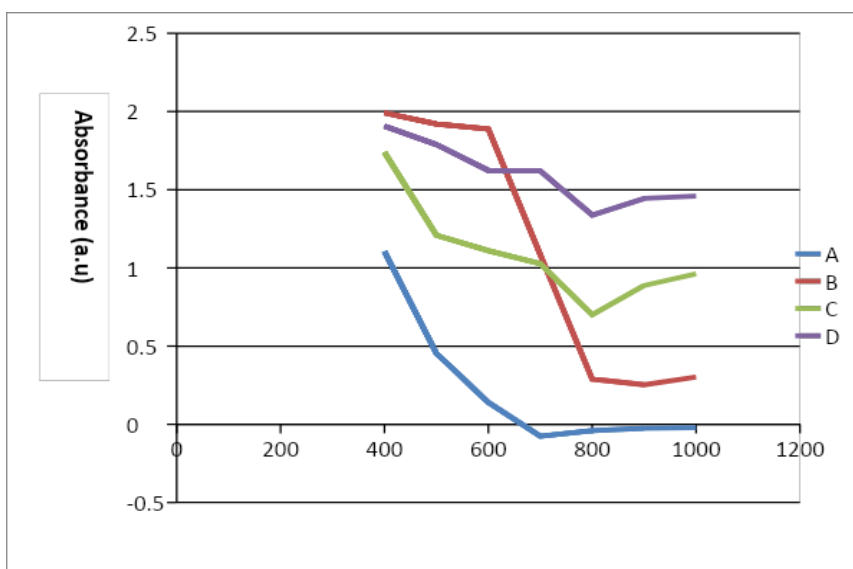


Figure 2a: Absorbance of PbS of the Four Samples (A, B, C and D) against Wavelength

Figure 2b shows at different dip times the transmittance spectra of PbS thin films. The samples exhibit low transmittance around the visible region and subsequently increase to the infrared region with a peak value of 98% B in the near infrared region for both sample A and B. This is consistent with (Ezekoye et al., 2015; Abbas et al., 2011) [11]. The reflectance of PbS was studied by plotting it against the wavelength shown in

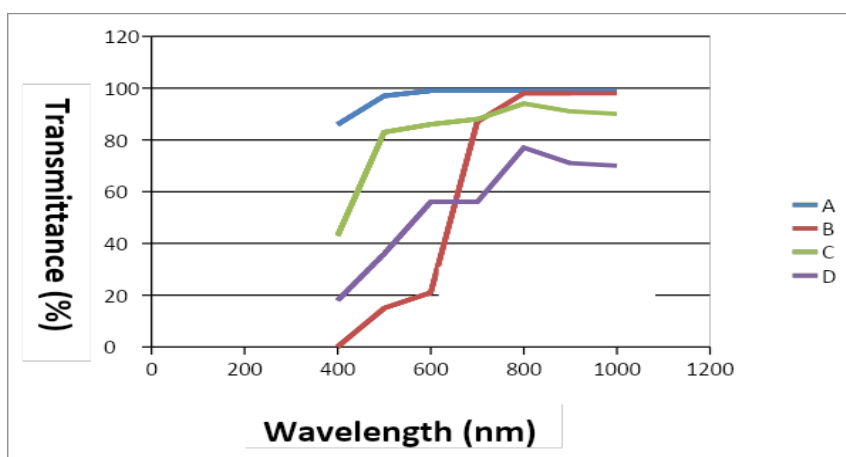


Figure 2b: Absorbance of PbS of the Four Samples (A, B, C and D) against Wavelength

Figure 2c. It was observed that the reflectance decreases with increase in wavelength. All the samples show high reflectance in the visible region which rapidly decreased in the near infrared region. Figure 3 shows the dependence of the refractive index on wavelength. The refractive index has a peak value

of 0.67 near the visible region for sample B. However, sample A, C and D shows the same dependence with wavelength with different refractive index.

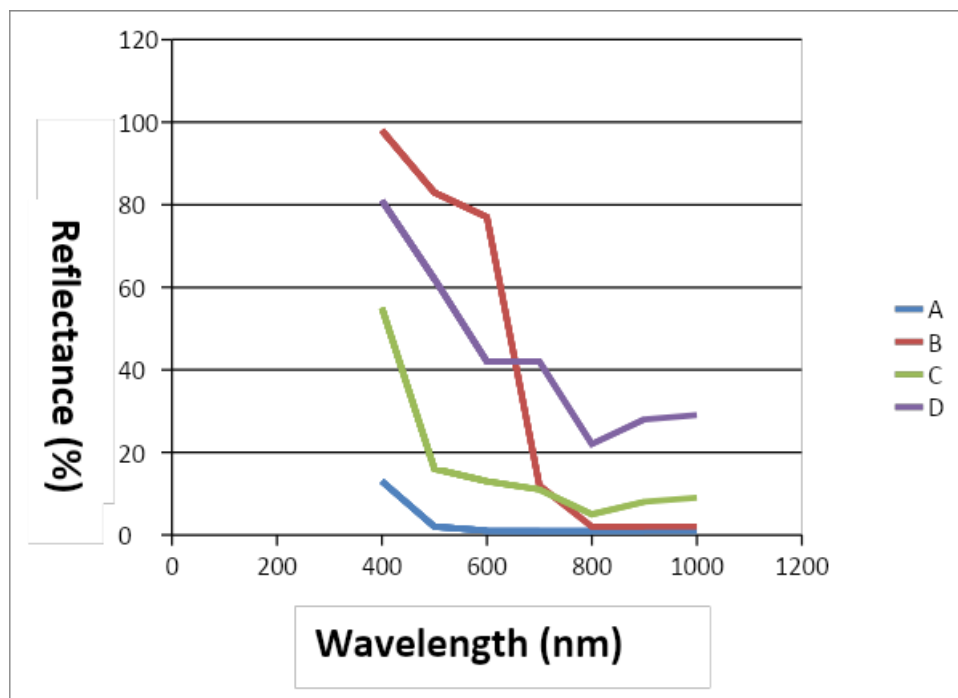
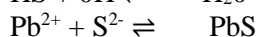
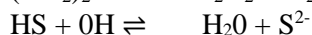
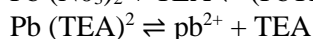
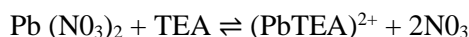


Figure 2c: Reflectance of PbS of the Four Samples (A, B, C and D) against Wavelength

Chemical Reactions



IV. CONCLUSION

The method adopted for this research is chemical bath deposition which is simple, inexpensive, easy availability of reagents and work goes on with or without electrical energy supply for the deposition of thin films of lead sulphide. The thickness of the films deposited was successfully measured using Meter Toledo (AB0084), electric beam balance. The thickness is obtained to be in range $0.71\mu\text{m} - 3.3\mu\text{m}$. It also verified that the thickness of the films deposited is proportional to the time of the deposition that is the thickness increases as the number of hour increases. The optical properties of the thin films of lead sulphide (PbS) such as absorbance, energy band gap, transmittance, reflectance were studied. The study revealed the absorbance to be in the range (0.02A-1.105A) transmittance in the range (0.9%)-99%) reflectance in the range (0.11%-98%) within the wave length of the radiations (400nm- 1000nm) energy band gap in the range (1.6eV – 2.70eV) which is in agreement with values obtained by other researchers in the field of lead sulphide.

The thin film is a layer of material deposited or coated on a substrate which could be plastics, glasses or metals to obtain a desirable effect. The films play a vital role in aspect of electronic optical devices. They have been used as electroplated films for decoration and protection, anti reflection coatings of windows, glasses, video screen, camera lenses etc. In 1998, I.C. Ndukwe carried out a research on optical properties and application of solution grown lead sulphide thin films on glass substrate at Federal University of Technology Owerri, Imo State from his analysis, the film thickness ranged from $0.34 - 0.44\mu\text{m}$, energy band gap ranged from 3.6 – 3.8 eV, high absorbance on average was 0.11 – 0.35 and high transmittance (78 -99%). Amusan J.A., Fajinmi G.R., Sanusi Y.K. and Okewoye S.A. (2007)

conducted research using chemical bath deposition method in the department of pure and applied physics, in research journal published 2007 the transmittance was in the range 20.9% - 69.5%. Ubale A.U., Kulkarni D.K (2006) conducted research titled thickness dependent structure and optical properties of chemically deposited lead sulphide thin films, energy band gap was obtained in range 1.88 – 2.65 eV. Lead sulphide PbS thin films were deposited on a glass substrate using chemical bath deposition method. It is confirmed that the material was found to be p-type semi-conductor and brownish in colour deposited tightly on the glass substrate. The thicknesses of the films were 0.71µm, 0.83µm, 2.92µm and 3.34µm for samples A 12 , B 12 , C 12 , and D 12 respectively. This shows that the thickness of the films increases as the number of day increases. The absorbance, transmittance and reflectance, refractive indices and the band gap energy for each sample s were also studied The optical properties studied and the result shows a high absorbance and high reflectance in the visible region, low absorbance and high reflectance in the near infrared region. These observations make the PbS film an excellent material for anti-reflection coating, for improving the solar energy conversion from visible light region to the near-infrared region and for solar thermal application.

It is recommended that other methods such as, physical vapour, (cathodic arc deposition, sputtering, etc) should be used. The result obtained would be compared with the results of this work. Also, testing of new combination of semi-conducting materials and electrolyte-solvent systems. Using other types of substrates such as metals. The possibility of coating the windows and doors for passive cooling should also be looked into. The possibility of using other group of III-VIII elements for thin film growth should also be looked into. Finally, concentration greater than one mole for the various reagents should be used.

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