SYNTHESIS AND OPTICAL PARAMETERS OF $Pb_{15}Cd_{45}S_{40}$ LAYERED COATING

J. C OSUWA*, C.I ORIAKU, E.C MGBAJA
Department of Physics, Michael Okpara University of Agriculture Umudike, P.M.B 7267, Umuahia, Abia State, Nigeria.

A comparative study of optical properties of ternary CdS-PbS layered coatings and binary CdS thin film is herein presented. The analysis of both CdS-PbS and CdS thin films synthesized by CBD technique was performed with RBS spectrometer and a computer aided double beam UV-VIS spectrophotometer (model JENWAY 6405). The results show that CdS-PbS exhibited improved optical and solid state properties in a wide range of lower and upper ends of the wavelength spectrum.

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1. Introduction

The synthesis of binary metal chalcogenides of group II-VI semiconductors in nanocrystalline form has experienced an enormous development in the recent years owing to their interesting size dependent optical and electrical properties [1, 2]. Exploring the behavior of semiconductors and insulators is of fundamental importance in the study of their band structures. A direct transition occurs when the lowest energy state in the conduction band has the same value of wave vector as the highest energy state in the valence band, otherwise indirect transition results [3]. Cadmium sulphide semiconductor thin film is the most widely studied chalcogenide material. It is a wide band gap semiconductor with energy band gap $E_g \approx 2.42$ eV [4]. PbS thin film is known to be a narrow direct transition band gap semiconductor, which at room temperature, is known to exhibit direct energy band gap of approximately 0.37-0.4eV [5]. The material properties of chemically deposited thin film PbS are known to depend strongly on the deposition conditions [5]. By chemical bath deposition (CBD) technique, the dimensions of the crystallites can be varied by controlling the deposition parameters such as deposition temperature, pH, reaction time, and presence of impurities in the solution bath [3, 6]. Improvements in optical and solid state properties have been reported for many ternary semiconductor materials. These materials can be achieved by layered coating or impurity doping. In this paper, we investigated the optical and solid state properties of CdS-PbS layer in comparison with CdS thin films.

2. Experimental Detail

2.1 Syntheses of CdS substrate and CdS-PbS layer

The formation of CdS-PbS layer was achieved by depositing PbS thin films on CdS substrate. The CdS substrate thin films were formed by the sequential addition of of 2ml 0.2M $CdCl_2.2\frac{1}{2}$ H_2O, of 5ml of 25% NH_3, 5ml of 1M CS $(NH_2)_2$ and 38ml of deionized water was added to make it up to 50ml. The deposition time was 3 hours, after which the substrate was

* Corresponding author:josuwa70@gmail.com

withdrawn and washed. The CdS substrate was formed by dipping a clean glass slide into a bath containing 2.5M of 1M $Pb(CH_3COO)_2.3H_2O$, 3.5ml of 2M NaOH, 3ml of 1M CS $(NH_2)_2$,1ml of 1M triethanolamine (TEA) and 40ml of water. The solution bath was allowed to stay for 30minutes thereafter it was withdrawn and dried.

2.2 Characterizations of the Films

Rutherfords Backscattering Spectrometry (RBS) was carried out for the determination of the compositions and thickness of the CdS-PbS layer. The optical transmission spectra of the thin films were performed with a computer controlled double beam UV- VIS spectrophotometer (model JENWAY 6405) with an uncoated glass as reference.

3. Results and discussion

3.1 Compositional Studies

Table1 shows the elemental compositions of CdS-PbS thin film layer as determined by RBS spectrometry. A tandem accelerator equipped for ion beam analysis having RBS cross-section was used. The beam primary ions were $^4He^+$ of incident energy of 2.2eV. The RBS results suggested that the CdS-PbS layer was of percentage composition form $Pb_{15}Cd_{45}S_{40}$. The RBS measurements also revealed that the thickness of the layer is 307nm.

Table1: Elemental compositions of glass and CdS-PbS layer.

Sample	% Oxygen	% Silicon	% Calcium	% Aluminum	% Sodium	% Lead	% Cadmium	% Sulphur
Glass	50.0	25.0	5.0	10.0	10.0	-	-	-
CdS-PbS	-	-	-	-	-	15	45	50

3.2 Optical Studies

3.2.1 Variation of Spectral Properties

The spectral transmittance and reflectance of the films are shown in Figures 1 and 2. Tables 2 and 3 present the measured spectral transmittance and reflectance values for CdS and CdS-PbS layer at some selected wavelength of the VIS-NIR region.

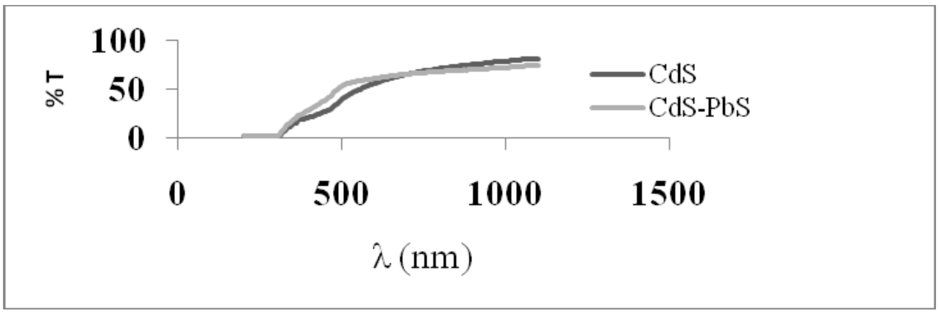

Fig1: Transmission spectra of CdS and CdS-PbS layer

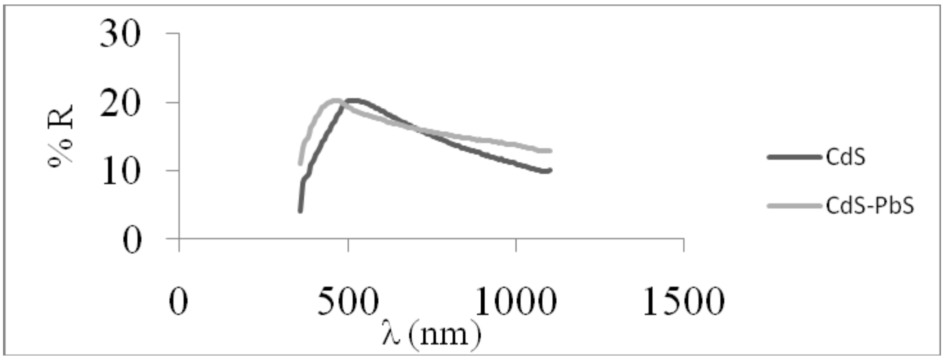

Fig2: Reflection spectra of CdS and CdS-PbS layer

Studies show that the percentage transmittance of CdS thin films ranges from 22% – 65% in the visible and 65% – 81% in the near infrared region of the solar spectrum. The transmittance of the CdS-PbS layer ranges between 30% and 65% in visible region and increased to 74% in the near infrared region. The percentage reflection of the CdS substrate is between 12% and 16% in the visible region and 11% - 20% in the near infrared. For CdS-PbS layer, the reflection is between 16% and 17% in the visible, and 14% - 20% in the near infrared region. The gradual reduction of solar transmission in the near infrared region and moderate transmission in the visible region which characterize CdS-PbS layer suggests its possible application in solar thermal control.

Table2: Variation of % spectral Transmittance with photon wavelength

Sample	400nm	500nm	600nm	700nm	800nm	900nm	1000nm	1100nm
CdS	21.63	39.72	55.98	65.16	71.20	75.24	78.25	80.63
CdS-PbS	29.14	53.21	60.88	65.31	68.16	70.14	71.86	73.79

Table3: Variation of % spectral reflectance with photon wavelength

Sample	400nm	500nm	600nm	700nm	800nm	900nm	1000nm	1100nm
CdS	11..87	20.18	18.82	16.24	14.04	12.40	11.10	10.02
CdS-PbS	17.31	19.39	17.57	16.19	15.22	14.49	13.78	13.01

3.2.2 Solid state properties

The solid state of both CdS substrate and CdS-PbS thin films layer were studied from measured optical transmission data. The details of the mathematical determination of thin film absorption coefficient α, refractive index n, real dielectric constant ε_r, and imaginary constant ε_i, from transmission data have been reported [7- 10]. Their various plots against photon energy are presented in figs 3,4,5 and 6. The average values of α, n, ε_r, ε_i and thickness t, of CdS and CdS-PbS layer are presented in table 4.

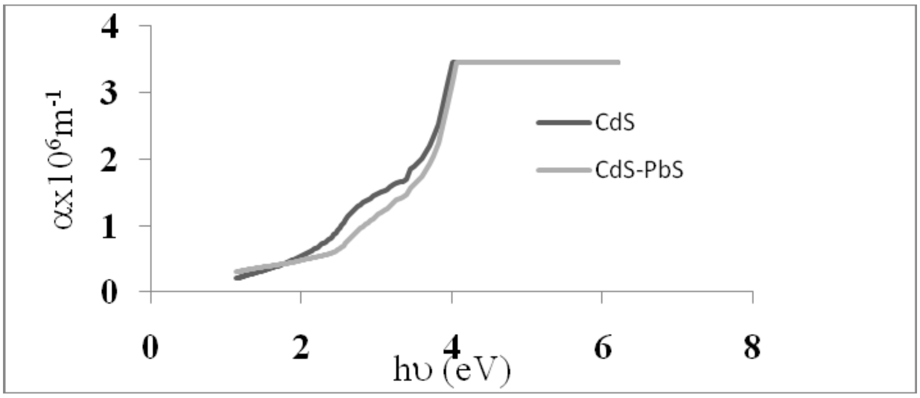

Fig3: Plot of absorption coefficient (α) versus photon energy of CdS and CdS-PbS layer

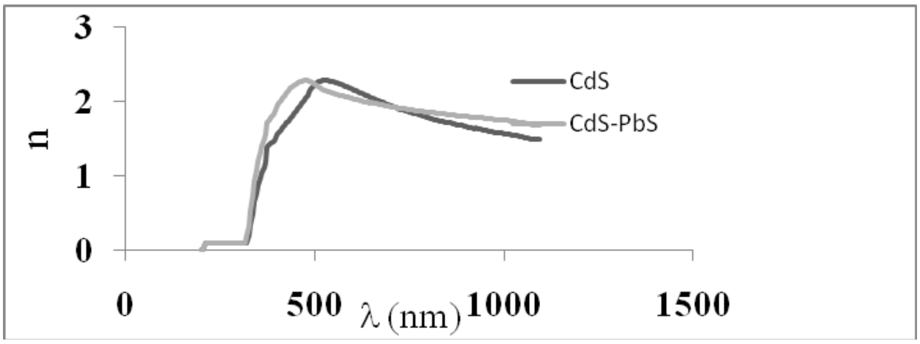

Fig4: Plot of refractive index (n) versus photon wavelength (λ) of CdS and CdS-PbS layer

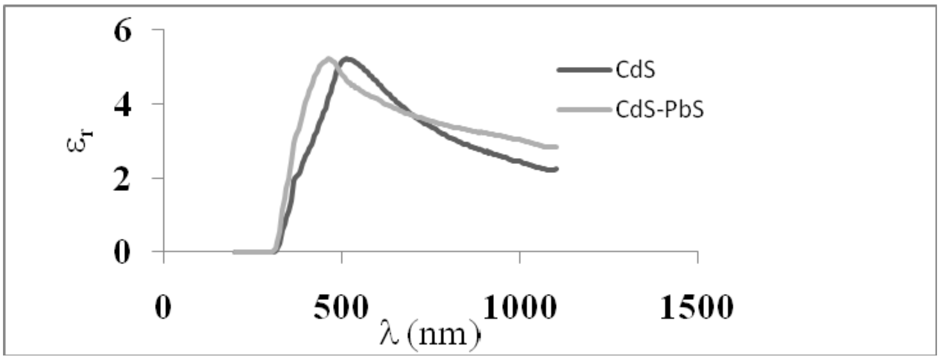

Fig5: Plot of real dielectric constant (ε_r) versus photon wavelength (λ) of CdS and CdS-PbS

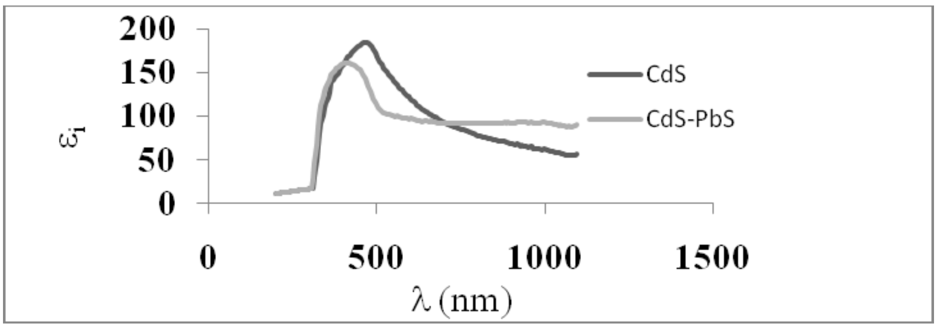

Fig6: Plot of imaginary dielectric constant (ε_i) versus wavelength (λ) of CdS and CdS-PbS

Table4: Average solid state parameters, optical band gap and thickness, t of CdS and CdS-PbS

Sample	$ax10^6$ (m^{-1})	n	ε_r	ε_i	t (nm)	E_g (eV)
CdS	1.04	1.54	2.80	90.31	43.2	2.48
CdS-PbS	0.98	1.64	3.10	92.11	68.16	2.52

3.2.3 Determination of optical band gap

The optical band gap E_g of the films was estimated by using the following relation [3-5, 7-11]:

$$(\alpha h\nu)^p = A (h\nu - E_g) \quad (1)$$

where A is a characteristic parameter independent of photon energy hν, p is a constant which depends on the nature of the transition between the top of the valence band and bottom of the conduction band. The lowest optical band gap energy in semiconducting materials is referred to as the fundamental absorption edge and nature of interband transition is characterized by p [12,13]. For allowed indirect transition p=1/2 and for the allowed direct transition p=2. Our plots for CdS and CdS/PbS layer indicate direct interband transition. By plotting $(\alpha h\nu)^2$ versus the incident photon energy (hν) as in Fig. 7 and extrapolating the straight-line portion of the plots toward low energies, the optical band gap can be obtained.

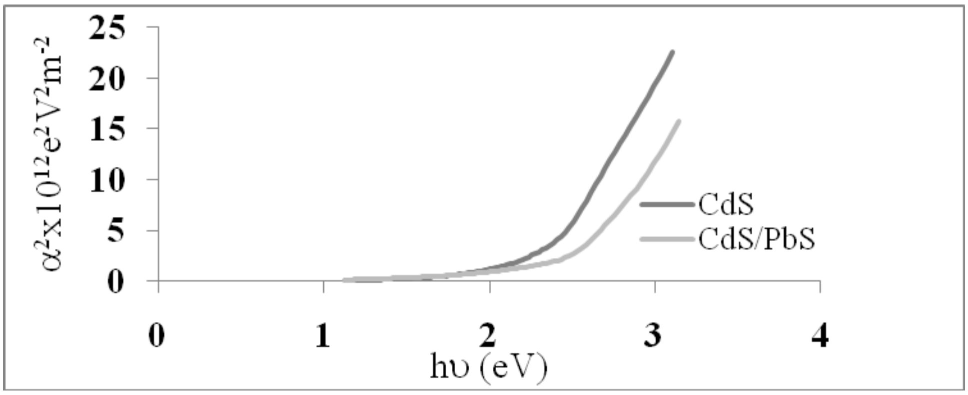

Fig7: Plot of α^2 versus photon energy of CdS and CdS-PbS

The value of optical band gap energy of CdS and CdS-PbS are 2.48eV and 2.52eV respectively. The closeness of band gap of the CdS-PbS layer to the band gap of bulk CdS [4] indicates that the layer is reach in Cd^{2+} ions.

4. Conclusion

Layered coatings of CdS-PbS ternary thin film was synthesized by CBD technique. Measured values of optical and solid state properties including transmittance, reflectance, absorption coefficient, refractive index, energy band gap, etc. showed significant improvements when compared with values for CdS binary thin film.

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