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Growth and Characterization of Lead Selenide (PbSe) Thin Film, by Chemical Bath Deposition

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Abstract

Lead Selenide (PbSe) thin film has been grown on glass slides by Chemical Bath Deposition method at 300k. Characterization of optical and structural properties of the films were carried out using a Jane way 6405 UV-VIS Spectrophotometer and an X-ray mini-diffraction (MD-10) using Cukα radiation with λ = 1.5406 nm . The absorbance of the deposited films was high while the transmittance was almost zero within the visible and infrared regions of electromagnetic spectrum. The optical band gap of the deposited film was found to be 0.28eV. The deposited thin films of Lead Selenide were found to be polycrystalline in nature. XRD studies reveals cubic structure with preferred orientation along (200) plane. The lattice constant was found to be 5.84Å.

Keywords: Lead Selenide, Chemical bath, Thin films, Optical and structural properties.

Introduction

Metal chalcogenides compounds, have semiconducting properties for which reason they are for technical interest in the production of electronics and electro - optical devices. For past years, research works have been carried out on the fabrication and characterization of these compounds in the form of thin film[1]. Lead Selenide thin film has motivated many researchers due to its application in solar cell technology[2-6]. There exist many methods for the deposition of PbSe thin films which were reported in the literature, these deposition methods are of two categories; chemical and physical deposition methods. Examples of chemical deposition methods are chemical bath deposition (solution growth technique), spin coating deposition, atomic layer deposition etc. while the physical deposition methods are sputtering deposition, electro spray deposition, cathodic arc deposition etc [7-15]. Lead Selenide thin films are mostly used as a major material in infrared sensor, grating, photo resistor, lenses and various optoelectronic devices[16-18]. In this paper, optical and structural properties of PbSe thin film prepared by chemical bath deposition method at 300k are presented.

Material and Methods

The films used for this experiment were synthesized by chemical bath deposition (CBD) method. The chemical reaction for the deposition of PbSe thin film was based on the reaction between lead acetate {$(CH_3COO)_2$ Pb. $3H_2O$)} as the source of lead ions, EDTA Di Sodium salt as the complexing agent, Selenium sulphate ($SeSO_4$) as the source of selenium ions, and Ammonia (NH_3) as pH adjuster at 300k. In this experiment, five chemical reaction baths (50mls beakers) were used. 5mls of lead acetate was measured into a 50ml beaker using burette; 2mls of EDTA was then added and stirred gently to achieve uniform mixture. The reaction is exothermic. 5mls of selenium sulphate was then added, 2mls, 4mls, 6mls, 8mls and 10mls of ammonia solution were then added to the mixtures in the reaction baths respectively. The mixtures were then topped with distilled water to 50mls mark and stirred to achieve uniform mixture. A glass substrate was dipped vertically into all of the five reaction baths. The baths were left to stand for 24 hours (as indicated in Table 1) after which the substrates were removed after 24 hours, rinsed with distilled water and dried in clean air. The slides were observed to have been coated with thin films. The optimal parameter was found to be pH of 10.38. The optical characterization of PbSe thin films was done using Janeway 6405 UV-VIS model of spectrophotometer while the X-ray mini-diffraction (MD-10) using Cukα radiation with λ = 1.5406 nm was used to study the structural properties. Chemical equations for the deposition are:

$(CH_3COO)_2Pb.3H_2O+EDTA \leftrightarrow [Pb(EDTA)]^{2+}+2(CH_2COOH)+2(OH)^-+H_2O$

$Pb(EDTA)^{2+} \leftrightarrow Pb^{2+} + EDTA$

$SeSO_4 + 2(OH)^- \leftrightarrow SO_4^{2-} + (OH)_2Se$

$(OH)_2Se + 2(OH)^- \leftrightarrow Se^{2-} + 2H_2O+O_2$

$PbS^+ + Se^{2-} \leftrightarrow PbSe$

Results and Discussion

Figure-1 and 2 shows the plots of transmittance and absorbance as a function of wavelength (λ) for PbSe thin film. The transmittance spectra displayed in figure-1, shows vibration of atomic constituent of PbSe in UV region and zero transmittance was shown in Vis and Infrared region of electromagnetic spectrum, while high absorbance was observed within visible and infrared regions of electromagnetic spectrum, hence the films can be used in fabrication of solar cells and also be for spectral selective windows and diachronic mirrors.

Table-1
Variation of pH for 24 hours for PbSe thin film Volume of reagents used (mls)

Reagents used	Slide 6	Slide 7	Slide 8	Slide 9	Side 10
$(CH_3COO)Pb.3H_2O$	5	5	5	5	5
EDTA	2	2	2	2	2
$SeSO_4$	5	5	5	5	5
NH_4	2	4	6	8	10
Distilled H_2O	36	34	33	30	28
pH value (no unit)	9.34	9.37	9.96	10.14	10.38

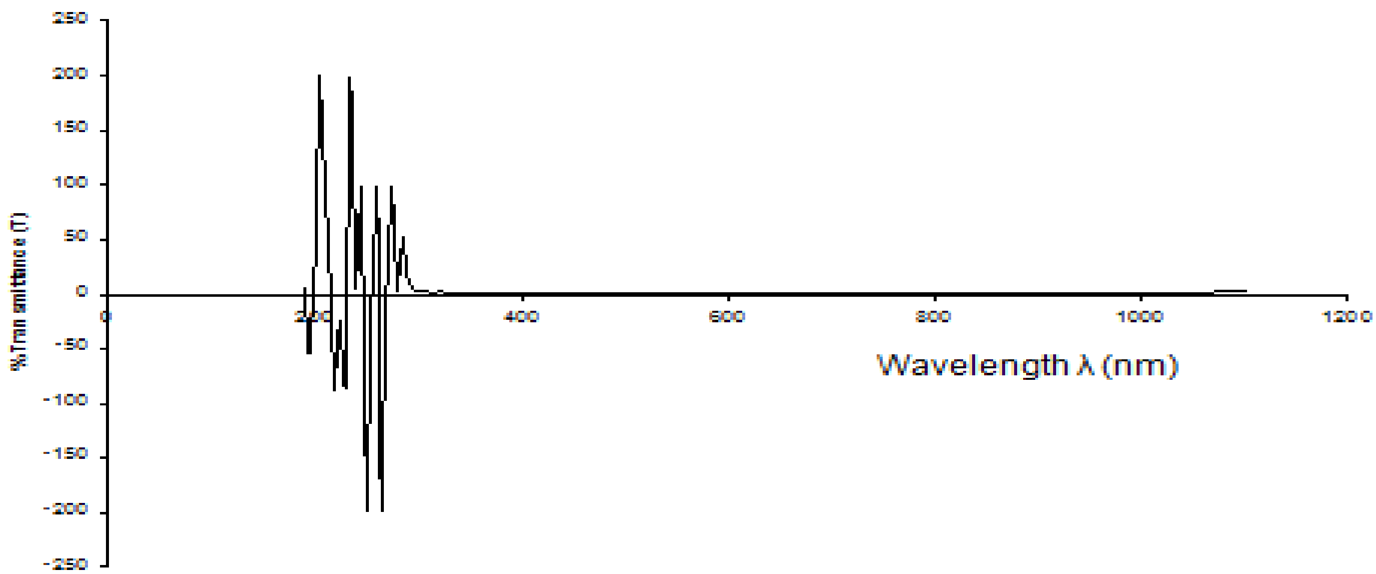


Figure-1
Transmittance as a function of wavelength (λ) for PbSe thin film

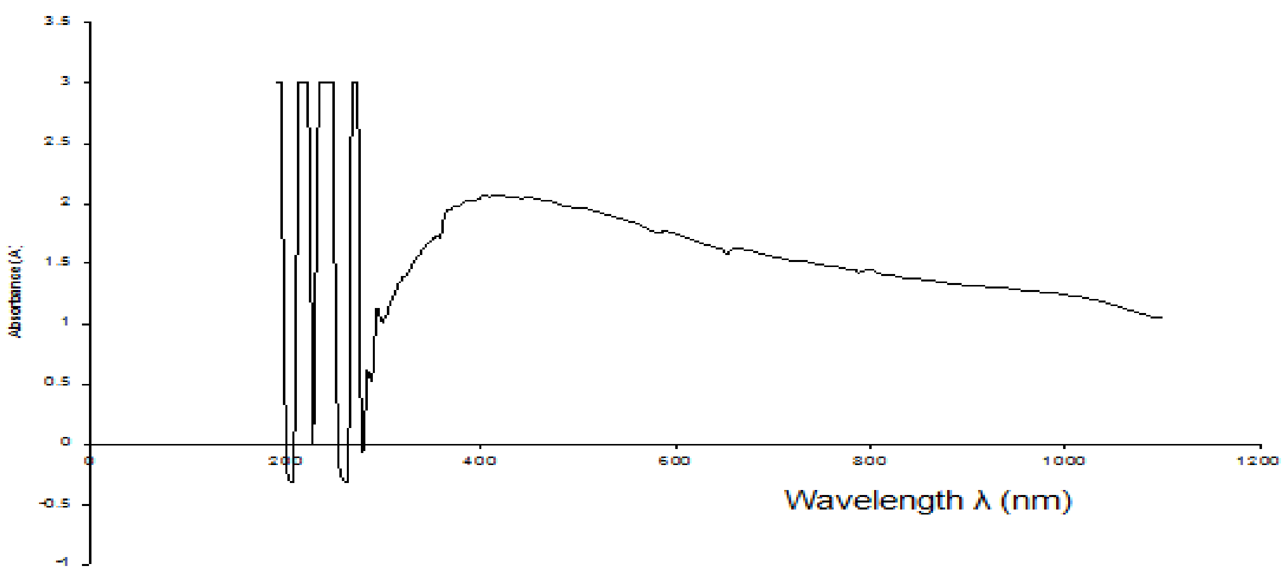


Figure-2
Absorbance as function of wavelength (λ) for PbSe thin film

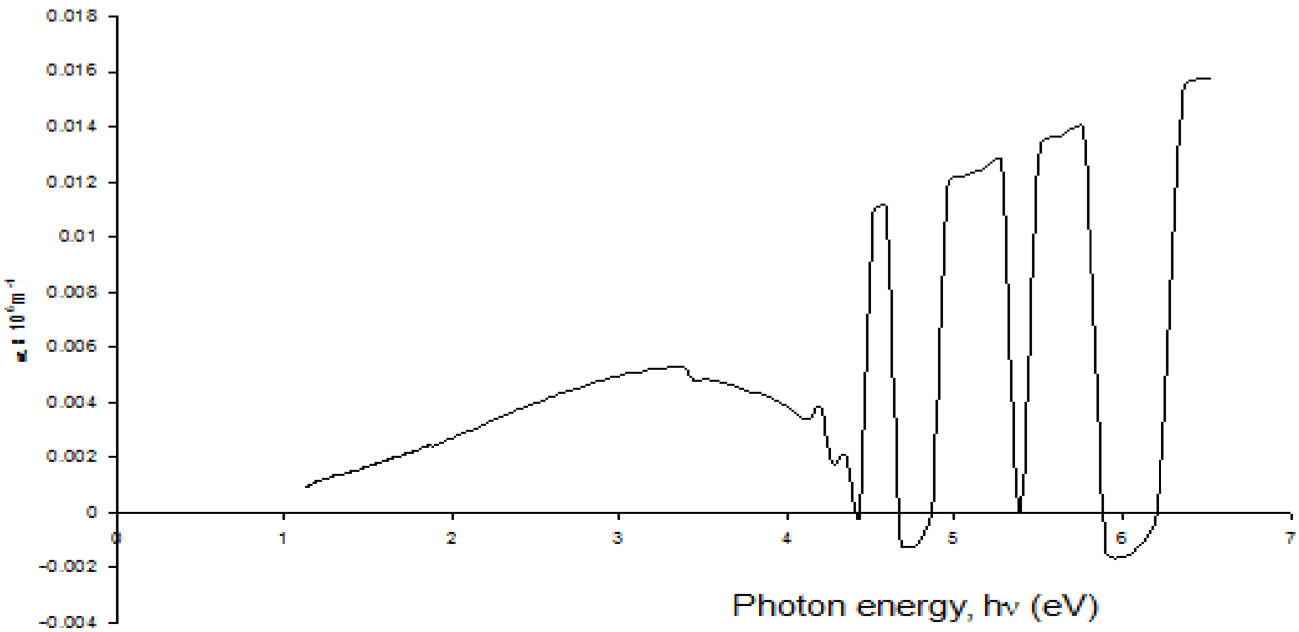
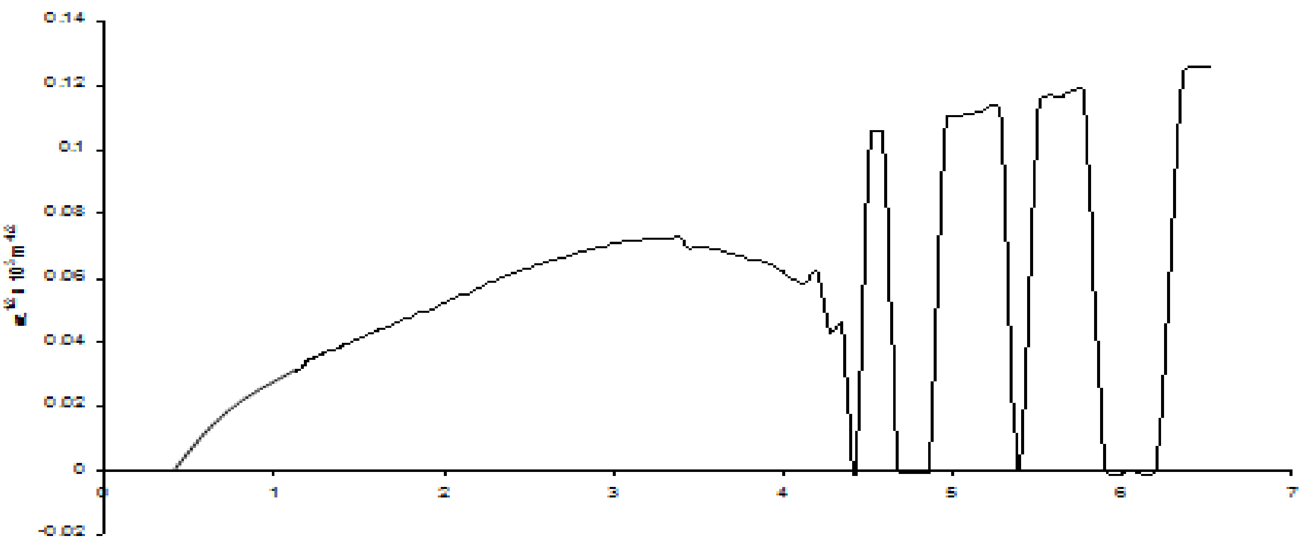


Figure-3
Absorption coefficient (α) as function photon energy (hν) for PbSe thin film



Photon energy hν (eV)
Figure-4
Square root of absorption coefficient ($\alpha^{1/2}$) as a function of photon energy (hν)

Figure-4 shows plot of square root of absorption coefficient ($\alpha^{1/2}$) as a function of photon energy (hν), which gives the intercept of the inverted curve with the photon energy axis, when $\alpha^{1/2} = 0$ gives the band gap of 0.28eV.

Figure-5 shows a plot of reference slide (a clean slide that has no deposition on its surface), which has no prominent peak because there was no deposition on it, and this confirms that glass is amorphous in nature.

Figure-6 shows prominent peak in 2θ values which correspond to (200) plane and other peaks at different 2θ values which also correspond to (220) and (111) planes respectively. The film is polycrystalline in nature due to the presences of the peaks[20]. The predominant growth of crystallites perpendicular to (200) plane gave rise to the clausthalite cubic structure with lattice constant 5.84Å and is in close agreement with Okereke[21]. The predominant orientation in the (200) plane has been reported by Prabahars[22].

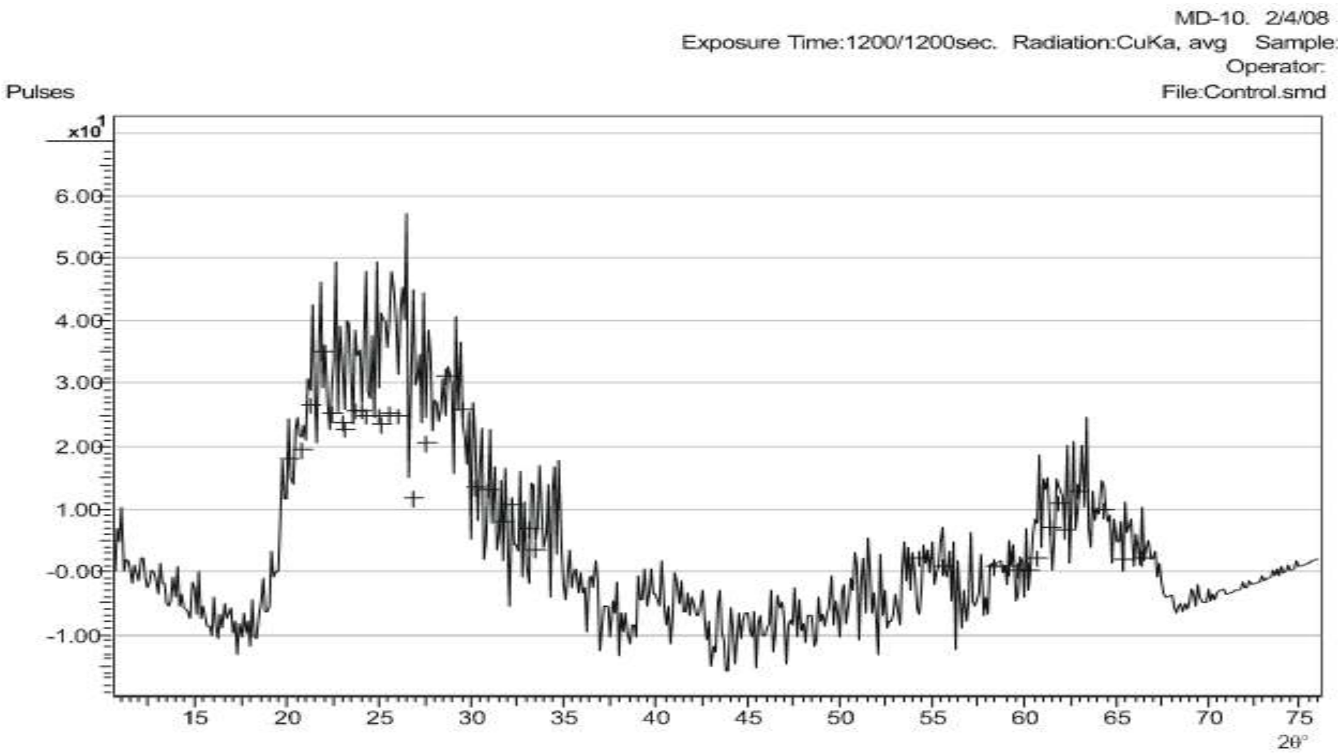


Figure-5
X-ray spectra for uncoated slide (control slide)

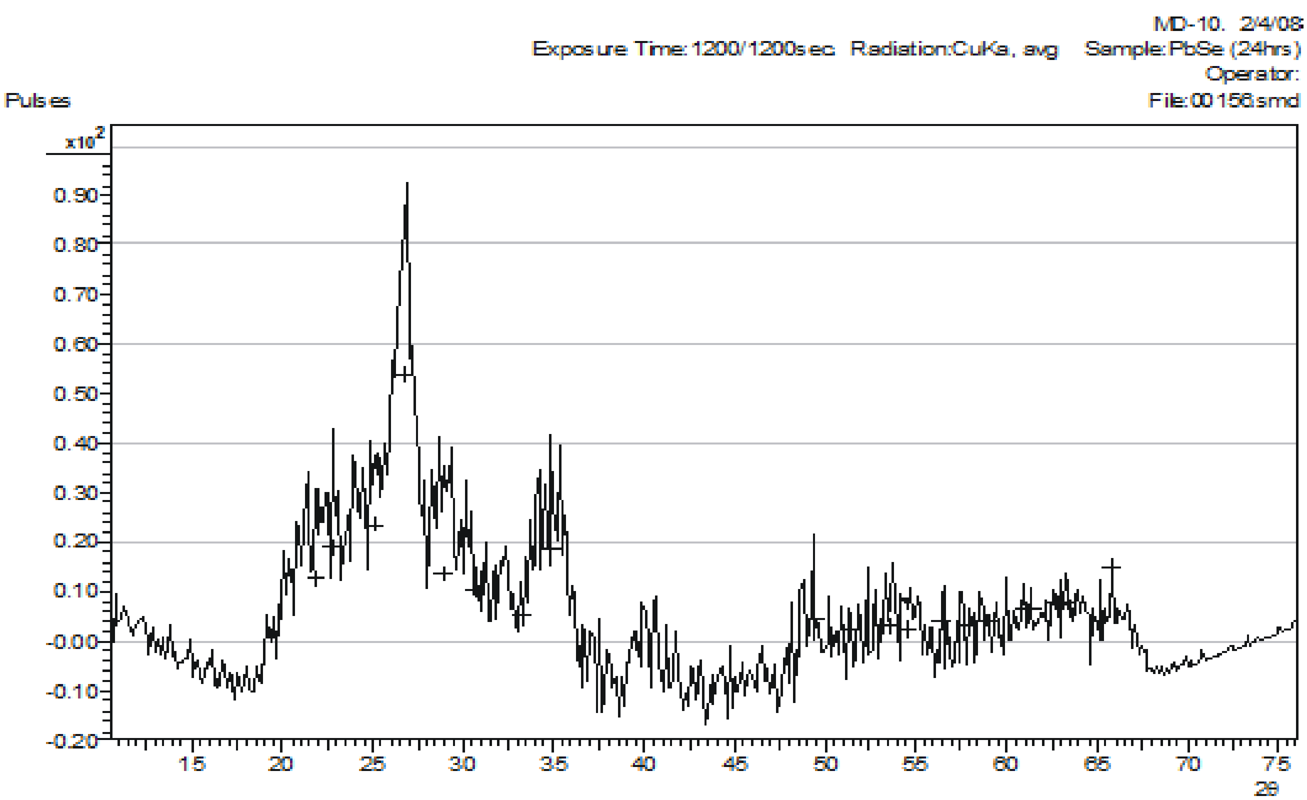
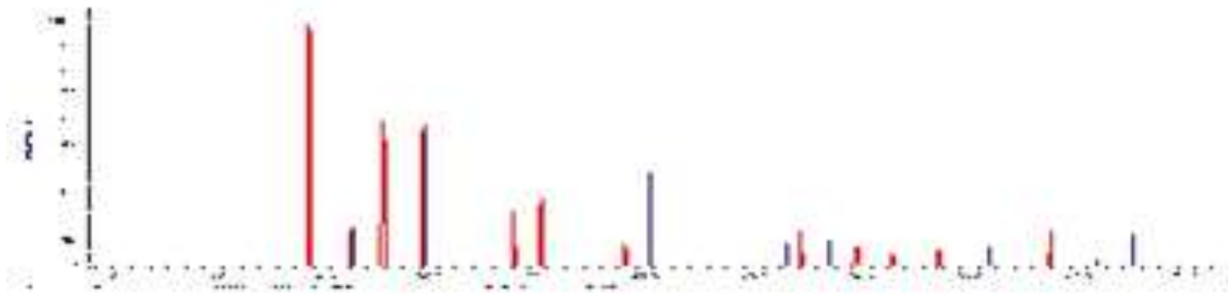


Figure-6
X-ray spectra for coated slide at 300k



Figure–7
XRD diffraction pattern for PbSe thin film

Conclusion

Thin films of Lead Selenide were successfully grown on glass slides by chemical bath deposition method. The reaction bath was formed with the solutions of $(CH_3COO)_2$ $Pb.3H_2O$, $SeSO_4$, EDTA and NH_3 in 50mls beaker. PbSe thin films were found to have zero transmittance within visible and infrared region of electromagnetic spectrum while the absorbance was high within VIS and decreased a little within infrared regions of electromagnetic spectrum. It therefore provides an opaque coating on glass which can be applied for thermal window glass coating. It also can be used in fabrication of solar cells. The energy band gap was determined to be 0.28eV. Structural characterization reveals that the films are crystalline of cubic structure. The relative intensity was maximum at $2\theta = 29.1406^0$ corresponding to the (200) plane. The lattice constant was calculated to be 5.84Å.

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