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Electrical Properties of Electrodeposited Lead Selenide (PbSe) Thin Films

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Authors' contributions

This work was carried out in collaboration between authors KIU and IIL. Author KIU designed the study, performed the statistical analysis, wrote the protocol and first draft of the manuscript. Authors KIU and IIL managed the analyses of the study. Author IIL managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

PbSe thin films were electrodeposited onto ITO substrate with variation of deposition voltage (1-5V). The deposited thin films were characterized using the four point probe technique to determine their electrical properties. The sheet resistivity of the thin films was found to vary from 1.50 $\times 10^4$ (Ωm) to 5.23 x 10^4(Ωm) and conductivity vary from 1.91 x 10^{-5} $(\Omega m)^{-1}$ to 7.40x$10^{-5}$$(\Omega m)^{-1}$, which is within the electrical conductivity range for semiconductor. It was observed that as the refractive index of the incident radiation increases the photon energy increases as well. It was noticed that sample N with 168nm thickness recorded the highest value of refractive index which increases from 2.424-2.643 and sample O with 164 nm thickness revealed the highest peak in all the samples deposited. It shows that as the optical conductivity of the incident radiation increases the photon energy increases. It was observed that sample follows the same thread and sample O with 164nm thickness revealed the highest peak in all the samples deposited.

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Keywords: Thin film; PbSe; Ito; four point probe; electrical properties; sheet resistivity; conductivity.

1. INTRODUCTION

Lead Selenide (PbSe) thin films is a semiconducting material and has been deposited using different technique for solar cell technology and others applications like infrared detectors, photographic plates, photodetectors, photoresistors and photoemitters in the infrared (IR). Lead Selenide (PbSe) thin films have received much research attention owing to their promising materials for application as selective and photovoltaic absorbers, light emitting diodes and lasers [1,2]. Since the electrical characteristics of semiconductor thin films play a crucial role in the practical application in microelectronics industry, hence they is a need to study the effects of deposition parameters on the electrical properties of PbSe thin films. The sheet resistivity of thin film which is the surface inherent resistance to the flow of electric current is directly utilized in determining the surface impurity content and hence doping level and electron mobility [3]. This also affects its component's capacitance, series resistance and threshold voltage. Lead selenide thin film has been found to have sheet resistivity of about 0.4 x 10^2 (Ωm) to 2.4 x 10^2 (Ωm) [4] and the electrical conductivity value vary from an average of 0.78 x 10^{-4} – 0.71 x $10^{-4}(\Omega m)^{-1}$ [5]. Different technique for preparing PbSe thin films both physical and chemical deposition techniques have been used to deposit lead selenide thin films, including electrodeposition [6,7-8], chemical bath deposition [9], electrochemical atomic layer epitaxy [10], photochemical [11], molecular beam epitaxy [12] and pulsed laser deposition method [13]. Electrodeposition is used to prepare PbSe thin film. Among the various methods electrodeposition technique provides a simple root of synthesizing thin films because of its simplicity, low-cost experimental setup from an economical point of view. In addition, this technique could be used for the production of large-area thin film deposition without any high vacuum system. CVD techniques, without exceptional, require high vacuum and or temperature because it is necessary to produce gaseous precursor molecules or atoms. Besides the high energy needed for the film processing, emission of gaseous waste materials is another serious problem with these technique [7-8]. In this study, the four point probe technique was used for the electrical characterization of the electrodeposited PbSe thin films in other to determine their electrical properties.

2. EXPERIMENTAL DETAILS

The Aqueous electrolytic baths for the electrodeposition of PbSe thin films were composed of 0.09M of SeO_2, 0.07M of $Pb(NO_3)_2$ as sources of selemiun and lead ions respectively, with addition of 0.14M of K_2SO_4 as a supporting electrolyte. The solution was acidified with 0.1M of H_2SO_4, which adjust the pH value to 1.8 +- 0.1. In each of the reaction baths prepared, an ITO substrate and carbon electrode was connected to the DC power supply source and thirteen slides were deposited under variation of deposition voltage (1-5V), from sample N-R we regulated the voltage from (1V-3V) and for others samples the voltage was regulated from (4V-5V) at constant time (60S) and pH (1.8).

The deposited PbSe thin films were characterized for electrical properties using the four point probe method. The four equally space probes were brought in contact with the deposited thin film of PbSe N to Z. The probe arrays were placed in the center of the thin films deposited. Two of the probes were used current source and the other two probes were used to measure the voltage across the deposited thin film. The error noted in the experimental measurement was $\pm 0.1 - 0.01$.

The sheet resistance (R_s), sheet resistivity (ρ) and electrical conductivity (σ) of the deposited thin films were calculated using the following equations:

$$R_s = \frac{\pi}{in2}\, x\, \frac{V}{I} = 4.53\, x\, V/I$$

$$\rho = R_s \text{ x thickness (t)}$$

$$\sigma = I/\rho$$

The 4-point probe setup consists of four equally spaced tungsten metal tips with finite radius. Each tip is supported by springs on the other end to minimize sample damage during probing. The four metal tips are part of an auto-mechanical stage which travels up and down during measurements. A high impedance current source is used to supply current through the outer two probes; a voltmeter measures the voltage across the inner two probes to determine the sample resistivity.

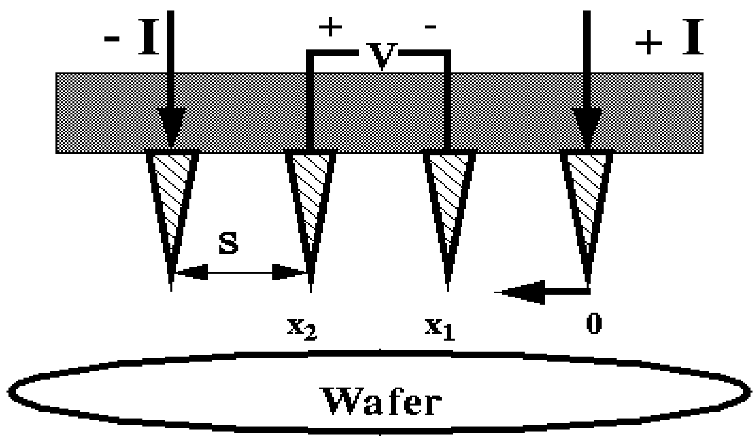

Fig. 1. Schematic of 4-point probe configuration

3. RESULTS AND DISCUSSION

The analysis carried out on electrical characterization PbSe thin films of various samples shown in Table 1. The plot of sheet resistivity as a function of thickness in Fig. 1 and the plot of conductivity as a function of thickness in Fig. 2 which revealed that sample PbSe S, T, U, V and W shows an increases in sheet resistivity from 2.51 X 10^2 (Ωm**)** to 2.22 X 10^5(Ωm**)** as the films thickness increases from 182nm to 217nm while the conductivity decreases. This is as a result of the increase in value of the deposition voltage. This result compare well with the result reported by [14-15]. Sample PbSe X, Y and Z Shows an increase in sheet resistivity as the thickness increases, which is as a result of the value of deposition pH.

Generally, It is observed that the sheet resistivity varies from 1.50 x10^4 (Ωm**)** to 5.23 x 10^4(Ωm**)** while the electrical conductivity varies from 1.91 x 10^{-5} (Ωm**)**$^{-1}$ to 7.40x10^{-5}(Ωm**)**$^{-1}$ which is within the electrical conductivity range of 10^{-6} (Ωm**)**$^{-1}$ to 10^4 (Ωm**)**$^{-1}$ for semiconductor [16].

The high resistivity value make this thin film useful in solar cells application to improve the conversion efficiency as this could reduce the inevitable defects in solar cells fabrication during the actual production process [17]. As a result, PbSe thin films values of 2.51 x10^2 (Ωm**)** and 2.38 x 10^5(Ωm**)** resistivity is quit suitable for a buffer layer in Solar cell and PV panel.

The optical analysis of PbSe thin films in Fig. 4-5 revealed the plot of refractive index as a

Table 1. Electrical properties of PbSe thin films

Samples	Thickness (t) (nm)	Sheet resistivity (ωm)	Conductivity (ωm)$^{-1}$
PbSe N	168	5.23 X 10^4	1.91 X 10^{-5}
PbSe O	164	2.94 X 10^2	3.40 X 10^{-3}
PbSe P	158	2.22 X 10^5	4.50 X 10^{-5}
PbSe Q	148	1.56 X 10^4	6.41 X 10^{-5}
PbSe R	138	1.41 X 10^5	7.09 X 10^{-6}
PbSe S	178	1.35 X 10^5	7.40 X 10^{-5}
PbSe T	182	2.87 X 10^4	3.48 X 10^{-3}
PbSe U	190	2.51 X 10^2	3.98 X 10^{-6}
PbSe V	206	2.17 X 10^5	4.61 X 10^{-6}
PbSe W	217	2.22 X 10^5	4.51 X 10^{-6}
PbSe X	158	2.38 X 10^5	4.20 X 10^{-6}
PbSe Y	156	1.64 X 10^4	6.09 X 10^{-5}
PbSe Z	150	1.50 X 10^4	6.67 X 10^{-6}

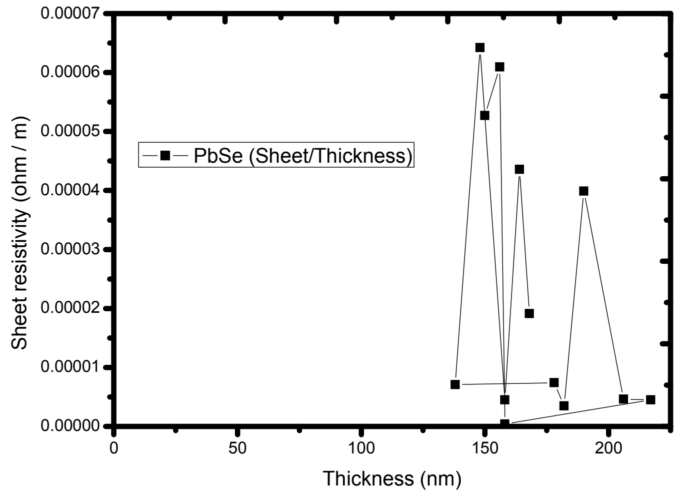

Fig. 2. Variation of sheet resistivity with thickness for PbSe thin films

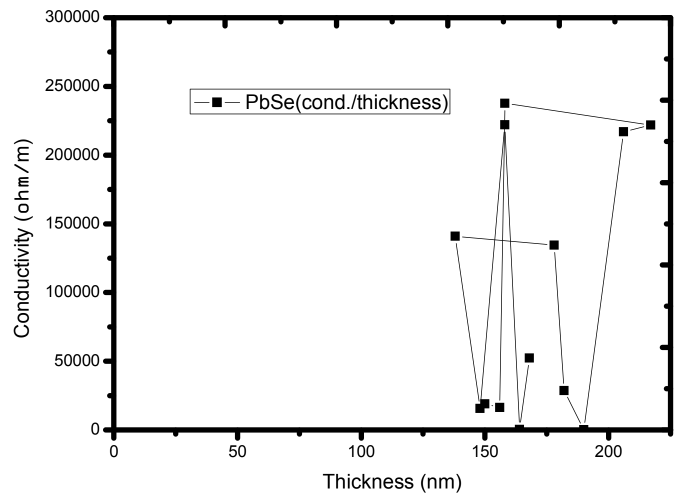

Fig. 3. Variation of conductivity with thickness for PbSe thin films

function of photon energy and wavelength respectively. From Fig. 4, it was observed that as the refractive index of the incident radiation increases the photon energy increases as well. It was noticed that sample N with 168nm thickness recorded the highest value of refractive index which increases from 2.424-2.643 and sample O with 164nm thickness revealed the highest peak in all the samples deposited which show that the material deposited is good for solar cell fabrications. The plot of refractive index versus wavelength as shown in Fig. 5 revealed that as the wavelength of the incident radiation increases the refractive index increases. It was noticed that all the deposited samples reflect much from 400 nm-880 nm in both infrared and ultraviolet region of the deposited material [17].

From Fig. 6-7 revealed the plot of optical conductivity as a function of photon energy and wavelength. From Fig. 6, it shows that as the optical conductivity of the incident radiation increases the photon energy increases. It was observed that sample follows the same thread and sample O with 164nm thickness revealed the highest peak in all the samples deposited which show that the material deposited is good for solar cell fabrications. The plot of optical conductivity versus wavelength as shown in Fig. 7 revealed that as the wavelength of the incident radiation increases the optical conductivity increases. It was noticed that all the deposited samples reflect much in both infrared and ultraviolet region of the deposited material [17].

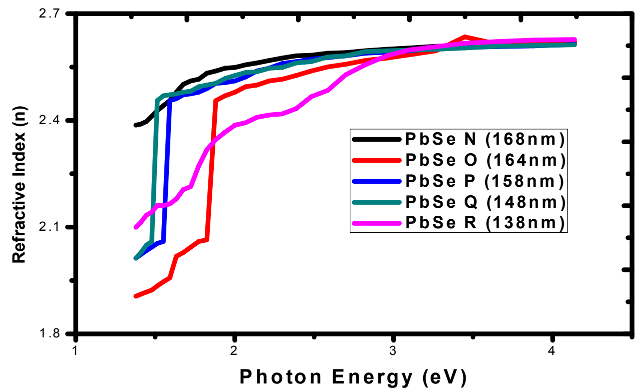

Fig. 4. The plot of refractive index as a function of photon energy

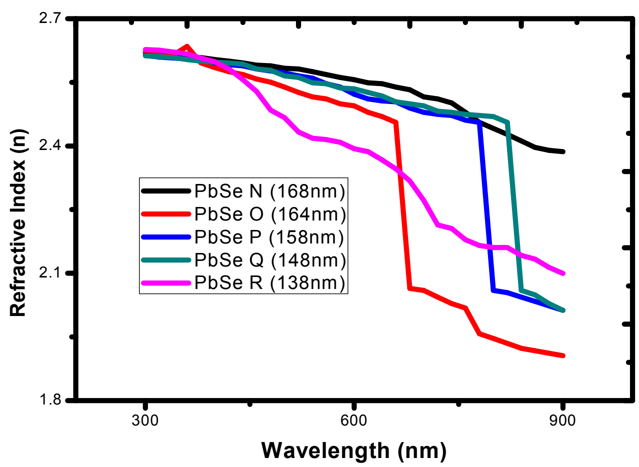

Fig. 5. The plot of refractive index as a function of wavelength

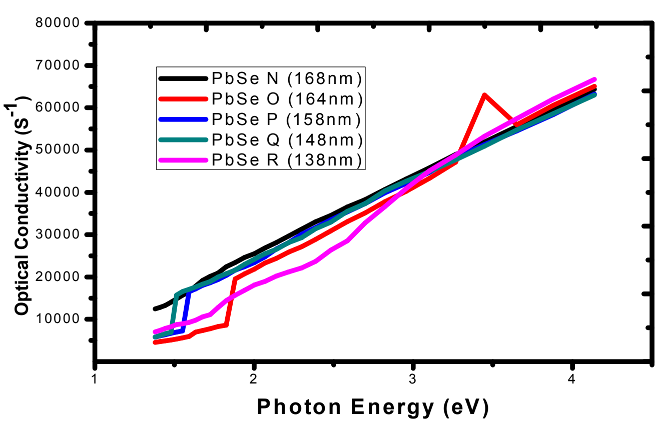

Fig. 6. The Plot of optical conductivity as a function of photon energy

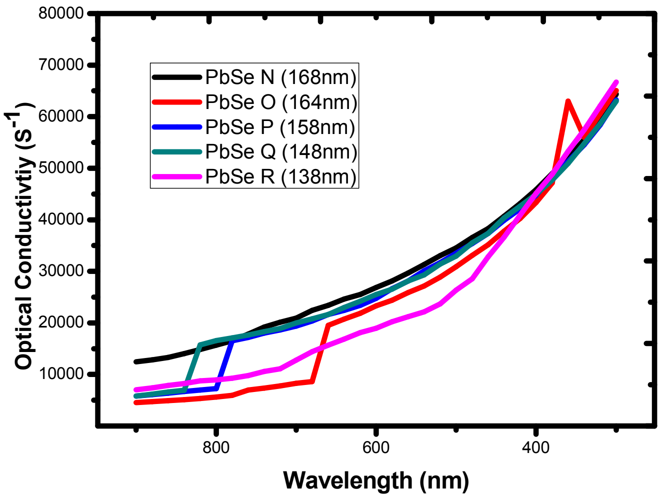

Fig. 7. The Plot of optical conductivity as a function of wavelength

4. CONCLUSIONS

PbSe thin films were electrodeposited onto ITO substrate with variation of deposition voltage *(1-5*V*)*. The deposited thin films were characterized using the four point probe technique to determine their electrical properties. The sheet resistivity of the thin films was found to vary from 1.50 $\times 10^4$ (Ωm**)** to 5.23 x 10^4(Ωm**)** and conductivity vary from 1.91 x 10^{-5} (Ωm**)**$^{-1}$ to 7.40x10^{-5}(Ωm**)**$^{-1}$, which is within the electrical conductivity range for semiconductor. it was observed that as the refractive index of the incident radiation increases the photon energy increases as well. It was noticed that sample N with 168 nm thickness recorded the highest value of refractive index which increases from 2.424-2.643 and sample O with 164 nm thickness revealed the highest peak in all the samples deposited. It shows that as the optical conductivity of the incident radiation increases the photon energy increases. It was observed that sample follows the same thread and sample O with 164 nm thickness revealed the highest peak in all the samples deposited.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Sethuramachandran T, Thaiyan M, Dhanasekaran A. Growth and characterization of lead selenide thin films. J Mater Sci: Mater Electro. 2012;23:1564-1568.
2. Ezenwa IA. Optical properties of chemical bath deposited lead selenide thin films. Advances in Applied Science Research. 2012;3(2):980-985.
3. Maria P, Gutierrez S, Haiyong I, Patton J. Thin film surface resistivity, in partial fulfillment of course requirements for Mate 210. Experimental Methods in Material Engineering, USA; 2002.
4. Arivazhagan V, Manonmani M, Rajesh S. Structural, optical, morphological and electrical properties of PbSe bi-layer thin films. Indian Journal of Material Science. 2011;7(5):325-330.
5. Oluyamo SS, Ojo AS, Nyayba MS. Characterization of nanostructured lead selenide (PbSe) thin films for solar device application. Journal of Applied Physics; 2015.
6. Molin AN, Dikusar AI. Thin solid films. 1995;265:3-9.
7. Ikhioya I Lucky, Ugbo FC, Ijabor B Okeghene. Growth and characterization of manganese sulphide (MnS) thin films. International Journal for Research in Applied and Natural Sciences. 2018;4(1): 1-9.
8. Ikhioya IL. Optical and electrical properties of copper telluride thin films. International Journal of Research in Chemistry and Environment. 2015;5(3):28-32.

9. Grozdanov IM, Najdoski Dey SK. Materials letters. 1999;38:28-32.
10. Vaidyanathan R, Stickney JL, Happek U. Electrochimica Acta. 2004;49:1321-1326.
11. Zhu JJ, Liao XH, Wang J, Chen HY. Materials research bulletin. 2001;36:1169-1176.
12. Gautier CG, Breton M, Nouaoura M, Cambon S Charar, Averous M. Thin solid films. 1998:315:118-122.
13. Rumianowski RT, Dygdala RS, Jung W, Bala W. Journal of Crystal Growth. 2003; 252:230-235.
14. Barote MA, Yadav AA, Surywanshi RV, Deshmukh LP, Masumder EU. Chemical bath deposited PbSe thin films: Optical and electrical transport properties. Res. J. Chem. Sci. 2012;2(1):15-19.
15. Rajesh S, Arivazhagan V, Manonmani PM. Structural, optical and electrical properties of vacuum evaporated PbSe/ZnSe multilayer thin films. AIP Conference Proceedings. 2012;1451:197.
16. Gosavi SR, Deshpande NG, Gudage YG. Sharma R. Physical, optical and electrical properties of copper selenide (CuSe) thin films deposited by solution growth technique at room temperature. Journal of Alloys and Compounds. 2008;448:344-348.
17. Ikhioya IL, Ekpunobi AJ. Electrical and structural properties of ZnSe thin films by electrodeposition technique. Journal of the Nigerian Association of Mathematical Physics. 2015;29:325-330.

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