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Optical Properties of Tin Selenide Thin Films Prepared by Chemical Bath Deposition Technique

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Abstract
Thin films of Tin Selenide (SnSe) semiconductor material were deposited on glass substrate using Chemical Bath Deposition Technique at room temperature (300K). The films were optically characterized using M501 Single Beam Scanning UV/Visible spectrophotometer at wavelength range of 320nm-600nm. The films show high absorption coefficient of 0.192 x 10^6m- 1.031x10^6m. They were also found to possess high optical conductivity value of 0.58 x $10^{13}S^{-1}$ – 6.47 x 10^{13} S^{-1} and low extinction coefficient of 0.0092-0.0262. The refractive index calculation shows a value range of 2.05-2.63 and the films were found to have high percentage transmittance value of 56%- 76%. The reflectance value was found to be generally low. The Band gap energy range of 1.20-1.70eV was obtained for the material. All these desirable properties made the material to be a good candidate for photovoltaic applications.
Keywords: Chemical Bath Deposition Technique, Optical Conductivity, Refractive index, Extinction Coefficient, Absorption coefficient Band gap energy and Photovoltaic.

1.1 Introduction
The discovery of semiconductor materials by Scientists has revolutionized electrical and electronic industries. Tin Selenide (SnSe) Semiconductor material has attracted the attention of researchers due to its interesting electrical and opto-electronic properties. It has found applications in fabrication of solar cells, switching devices and even in holographic reading systems [1-3]. Different methods have been used by researchers to prepare this semiconducting material. Some of these techniques include; Photo- electrochemical deposition [4], Electro-deposition [5], Vacuum deposition [6], hot wall epitaxy [7] and so on. In this work, chemical bath deposition technique was used to synthesize thin films of Tin Selenide (SnSe) on a glass substrate at various dip-times. The method was adopted because it is cost effective, simple, and reproducible, and with it large area of substrate can be coated with the material.

1.2 Materials and Methods
Thin films of Tin Selenide (SnSe) were deposited on the glass substrate at room temperature from the aqueous solution of potassium selennate (K_2SeO_4), tin chloride ($SnCl_2$), ammonia solution and ethylenediaminetetra acetate (EDTA) which serves as a complexing agent. To obtain the deposition of tin selenide (SnSe) thin films, 5ml of 0.2M $SnCl_2$ was put into a 50ml capacity glass beaker and EDTA was added and stirred very well. This was followed with addition of 5ml of 0.2M K_2SeO_4 and 5ml of ammonia solution and resulting solution was stirred. The volume was made up to 50ml mark with distilled water. The pre-clean glass substrate attached to a holder was mount vertically in the Bath and allowed to stay for six hours. After six hours the substrate was removed, rinsed with distilled water and allow to dry in the air. Three other set-ups were prepared in this way and allow to stay for 12hrs, 24hrs and 30hrs. Thereafter, the samples were optically characterized with M501 Single Beam Scanning UV/Visible Spectrophotometer. The equation of reaction is stated below;

$$SnCl_2 + EDTA \longleftrightarrow [Sn\,(EDTA)^{2+}] + 2Cl^-$$

$$[Sn\,(EDTA)^{2+}] \longleftrightarrow Sn^{2+} + EDTA$$

$$K_2SeO_4 + OH- \longleftrightarrow K_2O_5 + HSe^-$$

$$HSe^- + OH^- \longleftrightarrow Se^{2-} + H_2O$$

$$Sn^{2+} + Se^{2-} \longleftrightarrow SnSe \qquad (1.1)$$

1.3 Result and Discussion
Optical properties of the deposited films were studied. They include; absorbance, transmittance, reflectance, absorption coefficient, optical conductivity, refractive index, extinction coefficient and band gap energy. The absorbance of the film to incident radiation was obtained directly from the spectrophotometer. The values of the

absorbance were used in calculating other parameters. The results show that absorbance and reflectance values of the films were generally low. This is depicted in figures 1 and 2 respectively.

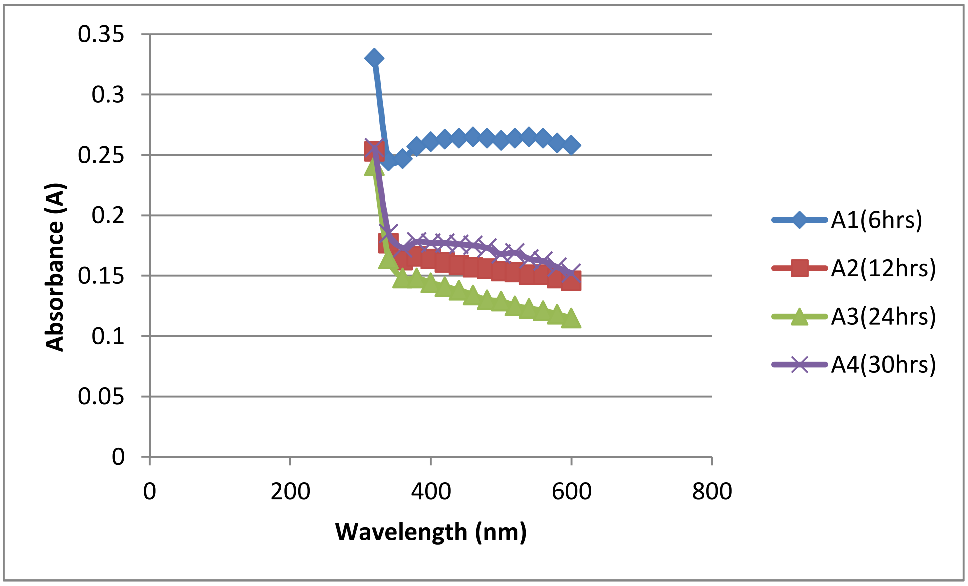

Figure 1 : Plot of Absorbance against Wavelength for the four samples at different Dip-times

The reflectance value was calculated using the equation 1.2 below;

$$R = 1 - (A+T) \quad (1.2)$$

Where A is the absorbance and T is the transmittance.

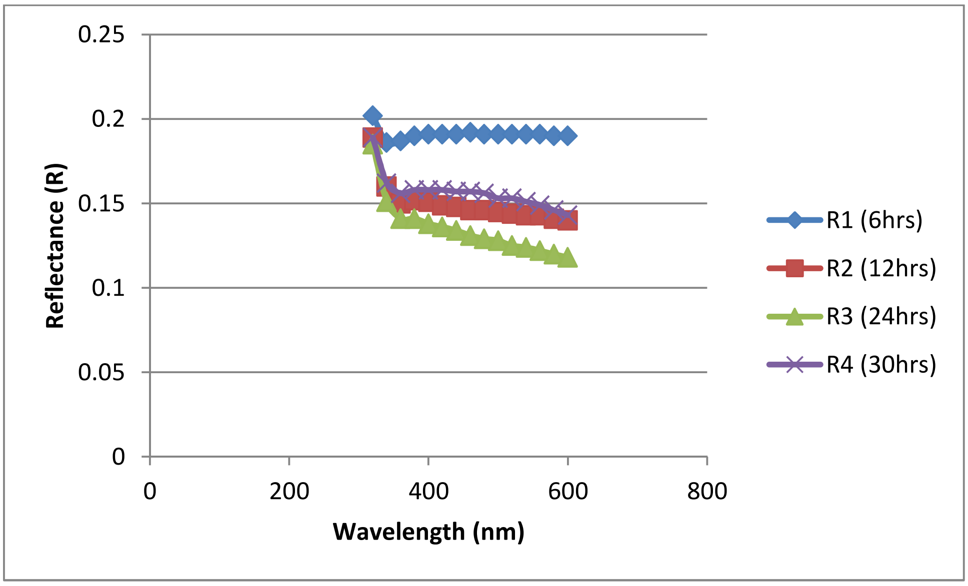

Figure 2: Plot of Reflectance against Wavelength for the four samples at different Dip-times

The transmittance (T) of the films was determined using the relation [8];

$$T = 10^{-A} \quad 1.3$$

where A is the absorbance.

The plot of transmittance against the wavelength is shown in figure 3. The graph shows that the films exhibited high transmittance percentage value of 56%- 76%. . And this made the material to be a good candidate for photonics applications.

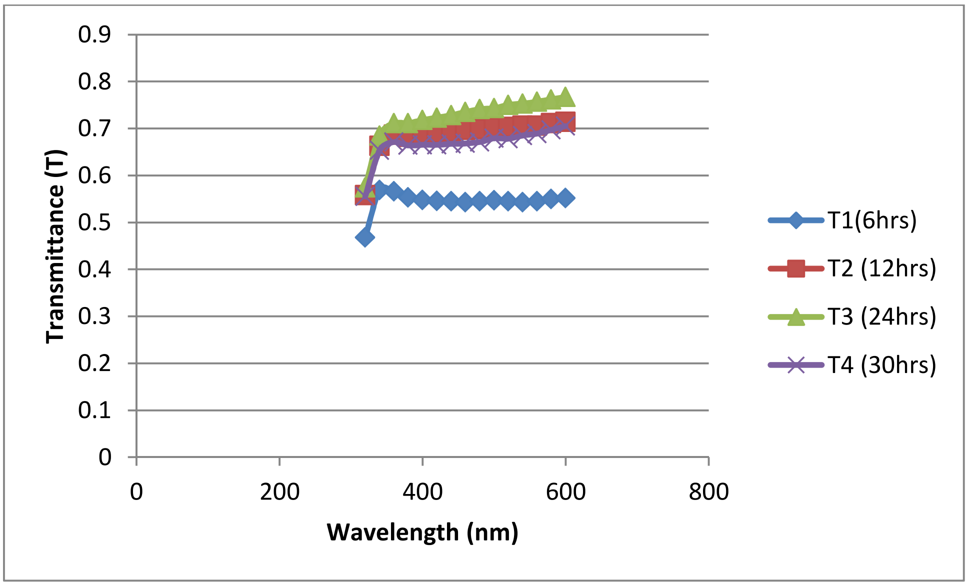

Figure 3: Graph of Transmittance against Wavelength for the four samples for different Dip-times

The optical conductivity of the films to solar radiation was found using the relation [9];
Optical conductivity (σ) = αnc/ 4π (1.4)

Where α is the absorption coefficient, n is the refractive index and c is the velocity of light.
The optical conductivity spectra of the films are as shown in figure 4. The spectra show that the films were of high optical conductivity values which range from $0.58 \times 10^{13} S^{-1}$ to $6.47 \times 10^{13} S^{-1}$ and increases as photon energy increases.

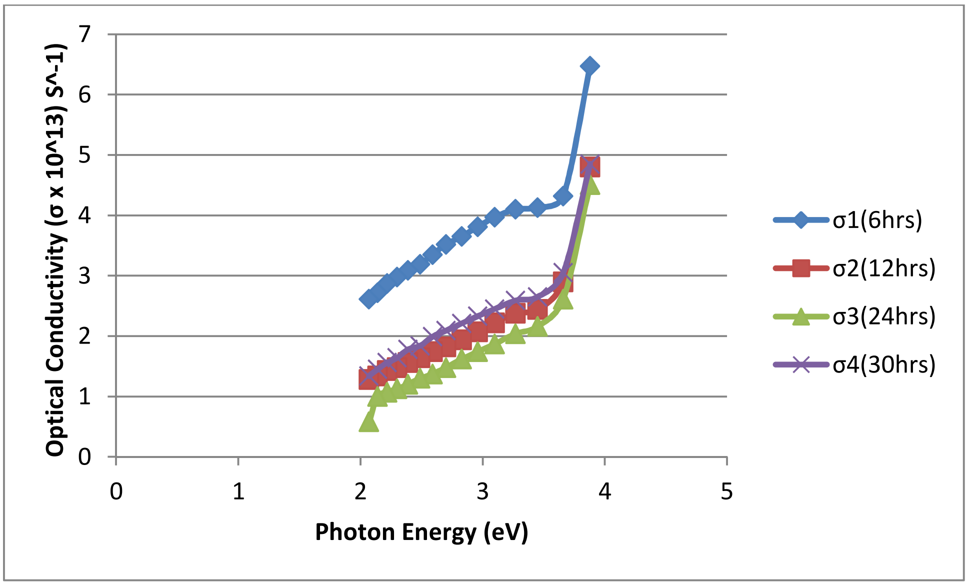

Figure 4: Plot of Optical Conductivity against Photon Energy for the four samples for different Dip-times

The optical constants of the deposited films were also determined. The ones calculated were the refractive index (n) and the extinction coefficient (k) using the respective relations [10] ;

$$K = \alpha\lambda/4\pi \quad (1.5)$$

And;

$$n= 1+ R^{0.5}/1-R^{0.5} \quad (1.6)$$

where R is the reflectance and λ is the wavelength of incident radiation.

Figure 5 shows the variation of refractive index with the photon energy. The films were found to possess high refractive index value range of 2.05-2.55. This also confirms SnSe to be a good material for fabrication of optical waveguides and ophthalmic devices.

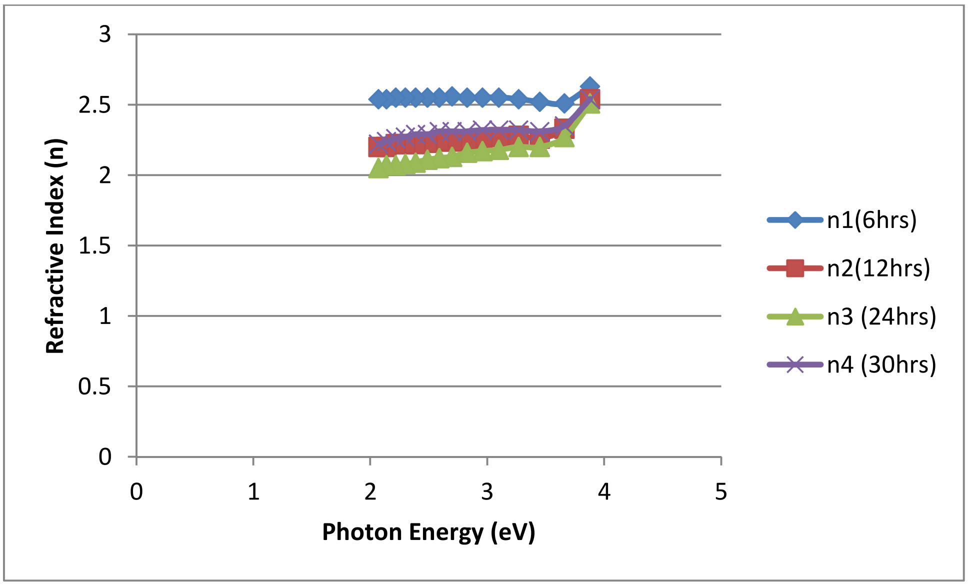

Figure 5: Graph of Refractive Index against Photon Energy for the four samples for different Dip-times

The graph of extinction coefficient against the photon energy is shown in figure 6, and it was found to be generally low. The film obtained at six hours was found to have higher extinction coefficient value than the rest; though, all their values were generally low.

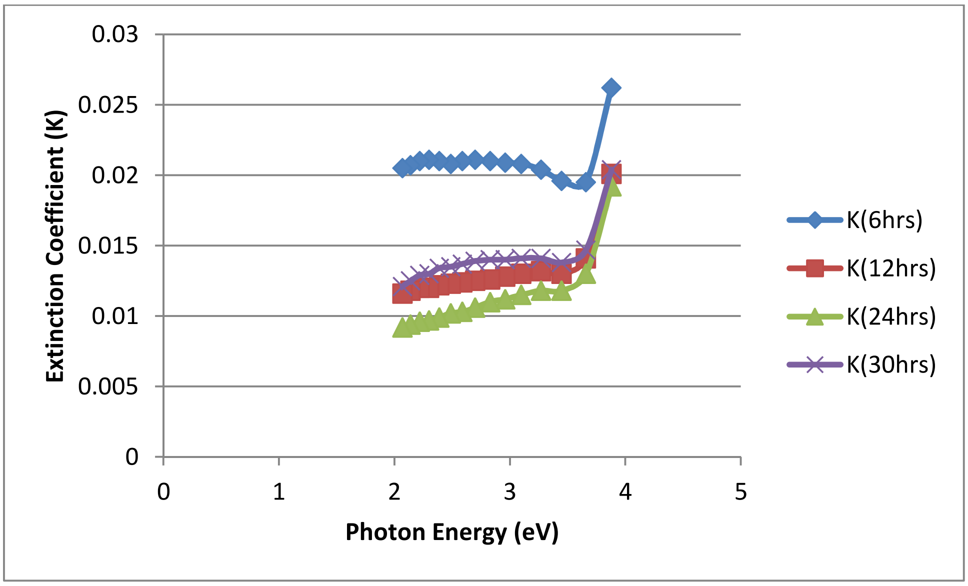

Figure 6: Plot of extinction coefficient against photon energy for the four samples for different Dip-times

Figure 7 shows the plot of absorption coefficient against the photon energy. It shows a very high value of 0.192x 10^6m- 1.031x10^6m for all the deposited films and increases as the photon energy increases. Though the one deposited at six hours was found to have better absorption value than the rest.

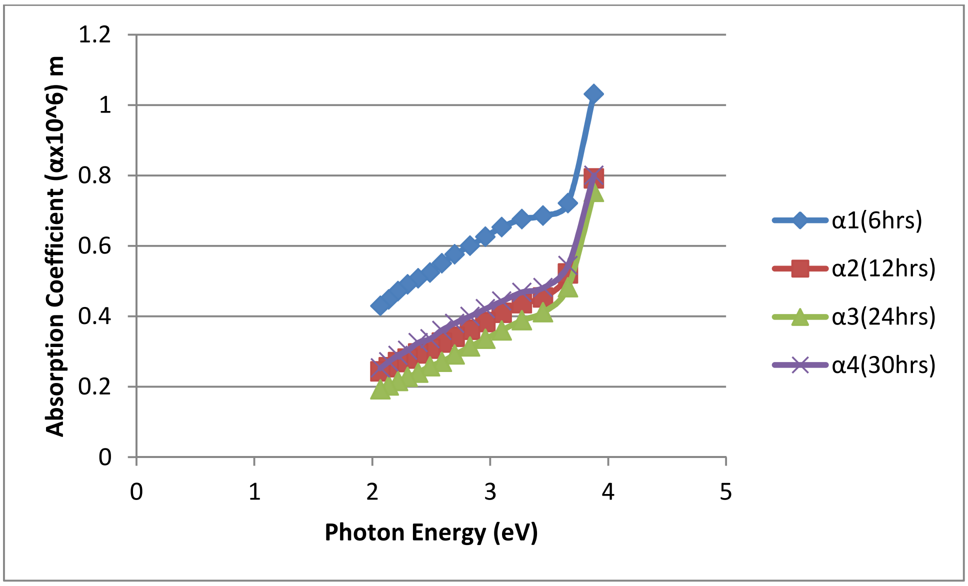

Figure 7: Graph of Absorption coefficient against photon energy

The band-gap energy was obtained when the absorption coefficient squared was plotted against the photon energy as shown in figure 8 below. The point where the linear part of the plot extrapolated to intercept the photon energy axis gives the value for the band gap energy. The values were found to range from 1.20eV – 1.70eV. These values were found to be in closed agreement with the value of 1.18 ± 0.05 eV obtained by Mugah et al, 2012[11]; 1.5 eV by Okereke and Ekpunobi [12], and 1.24-1.74eV by Kumar et al , 2012 [13].

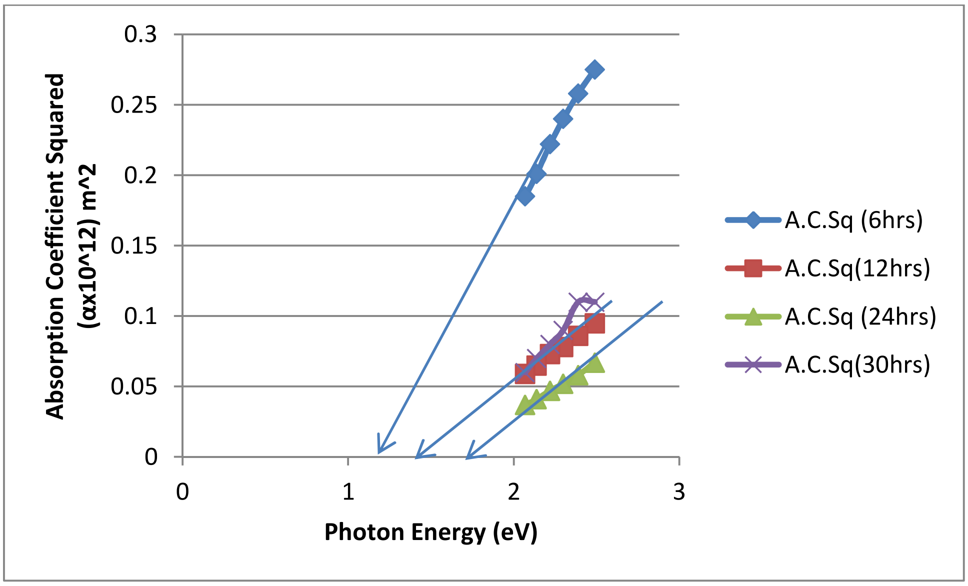

Figure 8: Plot of Absorption Coefficient squared against the Photon energy for the four samples at different Dip-times

1.4 Conclusions.

Tin Selenide thin films were successfully deposited on glass substrate using chemical bath deposition technique at room temperature, and at various dip-times. The technique was employed because it is cost effective, reproducible and with it large area of substrate can be coated with the film. The optical characterization performed on the films show that the films have high absorption coefficient (0.192x 10^6m- 1.031x10^6m), transmittance value (56%- 76%), optical conductivity (0.58x$10^{13}$$S^{-1}$ - 6.47 x 10^{13} S^{-1})and refractive index (2.05-2.55) respectively .The films were also found to exhibit band gap energy range of 1.2eV -1.70eV and low extinction coefficient value of 0.0092-0.0262. All these desirable properties made the material to be a good candidate for photovoltaic and Opto-electronic applications. For instance, the low reflectance value (0.118-0.202) property of the material disposes it for use as anti-reflection coatings for solar cells, displays and contact lenses.

1.5 References

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