

# Using The Thermal Evaporation Method to Prepare Thin Films of Tin Selenide and Studying Their Structural and Optical Properties.

<i>Authors Names</i>	<b>ABSTRACT</b>
<p><i>Yousif A. Jassim</i><sup>a, 1</sup> <i>Saleem A. Hussain</i><sup>b, 2</sup></p> <p>Publication date: 1 / 3 /2026</p> <p><b>Keywords:</b> Thermal evaporation , Thin films , Tin selenide ,</p>	<p>In this research, SnSe thin films were prepared by thermal evaporation of high purity SnSe (99.99% from Mhition), the material was evaporated using homemade coating unit at pressure of <math>2 \times 10^{-5}</math> mbar. The structural and optical properties of prepared films with different thicknesses (100 , 200 and 300) nm were studied in an attempt to understand the practical benefit of the properties of the prepared film in various industrial applications. XRD technique was used to investigate the film's crystal structures of the prepared films, and the results showed that the films have polycrystalline structure with orthorhombic phase and the preferred orientation in (111) plane. Optical characterization was studied using UV –VIS. Spectrophotometer, the wavelength range was from(300 - 1100) nm and the results showed that the prepared films were highly homogeneous and characterized by being highly absorbent in the visible light range . Optical properties such as absorption coefficient and optical band-gap have been measured and calculated.</p>

## 1. Introduction

Energy consumption has steadily risen as society has progressed. Since fossil fuel resources are running low and carbon dioxide emissions are increasing, energy issues have led to more focus on clean energy sources. Future projections indicate that electrical energy applications will increase to support human growth [1]. Solar cells may be accepted as economically environmentally friendly energy sources; solar cells have significant and promising uses. One of the absorber materials utilized in the current surge in looking for thin-film materials for solar energy converting and other associated uses for capturing renewable energy is SnSe. Silicon-based technologies dominate the solar cell operation. Because of its indirect band, silicon is less able to absorb sunlight than materials with direct band gaps[2]. For the advantages they have over other materials, chalcogenides particularly SnSe thin films have received much interest[3]. chalcogenides have been produced as thin films by several researchers. Large-scale production of solar cells requires a thin film deposition technique that is practical and affordable[4,5].

Thin films are prepared using various methods, but they generally fall into two categories: chemical methods and physical methods, including vacuum evaporation [6], pulsed laser [7], and reactive materials [8]. There are also many other methods, including hot wall[9], laser ablation[10], chemical bath deposition[11], and brush coating[12]. On the other hand, the majority of these techniques are expensive and involve toxic materials, leading to a number of technical and environmental issues. Thermal evaporation is considered a direct and practical physical method for preparing high-quality thin films at low economic cost, and it is used for various electronic device applications.

In this study, SnSe films with different thicknesses were made using the thermal evaporation method and their Structural, optical properties were studied.

## 2- Experimental Procedure

In this research, thin films of different thicknesses of Tin Selenide were prepared using thermal evaporation method by a locally manufactured system consisting of a vacuum system consisting of a stainless steel chamber with a glass window. It also contains a rotary pump, a diffusion pump, and connections used to

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connect the vacuum system to the chamber, a digital high-pressure gauge (Perani + penning), and a high-current power supply system. Silicon wafers were used as substrates for depositing the thin films after sterilization and then cleaning with alcohol, drying, and placing in the oven for five minutes at a temperature 448 K. After that, it is fixed on the slide holder at a distance of 10 cm above the boat. Next, the Tin Selenide material to be deposited is placed in the boat, which is made of a high melting point material such as tungsten or molybdenum, and aluminum spiral wire was also used for the electrodes deposition, Tin Selenide powder is heated by passing an electric current, under a low pressure of about  $2 \times 10^{-5}$  mbar, and upon reaching the desired pressure, the material began to evaporate gradually. At that point, thin film formation started by depositing on the slides. The thickness of the films to be deposited was calculated using the gravimetric method.

In this study, the films were prepared with thicknesses of  $((100, 200, 300) \pm 20$  nm). Their structural and morphological properties were studied using X-ray diffraction, to investigate the film's crystal structures using Shimadzu XRD6000 with Cu K  $\alpha_1$  radiation of wavelength  $\lambda=0.154 \text{ \AA}$ . The diffraction patterns were recorded with angle ( $2\theta$ ) from  $15^\circ$  to  $90^\circ$ . The crystallite size of the SnSe thin films was calculated by using Scherrer's formula [13]:  $D = 0.94\lambda / \beta \cos \theta$  (1)

where  $\lambda = 1.541 \text{ \AA}$  is X-ray wavelength,  $\theta$  is the Bragg angle,  $\beta$  is the full width at half maximum (FWHM) of the Bragg peaks (in radian) and  $D$  the grain size of the Crystalline. Optical characterization was studied using UV-VIS. Spectrophotometer, the wavelength range was from (200 -1000) nm this was capable of recording spectra in the visible range as well as near infrared and UV. The optical properties of films were studied as a function of film thickness. The absorption coefficient was calculated by using absorbance spectrum according to the following relationship [14]:

$$\alpha = 2.303A/t \quad (2)$$

where  $\alpha$  is absorption coefficient,  $A$  is absorbance and  $t$  thickness of film. The band gap of the films corresponding to thickness was calculated by plotting  $(\alpha h\nu)^2$  versus  $(h\nu)$  using the relation [14]:

$$\alpha h\nu = B (h\nu - E_g)^{1/2} \quad (3)$$

where  $E_g$  is the band-gap,  $\alpha$  is the absorption coefficient,  $h\nu$  is the photon energy and  $B$  is an energy-independent constant. The refractive index ( $n$ ) for the prepared films was calculated by using the relation

$$[15]. \quad n = \frac{1 + \sqrt{R}}{1 - \sqrt{R}} \quad (4)$$

where  $R$  is the reflectance of SnSe thin film

### 3. Results and Discussions

X-ray diffraction (XRD) technique was used to investigate the film's crystal structures using Shimadzu XRD6000 with Cu K  $\alpha_1$  radiation of wavelength  $1.5406 \text{ \AA}$ . The XRD diffraction pattern of SnSe samples deposited by thermal evaporation technique at different thicknesses are shown in Fig1.

It is observed three characteristic diffraction peaks corresponding to the (210), (111) and (411) reflections at Bragg angles ( $2\theta_s$ ): ( $27.4154^\circ$ ), ( $30.4109^\circ$ ) and ( $43.2978^\circ$ ), respectively. These peaks clearly indicate that the structure of the films is polycrystalline. According to ASTM Card No. 96-210-7516, the reflections represent Orthorhombic unit cell and The preferred orientation of the crystal along (111) plane. The crystallite size of the SnSe thin films was calculated by using the Scherer's formula eq. (1) as shown in Table 1. The results show that the crystallite size increases with increasing film thickness which can be attributed to increasing of films homogeneity growth process and also reducing of the crystal defects. These results are consistent with [16].

SnSe Thin fim	hkl	2θ (deg)	FWHM	d(A°) exp)(	d(A°) (sta	grain size(nm)
100 nm	210	27.4154	4.1687	3.25063	3.37319	1.960892722
	111	30.4109	0.6272	2.93692	2.93414	13.12116555
	411	43.2978	0.022	2.088	2.08859	388.3564645
200 nm	210	26.209	4.1687	3.39751	3.37319	1.955983508
	111	30.382	6.3259	2.93963	2.93414	1.300847596
	411	43.122	0.0889	2.09611	2.08859	96.04790087
300 nm	210	26.209	0.543	3.39751	3.37319	15.11087831
	111	30.382	0.4616	2.96633	2.93414	17.81545004
	411	43.1209	0.0889	2.09615	2.08859	96.04753695

Table 1

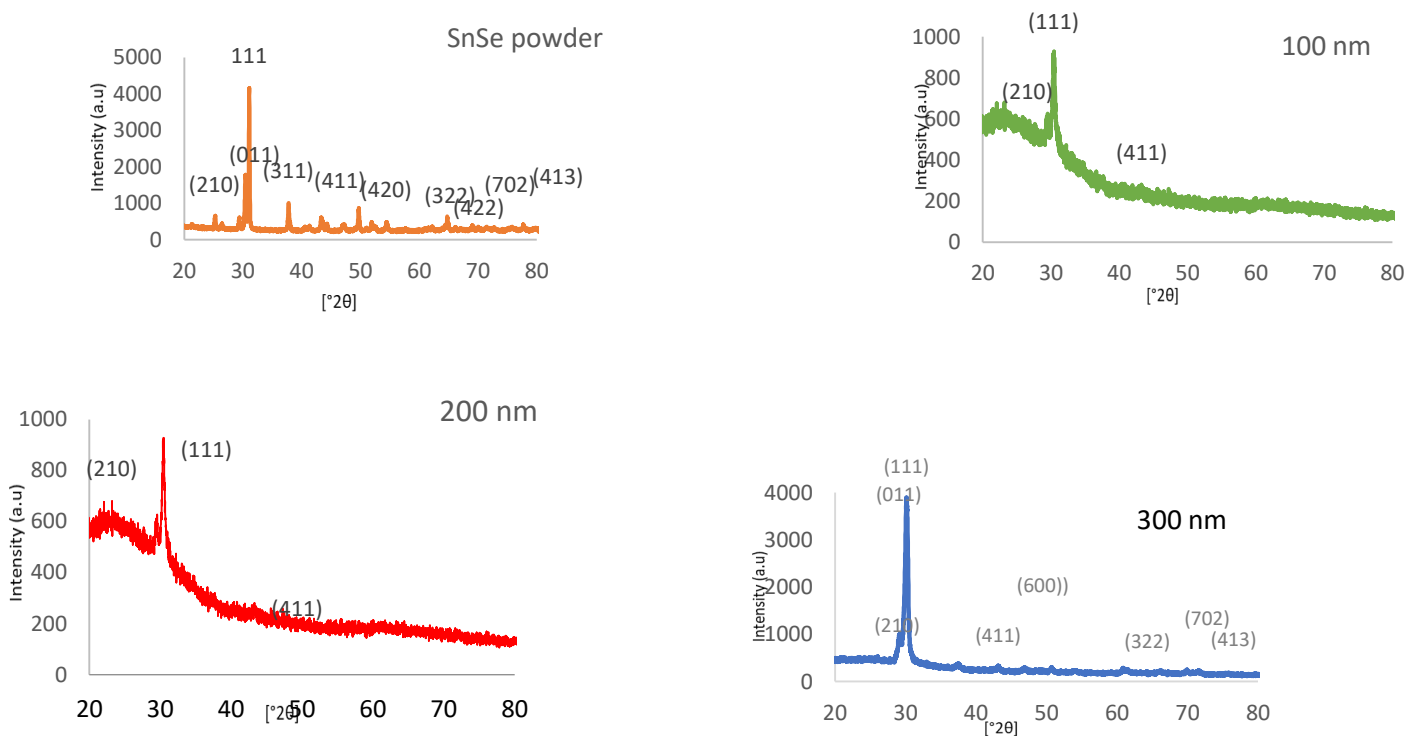


Fig. 1. XRD spectrum of SnSe films with different thicknesses

Optical properties which Includes absorbance spectra and transmittance as a function of incident wavelength, absorption coefficient and optical energy gap for SnSe thin films were measured by using a UV-visible spectrophotometer, UV-1900. Model (S/N): UV-1900i (A12535901917). The transmittance of the SnSe thin films deposited varied according to film thickness. To compensate for the complicated intensity distribution of the light source the spectrophotometer did not measure absolute values but compared the signal from the sample to a reference beam. Fig. 2 shows the results of absorbance spectra as a function of incident wave length for SnSe thin films with different thicknesses.

The absorbance behavior of Tin Selenide thin films reveals a strong dependence on thickness, where an increase in absorbance is particularly evident in the UV-visible region due to enhanced optical path length and material density highlights improved photon capture efficiency with increasing film thickness. and that reveals

to their suitability for a range of optoelectronic applications, increasing the film thickness enhances absorption in the UV-visible region. This is attributed to an extended photon path length and increased material density, improving photon capture efficiency, as supported by Zhang et al. (2020) [17].

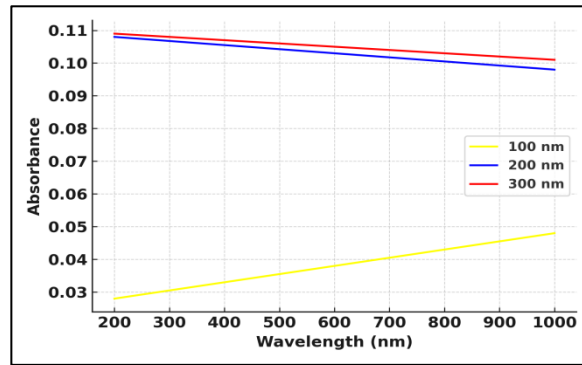


Fig.2. Absorbance as a function of wave length for SnSe films with different thicknesses

In contrast, the optical transmittance of these films, as illustrated in Figure 3, demonstrates a clear inverse relationship to absorbance. Thinner films transmit more light, while thicker ones significantly reduce transmittance, confirming the semiconducting nature of SnSe and the influence of thickness on its optical transparency. The transmittance spectra decrease with thickness, reflecting the material’s growing opacity. This inverse relationship is characteristic of semiconductors, where thicker films allow for improved light trapping, aligning with the findings of Pradhan et al. (2021) [18].

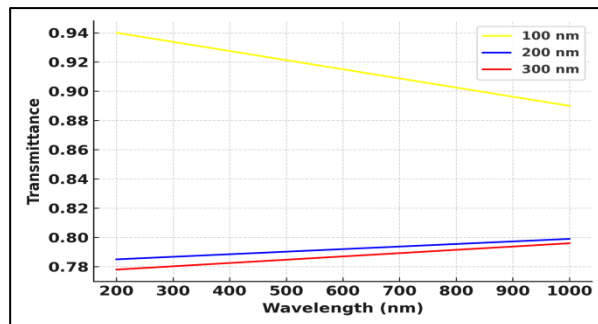


Figure 3. transmittance as a function of wave length for SnSe films with different thicknesses

Reflectance characteristics are also affected by thickness, as indicated in Figure 4, where a modest increase in reflectance is observed for thicker films, especially at longer wavelengths. This may result from increased surface roughness and internal interference effects within the multilayered structure. Additionally, reflectance is seen to increase slightly. This can be linked to enhanced surface roughness and optical interference at higher thicknesses. However, reflectance remains within acceptable levels for energy harvesting materials, as reported by Mahapatra et al. (2022) [19].

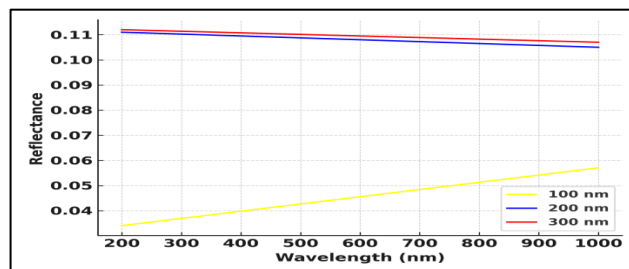


Figure 4: Reflectance as a function of wavelength for SnSe films with different thicknesses

The absorption coefficient  $\alpha$ , shown in Figure 5, further supports these findings by displaying higher values for thicker films, suggesting more efficient light–matter interaction. This property is particularly desirable for optoelectronic applications that require strong light absorption across a broad spectral range and there for The absorption coefficient  $\alpha$  increases steadily with film thickness, maintaining values above  $10^4 \text{ cm}^{-1}$  across the visible range. This indicates strong light-matter interaction and confirms the potential of SnSe in thin-film solar cells (Sun et al., 2023) [20].

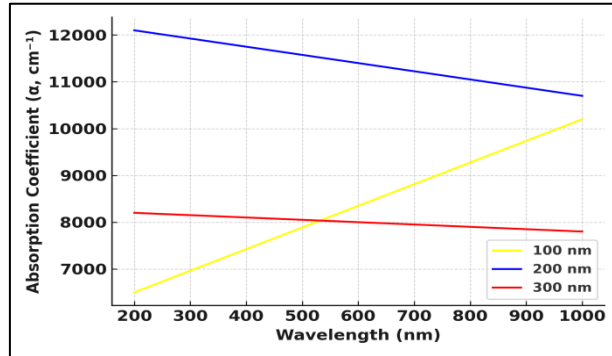


Figure 5: Absorption coefficient of SnSe thin films with different thicknesses.

A similar thickness-dependent behavior is observed in the real part of the refractive index  $n$ . According to Figure 6, all films exhibit a normal dispersion profile, where  $n$  decreases with increasing wavelength. However, slightly higher  $n$  values in thicker films suggest denser molecular packing and improved polarization response. Moreover, the real part of the refractive index  $n$  decreases with wavelength showing normal dispersion. Slight increases in  $n$  for thicker films imply improved crystallinity and polarization properties, a pattern consistent with Raza et al. (2021) [21].

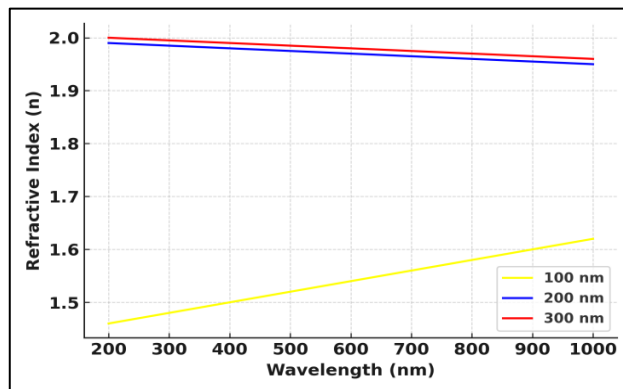
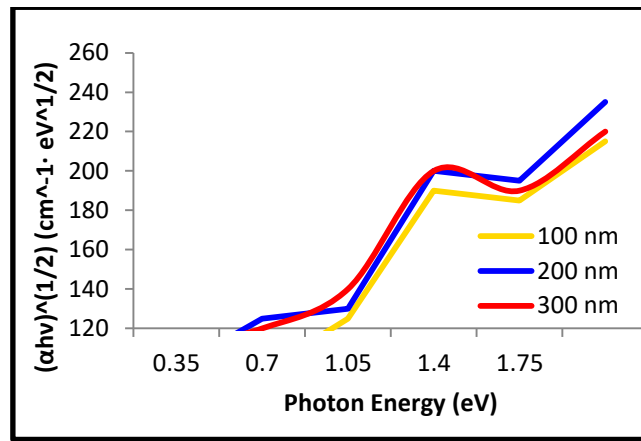


Figure 6: refractive index ( $n$ ) versus wavelength for SnSe.

Finally, the Indirect band gap extracted from the Tauc plot (Figure 7) shows a decrease with increasing thickness, reflecting a red-shift. This behavior is linked to reduced quantum confinement and the formation of mid-gap defect states, aligning with recent observations by Ghosh et al. (2022) [22]



Indirect band gap estimation of SnSe thin films. Figure 7: Tauc plot for

#### 4. Conclusions

Tin Selenide (SnSe) thin films were successfully deposited on a glass substrate using the thermal evaporation method. The absorption behavior of tin selenide (SnSe) films is highly thickness-dependent, with absorption increasing with increasing thickness. In contrast, optical transmittance shows a clear inverse relationship with absorption, with thinner films transmitting more light, while thicker films significantly decrease transmittance. A slight increase in reflectivity is observed with increasing thickness. The absorption coefficient supports these results, registering higher values for thicker films. A similar behavior is observed in the real part of the refractive index,  $n$ , with  $n$  increasing in thicker films. Estimation of the indirect energy gap using the Tauc method reveals a slight decrease in the indirect energy gap value with increasing thickness.

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