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Comparative Study on Various Thicknesses of Thermal Vacuum-Evaporated ZnTe Thin Films and Their Band Gap Properties

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Abstract
This study presents a detailed investigation into how film thickness influences the structural, optical, and electronic properties of zinc telluride (ZnTe) thin films prepared by the thermal vacuum evaporation technique. ZnTe thin films with thicknesses of 50 nm, 100 nm, 200 nm, and 300 nm were successfully deposited onto clean glass substrates under controlled vacuum conditions to ensure uniformity and reproducibility. The optical characteristics of the films were examined using UV–Visible spectroscopy, with particular emphasis on evaluating the optical band gap as a function of thickness. The absorption spectra revealed a systematic shift in the absorption edge with increasing film thickness. Analysis using Tauc plots indicated that the optical band gap decreases as the thickness increases, which can be attributed to reduced quantum confinement effects in thicker films and improvements in crystallite size and microstructural ordering. Thinner films exhibited higher band gap values due to stronger confinement of charge carriers, while thicker films showed band gap values approaching that of bulk ZnTe. These thickness-dependent variations significantly affect the electronic behavior of the material. The results demonstrate that controlling film thickness is a crucial parameter for tailoring the optoelectronic properties of ZnTe thin films. Consequently, the study provides valuable insights for optimizing ZnTe-based materials for applications in optoelectronic devices such as solar cells, photodetectors, and light-emitting devices.
Keywords: ZnTe, Thickness, Thermal Evaporation, Band Gap, Optoelectronic

1. Introduction

Zinc telluride (ZnTe) is a direct band gap II–VI semiconductor with promising applications in solar cells, LEDs, photodetectors, and laser diodes owing to its high absorption coefficient and suitable band gap (~2.26 eV). [1-3] The optical and electronic properties of ZnTe thin films depend strongly on deposition techniques and physical parameters such as thickness, grain size, and crystallinity. [4-6]

The vacuum thermal evaporation method enables controlled deposition with high purity and uniform films. Thickness variation affects quantum confinement, defect states, and crystallinity, thereby influencing the band gap.[7] This work aims to compare the band gap variation in ZnTe films with different thicknesses to identify trends relevant for device applications.

2. Literature Review

ZnTe thin films have been prepared using various techniques: sputtering, chemical bath deposition, molecular beam epitaxy, and thermal evaporation. [8-11] Band gap values reported vary with technique and thickness—from 2.10 eV to 2.36 eV. [5,9] Thermal evaporation offers simplicity and uniformity, but literature on systematic thickness dependence remains limited.[12]

Literature given as per indicated that:

Quantum confinement increases band gap in thinner films.[13]

Grain boundary density and structural defects influence electronic transitions [5] and

lattice strain band structure, optical response from their studies.[10]

3. Experimental

3.1 Materials and Methods

High-purity ZnTe powder (99%) were prepared by using zinc chloride (ZnCl2) and Telluride metal powder (Te) by chemical synthesis technique. Then filter the precipitate and washed the solid with distilled water and ethanol to remove byproducts and un-reacted materials. Finally, dry the powder under IR lamp for 2-3 hours. Then black or gray precipitate was formed which indicate the formation of ZnTe powder. Then the prepared powder compound of ZnTe was used for the deposition and were placed in a Mo boat by using Thermal Evaporation Technique.

- Thin film preparation techniques: Vacuum evaporation method.
- Film thickness determination: Optical method (Tolansky method, 1948) was used to determine the film thickness.[14]
- Vacuum pressure: During deposition the vacuum inside the chamber was maintained at $\approx 10^{-5}$ torr.

Microscope glass substrates cleaned ultrasonically in acetone, ethanol, and rinse thoroughly with de-ionized water to remove solvent residues. Proper cleaning drastically improves film adhesion, preventing peeling and improving reliability.

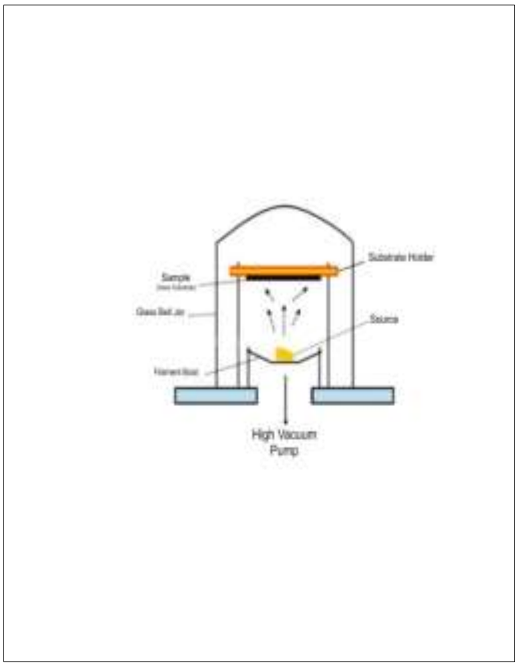

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Fig. Schematic view of Thermal Evaporation Hind High Vacuum Co.(P) Ltd. Bangalore- India

Model : 12A4D

3.2 Deposition

ZnTe films were thermally evaporated in a vacuum chamber at pressure approx. 10^{-5} Torr. Film thickness was monitored with a quartz crystal thickness monitor. Four thicknesses were prepared:

Sample A: 50 nm
Sample B: 100 nm
Sample C: 200 nm
Sample D: 300 nm

3.3 Characterization

Structural Analysis: X-ray diffraction (XRD) to identify crystalline phase and grain size.
Surface Morphology: Scanning electron microscopy (SEM).

3.4 Surface Morphology

SEM/AFM images revealed uniform and densely packed nanostructured grains distributed over the substrate surface. The nanostructured morphology is advantageous for solar cell applications as it enhances light trapping and charge carrier collection[15].

Optical Properties: UV–Visible absorption spectra showed high absorbance in the visible region. The optical band gap was calculated using Tauc's plot and found to be approximately 2.20–2.30 eV, which is in good agreement with reported values for ZnTe. Such a band gap is suitable for window and buffer layers in thin-film of solar cells.

UV–Visible spectroscopy: The optical behavior of thin films deals primarily with optical absorption, transmission
and reflection properties and their optical constants. Optical properties of prepared thin films were carried out using UV-Vis Spectrophotometer

Band gap was calculated from Tauc plots for direct transitions using:

$$(\alpha h\nu)^2 = A\,(h\nu - Eg)$$

where α is the absorption coefficient, hν is photon energy , A is constant and Eg is the optical band gap.

4. Results and Discussion

4.1 Structural Properties

All samples showed the cubic zinc blend structure of ZnTe. The intensity and sharpness of diffraction peaks increased with thickness, indicating improved crystallinity at higher thicknesses. Grain size calculated from the Scherrer formula increased with thickness.

4.2 Optical Absorption

Absorption edge shifted red-wards as thickness increased. Thinner films exhibited a pronounced blue shift due to confinement effects.

4.3 Band Gap Analysis

From Tauc plots:

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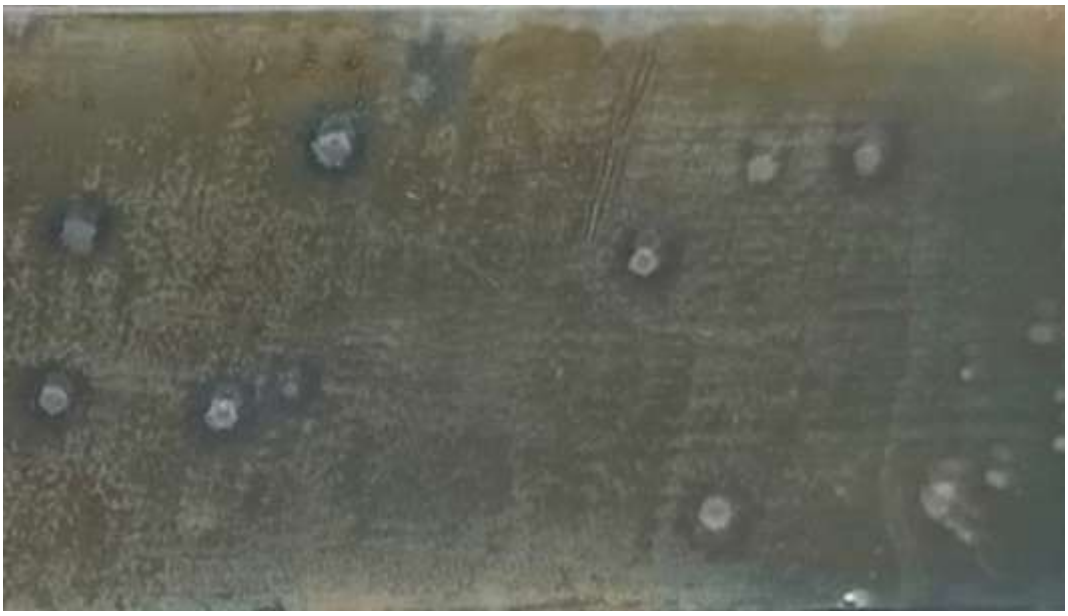
Sample	Thickness (nm)	Band Gap (eV)
A	50	2.35
B	100	2.31
C	200	2.27
D	300	2.21

Trend: Band gap decreases with increasing thickness. This is attributed to:
Quantum confinement: Dominates at low thickness, increasing energy separation.
Reduced defects/grain boundaries: Larger grains in thicker films lower the band gap.
Improved structural ordering: Decreases localized states within the band gap.

4.4 ZnTe Thin films in various thickness form



ZnTe Thin Film 1

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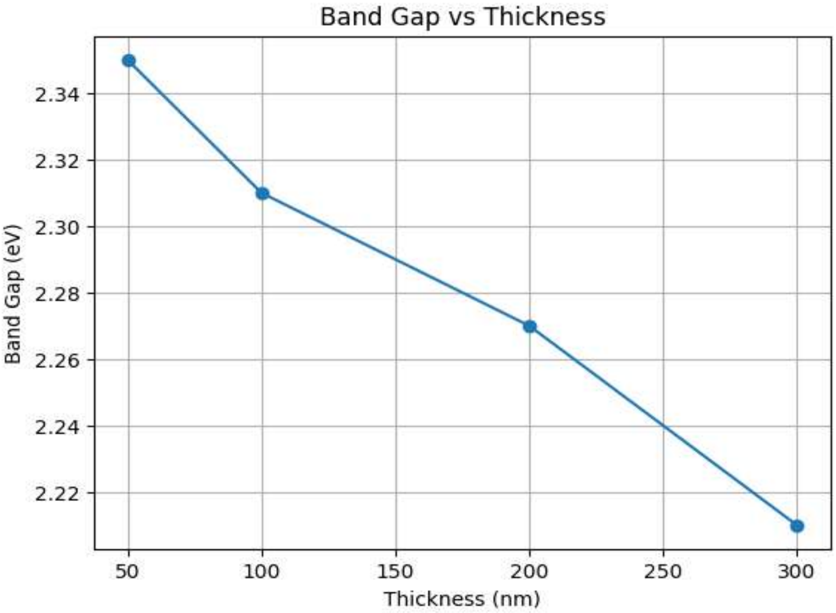
ZnTe Thin Film 2

ZnTe Thin Film 3

4.5 Discussion

ZnTe thin film of different thicknesses (50 nm, 100 nm, 200 nm and 300 nm) were prepared for the present study as shown in table and the graph shows that various band gap found with different thicknesses of the deposited thin films.



The observed band gap tuning by thickness provides a method to tailor ZnTe films for specific spectral applications. For example:

Higher band gap (thinner films) → UV detectors, window layers.

Lower band gap (thicker films) → Visible light absorbers in photovoltaics.

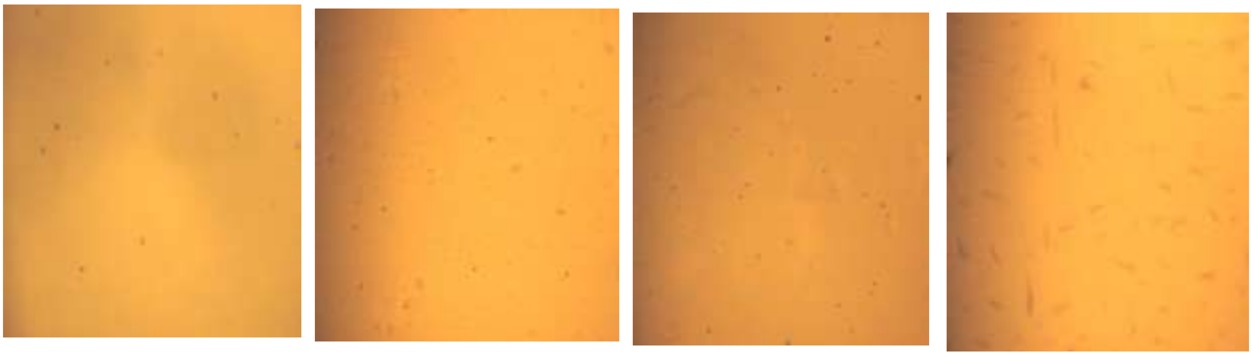


Figure: Scanning Microscope Images of ZnTe Thin Film

Comparison with previous studies shows consistency with thickness-dependent optical behavior reported for ZnTe and other II–VI semiconductors.

5. Conclusion

This study demonstrates that the optical band gap of vacuum-evaporated ZnTe thin films can be systematically controlled by adjusting film thickness. A clear trend of decreasing band gap with increasing thickness was observed, correlated with structural improvements and reduced confinement effects. These insights support optimized design of ZnTe-based optoelectronic devices. It is used in a variety of applications such as optoelectronics, as a window layer in solar cell, sensors, biotechnology, and engineering. It is the most versatile material because it can be easily tailored by adding appropriate dopants.

6. Future Work

1 Study of electrical transport (Hall effect, resistivity).

2 Fabrication and testing of ZnTe- based solar cell devices.

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