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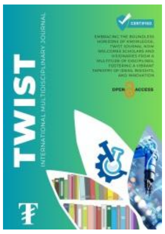

Optical Properties of Indium Chalcogenide $In_2Se_{3x}Te_{3(1-X)}$ Vacuum Evaporated Polycrystalline Thin Films

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Abstract

The energy band gaps of Indium chalcogenide $In_2Se_{3X}Te_{3(1-X)}$ thin films (X = 0 to 1) have been studied at room temperature. Ternary polycrystalline of desired composition were prepared by drop quenching technique. Thus, prepared material was then used to deposited thin films on glass substrate employing thermal evaporation technique. The Varian Cary 5000 Spectrophotometer is used to measure the absorption spectra of these polycrystalline materials in the wavelength range of 600 to 2000 nm. The optical energy band gap is obtained through the examination of the absorption spectra. The range of values for this is determined to be between 0.89 and 2.18 electron volts (eV). The optical band gap is maximum in case of In_2Se_3 at X= 1. The optical band gap increases as we increase the concentration of selenium in InSeTe system. Polycrystalline nature of the films was confirmed by their XRD patterns.

Keywords

Indium chalcogenide, Thermal evaporation, Absorption spectra, Optical band gap

INTRODUCTION

The polycrystalline Chalcogenide semiconductor play an important role in fabrication of solar cell due to their optical properties. In recent years major attention have been given to investigation of optical and structural properties of InSeTe to improve the performance of the device and for finding new application.

The latest developments and current directions in the field of chalcogenide semiconductors demonstrate its utilization in xerography, switching and memory devices, as well as reversible phase change optical recording. The range of numbers is from 1 to 6, inclusive. Various binary and ternary semiconductors are presently being studied for their possible use in solar applications. Studying these materials is crucial as the cation content can be manipulated to alter the band gap and lattice properties. Indium Telluride exhibits intriguing optical and electrical characteristics [7-11], making it a promising candidate for future applications in solar cells or detectors. In_2Te_3 has been studied for its potential utilization in several applications, including thermoelectric power generation [12], gas sensing [13], strain measurement [14], and as a switching memory component [15]. In_2Te_3 and In_2Se_3 are two types of stacked semiconductors that have attracted significant attention due to their photovoltaic capabilities resulting from their unique structure [16-17]. Indium selenide possesses distinctive features that arise from its crystal structure. Indium Selenide semiconductors have garnered attention in recent years due to their desirable features for device applications, particularly in thin film form [18-21]. In_2Se_3 is a well-researched compound belonging to the binary III-VI chalcogenide family.

MATERIAL PREPARATION AND EXPERIMENTAL PROCEDURE

The current study utilizes the drop quenching technique to synthesize the indium chalcogenide $In_2Se_{3X}Te_{3(1-X)}$ materials, where X ranges from 0 to 1. The required quantities of the elements with a high level of purity (99.99) were measured using an electronic balance. The material, which had a high level of purity and the desired ratio of elements, was enclosed in a quartz ampoule with a length of 5 cm and an internal diameter of 8 mm. This was done in a vacuum with a pressure of 10-6 torr. The ampoule was then heated in a furnace, with the temperature increasing at a rate of 3-4 0C per minute, until it reached 900 0C. The material was kept at this temperature for a period of 9-10 hours to ensure that the samples were homogeneous. The liquefied samples were thereafter swiftly cooled in water chilled with ice. The ingot of material was pulverized into a powdered state. The power's characteristics have been verified using X-ray diffraction with the Bruker D8 Advance apparatus at USIC IIT Roorkee. The materials have been applied as thin films onto clean glass substrates using the vacuum evaporation method in a vacuum coating equipment, all at room temperature. In order to achieve this objective, a sample of $In_2Se_{3X}Te_{3(1-X)}$ with prepared material has been placed in a molybdenum boat inside a vacuum chamber. Once a vacuum with a pressure of approximately 2 x 10-5 torr is attained, the boat is heated in order to evaporate $In_2Se_{3X}Te_{3(1-X)}$ samples for the purpose of depositing thin coatings. The thin films are subjected to a temperature of 348 K in the vacuum chamber for 10 minutes in order to enhance adhesion and eliminate surface imperfections. The films of the $In_2Se_{3X}Te_{3(1-X)}$ system have been deposited using identical experimental conditions. The Varian Cary 5000 spectrophotometer was used to measure the absorption spectra of these films at room temperature, for various amounts of selenium in the indium-tellurium combination. These spectra were used to calculate the optical band gap using Taue relation. Fig. 2 to 4 show the absorption of these films. Fig. 6-7 show the calculation of band gap of $In_2Se_{3X}Te_{3(1-X)}$ (X = 0 and 1) film. Table 1 show variation of energy band gap (Eg) in $In_2Se_{3X}Te_{3(1-X)}$ films. The variation of optical band gap with respect to Se content in InSeTe system is plotted as prepared and after six months in Fig. [8].

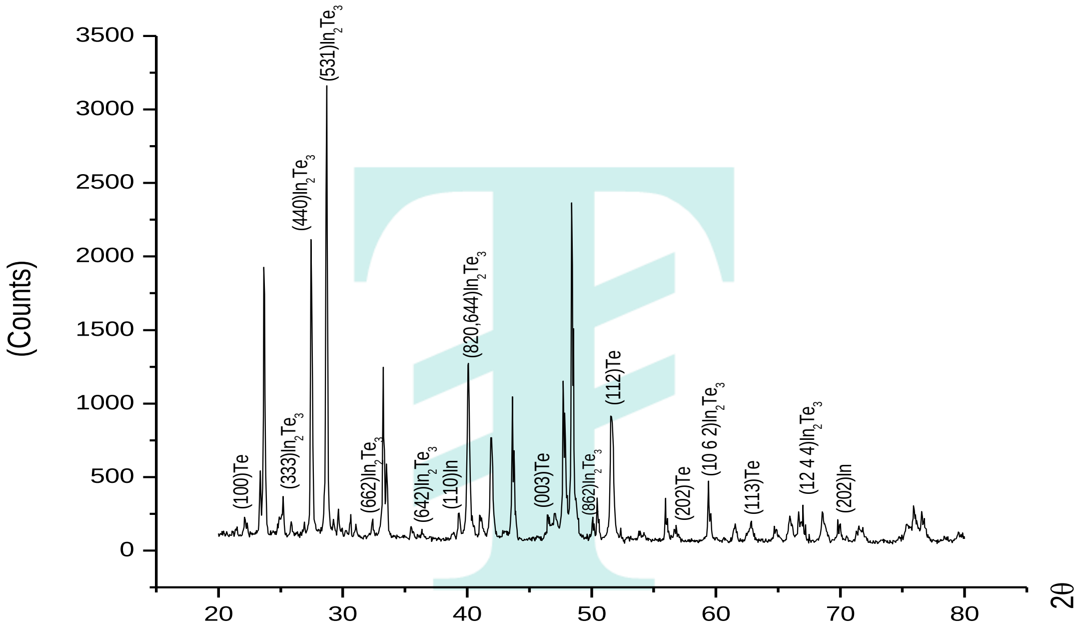

Fig. 1 XRD pattern of In_2Te_3 at X = 0

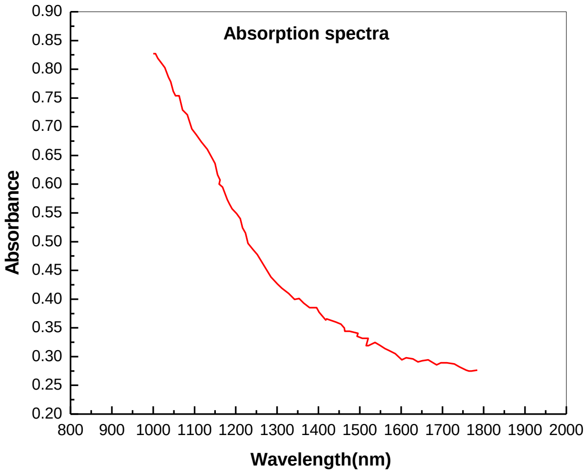

Fig. 2 Absorption spectra of In_2Te_3

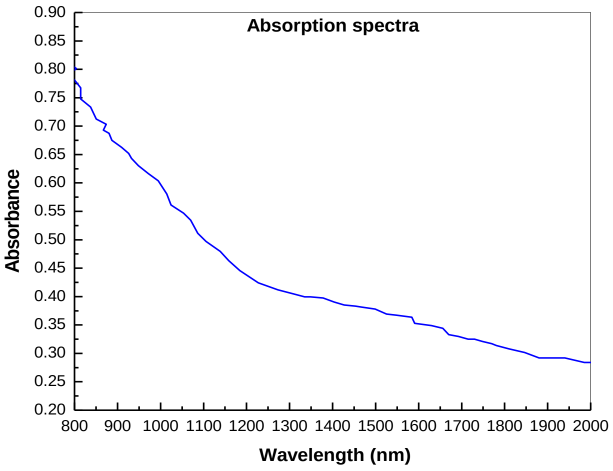

Fig. 3 Absorption spectra of $In_2Se_{.6}Te_{2.4}$

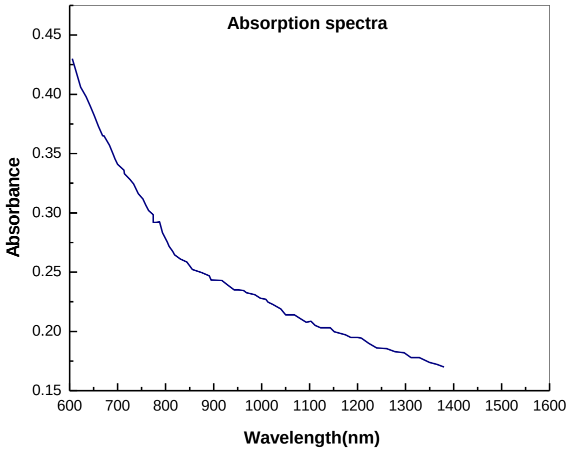

Fig. 4 Absorption spectra of $In_2Se_{1.8}Te_{1.2}$

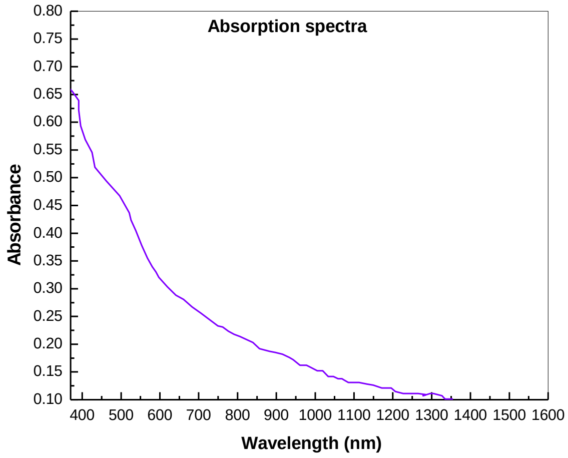

Fig. 5 Absorption spectra of In_2Se_3

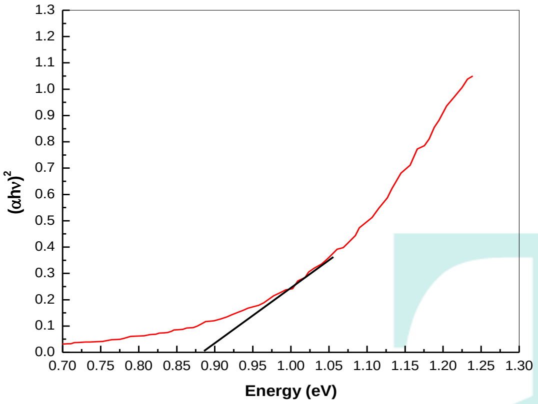

Fig. 6 Band gap of In_2Te_3 film

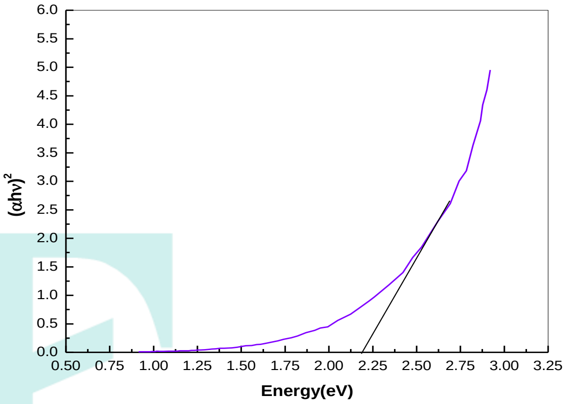

Fig. 7 Band gap of In_2Se_3 film

Table 1 Variation of energy band gap (Eg) in $In_2Se_{3X}Te_{3(1-X)}$

Composition (X)	Energy band gap As prepared (eV)	Energy band gap after Six months (eV)
0	0.89	0.81
0.2	1.01	0.94
0.4	1.25	1.19
0.6	1.30	1.24
1	2.18	2.12

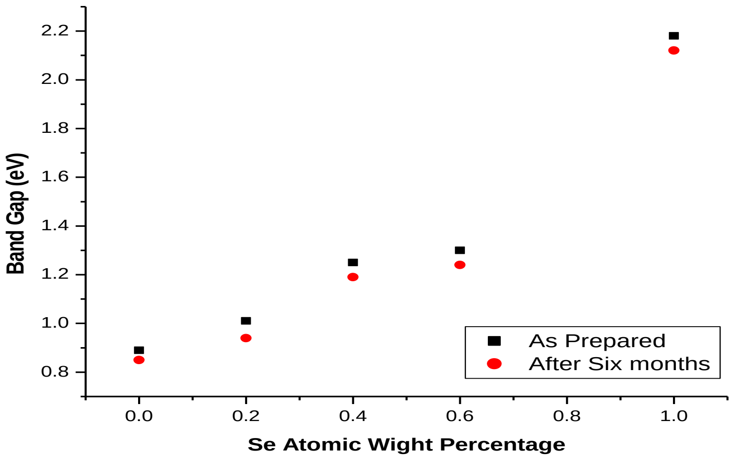

Fig. 8 Band gap Vs Concentration

RESULT AND DISCUSSION

The XRD pattern of indium telluride show the material is in polycrystalline nature. The energy band gap for the polycrystalline films increases with the increase in composition of Selenium. The energy band gaps vary in the range 0.89 to 2.18 eV with the increase of Se concentration from 0 to 1. The optical absorption results suggest that direct allowed transitions are predominate in these compounds. The variation of band gap with respect to composition is shown in figure 8. The optical band gap shows in increasing nature. This is in good agreement with values reported in the literature. The band gap reported value of Indium Telluride In_2Te_3 is 0.6 to 1.5 eV [22] and band gap reported value of Indium selenide In_2Se_3 is 2.0 to 2.35 eV [23-24]. So, formation of In_2Se_3 is the basis of increase of band gap. The variation of band gap of these thin films could be explained based on bond formation between Indium telluride and Indium selenide. The addition of selenium in InTe system changes the configuration decreases the concentration of Te member rings. When content of selenium is increased in the InSeTe system, Se makes bonds with both In and Te. To investigate the aging effect leading towards the degradation of material, optical band gap study on the same films was repeated after six months. It has been observed that morphology of the films has changed in due course of time. Same result of decrease in band gap has been observed in the series as we get in previous studies of films Indium chalcogenide $In_2Se_{3X}Te_{3(1-X)}$. This decrease in band gap of Indium chalcogenide films with time is due to the creation of some staking fault and points defects.

CONCLUSION

Following conclusion has been drawn: From the studies, it is observed that the optical band gap is mostly direct and varies with composition and increasing with selenium content in the compounds. So, the formation of indium telluride and indium selenide is the basis of increase of band gap. Degradation study with time show that Indium chalcogenide thin film band gap decreases due to the creation of some staking fault and points defects. In_2Se_3 polycrystalline films gives the highest value of band gap in the proposed series. The increase in the band gap may be due to the compositional change occurred during the preparation of thin film.

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