Structural and optical properties of vacuum evaporated indium selenide thin films

K. S. Chaudhari[1], Y. R. Toda[2], A. B. Jain[2]and D. N. Gujarathi[2]

[1]*S.V.S's Arts and Science College, Dondaicha*
[2]*Thin Film Lab, Department of Physics, Pratap College, Amalner(MS) India*

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ABSTRACT

Thin films having different thickness of InSe were deposited by thermal evaporation technique, onto precleaned amorphous glass substrate. The structural properties of films were evaluated by XRD, optical microscopy and TEM. The X-ray diffraction analysis confirms that films are polycrystalline having cubic structure cell. The average grain size is found to be 11.18-11.93 nm. The optical band gap of the films was measured by using optical absorption spectra. The estimated values of the direct and indirect optical band gaps of these samples were 0.81 to 0.84 eV and 1.31 to 2.18 eV respectively.

Key words: XRD, Optical microscopy, TEM, absorption coefficient, Optical band gaps.

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INTRODUCTION

Indium Selenide is important material of III - VI group compounds. The energy gap of InSe at room temperature is 1.3 eV, which makes it an attractive material for solar energy conversion (1-5), diodes (6), infrared devices, and lasers (4). It is also used as promising material for application in solid solution electrode (7), opto electronic devices (7), etc but little work has been reported concerning the thin film state (7).   Although there have been several studies on the growth and characterization of InSe thin films, deposited by different growth techniques, there is still a lack of understanding of the electrical and structural properties which strongly affect device performance (3). Therefore we have made an attempt to synthesize indium selenide thin films by vacuum evaporation technique. In present work, the effect of film thickness on the optical properties of InSe films over the thickness range 1000 – 3000 Å has been investigated. An attempt has been made to evaluate the optical direct and indirect band gap.

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MATERIALS AND METHODS

Experimental

The starting material was prepared by mixing quantities of high-purity (99.999%) indium and selenium powder shot in the atomic weight proportion 1:1. The mixture was sealed in an evacuated quartz tube at pressure 10^{-5} torr and heated at 1070 K for 36 hr in furnace and then quenched in ice cooled water. Polycrystalline InSe films have been deposited by physical evaporation technique under vacuum of about 10^{-5} torr. The substrate to source distance was kept 20cm. The samples of different thicknesses were deposited under similar conditions. The thickness of the films was controlled by quartz crystal thickness monitor model No. DTM-101 provided by Hind-HiVac. In each deposition, a given quantity of material was taken in the boat of molybdenum and evaporated at the rate of 5 to10 A^0 per second. Before evaporation, the glass substrates were cleaned thoroughly using concentrated chromic acid, detergent, isopropyl alcohol and distilled water.

X – Ray diffractogram (Rigaku Miniflex, Japan) were obtained of these samples to find out structural information and to identify the film structure qualitatively. The scanning angle (2θ) range was from 20^0 - 80^0 (CuK$_\alpha$ line). Optical absorption was measured by UV-VIS spectrophotometer model no. Shimadzu -2450. The sample deposited on glass was placed in front of the reference beam and the spectra were collected.
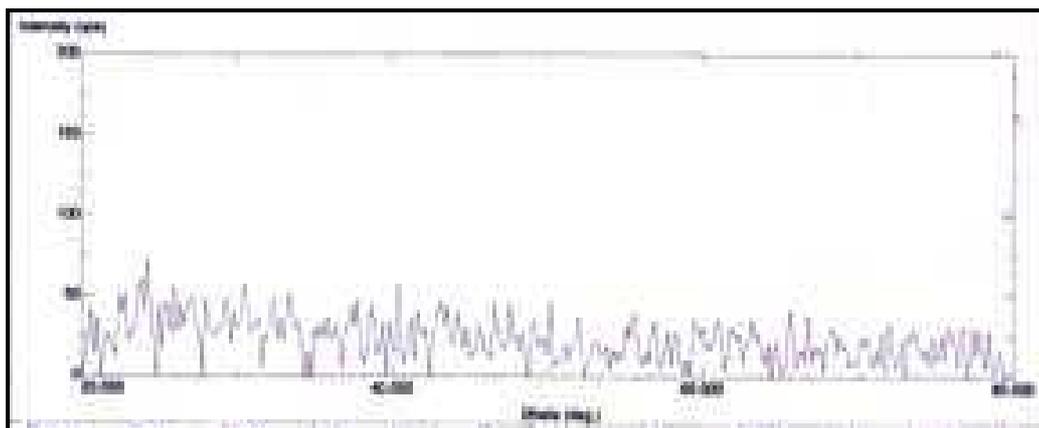
Fig.1 XRD of InSe thin film of thickness 2000 Å
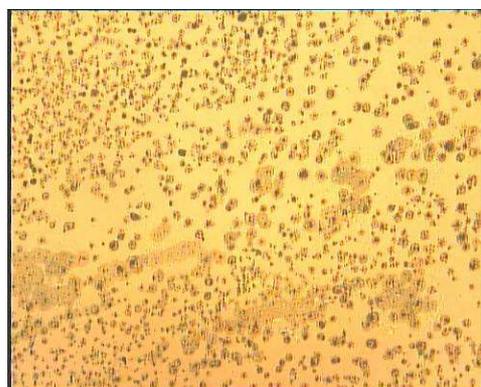
Fig. 2 Micrograph of InSe film of thickness 3000 Å

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RESULTS AND DISCUSSION

Structural characterization
The structural composition of the grown films was studied through the XRD analysis and optical microscopy. Figure 1 shows the XRD pattern of InSe thin film prepared at substrate temperature of 303k.   The observed data have been compared with standard data from this, It is found that the deposited films are polycrystalline having cubic structure [4, 6]. These results are well in agreement with the reported values. The grain size is found to be 11.18-11.93 nm.

Fig. 2 shows the micrograph of InSe of thickness 3000 Å indicates particles are uniformly distributed over the surface.
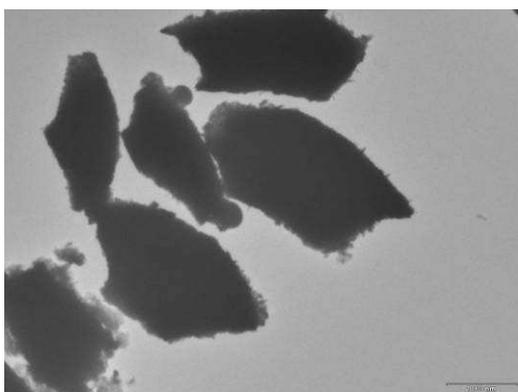
Fig. 3(a) TEM Micrograph of InSe film of thickness 1000 Å
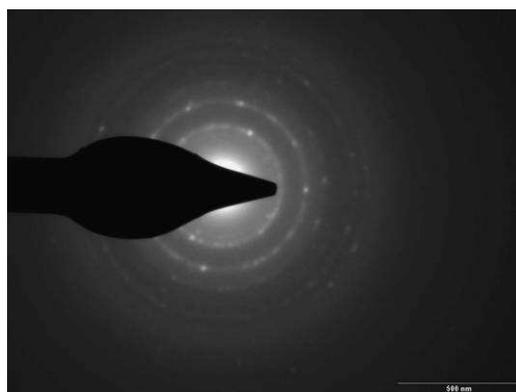
Fig. 3(b) SAED patternn of InSe film of thickness 1000 Å

TEM micrograph gives the morphology of the nanocrystallites. Figure 3(a) shows the TEM micrograph of as-prepared InSe nanoparticles. The image obtained is a translucent; it may be due to higher thickness. This result was in good agreement with XRD result. The selected area electron diffraction (SAED) pattern in figure 3(b) furthermore indicated that the nanocrystalline InSe   had a polycrystalline in nature.

Optical Properties of InSe thin Films
The optical absorption spectra were obtained in the 200nm-1100 nm wavelength range by employing a Shimadzu 2450 UV-Visible model of the spectrophotometer. Figure 4 shows the optical absorbance spectra in the wave length range 200-1100 nm of the films deposited in this work. To find α, the relation used is given by $\alpha = -1/d \ln T$, where T is the transmittance and d is the thickness of the film at room temperature.

The fundamental absorption edge is one of the most important features of the absorption spectrum of a semiconductor. The increased absorption near the edge is caused by the transition of electron from the valance band to conduction band. Figure 5 shows the plot of absorption coefficient α against photon energy. The value of fundamental absorption edge from the intercept lies at 0.97-1.49 eV and the corresponding α values are 0.02×10^6 to 0.05×10^6 cm^{-1}. The higher value of α in the UV region makes the material useful in forming p-n junction solar cells with other suitable thin film materials for photovoltaic applications [14].

The optical band gap of these films has been calculated using the relation (Tauc 1974).

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

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Where, $h\nu$ is the photon energy, α is the absorption coefficient, Eg the band gap, A is constant and, $n = 0.5$ for direct band gap material, $n = 2$ for indirect band gap material.   Figure 6 shows $(\alpha h\nu)^{1/2}$ verses photon energy for InSe thin films which shows the value of direct optical band gap for films. Figure 7 shows $(\alpha h\nu)^2$ verses photon energy for InSe thin films which shows the value of indirect optical band gap for films.   The direct and indirect energy band gaps of these samples were 0.81 to 0.84 eV and 1.31 to 2.18 eV respectively [8-13].
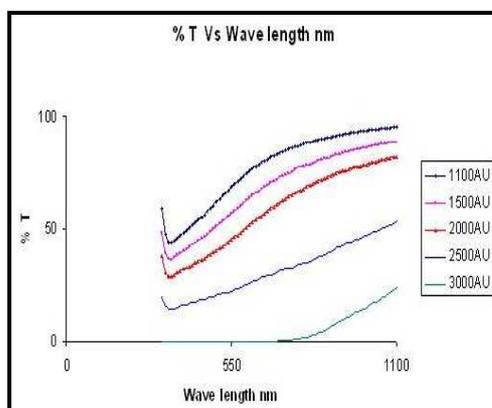
Figure 4 Plot of % T verses Wave length nm.
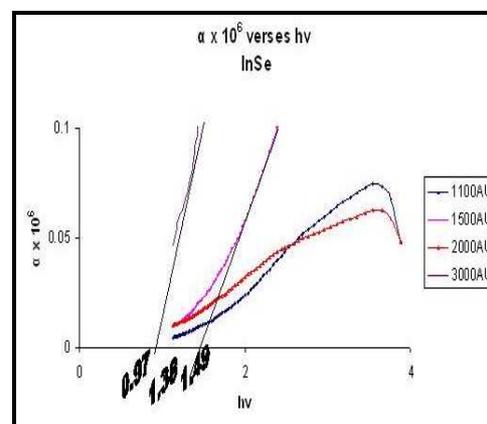
Figure 5 Plot of α x 10⁶ verses *hν*.

Fig 6 Plot of (α*h*ν)^{1/2} verses *h*ν.
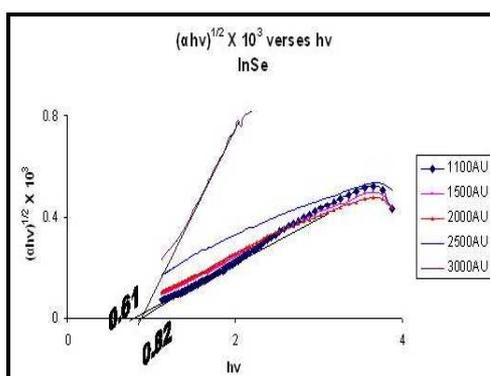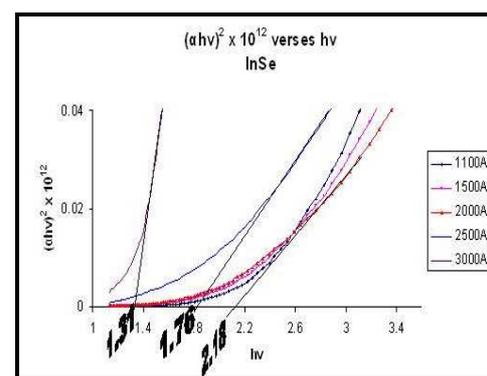
Figure 7 Plot of (α*h*ν)² versus *h*ν

CONCLUSION

Indium selenide thin films of different thickness have been deposited successfully on glass substrate. The X- ray analysis revealed that the deposited films are polycrystalline which is again confirmed by TEM. From optical studies, the fundamental absorption edge arises at 0.97 -1.49 eV which is due to direct electronic transition.   The direct and indirect energy band gaps of these samples were 0.81 to 0.84 eV and 1.31 to 2.18 eV respectively. Optical analysis revealed that prepared InSe thin films were direct allowed and it is suitable absorber layer for photovoltaic application.

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