Synthesis and Characterization of Nanostructured Vacuum Evaporated CdInSe Thin Films

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ABSTRACT

Nano structured thin films having different thickness of indium doped CdSe were deposited by thermal evaporation techniques, onto precleaned amorphous glass substrate at room temperature. The structural properties of films were evaluated by XRD and Scanning Electron Microscopy (SEM). The quantitative analysis was done by Energy Dispersive Analysis for X – Ray to determine atomic % of the material used. The optical band gaps of the films were measured by using optical absorption spectra. The X-ray diffraction analysis confirms that films were polycrystalline in nature having hexagonal structure with a preferential orientation along the (002) plane. The lattice parameters (a = 3.9652 &c = 5.8270 Å) and crystallite size (D) were calculated and found to be 200.1 nm – 240.4 nm. Unit cell volume is found to be 91.61. SEM investigation confirms that films were uniformly deposited over the surface and particles were granular in nature. The small gains in figure are the tips of nano rod. It is clear that these nano rods are uniformly distributed over smooth substrate. The length of nano tube was varied in the range of 200 nm to 800 nm and diameter of the tube was 35 – 40 nm. The thin films were found to be photosensitive which can be further utilized in various optoelectronic applications due to its charge carrier dynamics. It is found that CdInSe is direct band gap material having value of 2.05 – 2.45eV.

Keywords: Optical band gap, thermal evaporation, XRD, SEM, EDAX.

1. INTRODUCTION

Studies on amorphous chalcogenides glasses are of great interest due to their importance in preparing electrical memories, laser hosts [1] and optical application as good IR-transmitting material [2]. Cd chalcogenides alloys were studied by several researchers using different techniques for preparation [3–5]. CdSe is a narrow direct band semiconductor and its optical band gap is (E_g = 1.74 eV) [6]. In addition, CdSe has large absorption coefficient to visible light. This property is useful for good theoretical conversion efficiency and has led to the investigations for obtaining efficient solar cells. It was investigated for many years for its potential application in photovoltaic cells, thin film transistors, optical fibers, photoconductors xerography, g-ray detectors [7], photo electrochemical cells and electrography [3, 8–12]. Now, there are some recent applications of CdSe as nano particle layers [13] and for photoemission spectroscopic studies [14].

On the other hand, for InSe (Eg = 1.56 eV at room temperature) [15], kinetics, photoluminescence, physical properties and optical properties were studied [16–20]. (CdSe + InSe) alloys can be used as active layers in the fabrication of photovoltaic devices [21]. CdInSe is used as resistivity switching nonvolatile memory cell [22] in case of dye-sanitized solar cells [23] and in nanotechnology.

In this work we focus on the effect of thickness variation on the structural, optical and luminescent properties of thermally evaporated CdInSe thin films. Structural parameters such as grain size measured from XRD spectra are found to depend on the film thickness. The details have been reported in this paper.

2. EXPERIMENTAL

2.1 Material preparation

The CdInSe compound ingots were obtained by taking appropriate amount of 99.999% pure Cd, In and Se in an evacuated cleaned quartz ampoule. The ampoule with the charge was then sealed under a pressure of 10^{-5} Pa and was placed in rotating furnace. The temperature of the furnace was raised gradually to 1015 K and left at this temperature for about 12 h. Well mixed charges were then quenched in an ice bath [24, 25]. The CdInSe ingot was taken out from the ampoule and made into fine powder and used for film preparation

2.2 Synthesis and Characterization

Polycrystalline CdInSe films have been deposited by thermal evaporation technique under vacuum of about 10^{-5}torr onto precleaned amorphous glass substrate. The substrate to source distance was kept 10 cm. 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-Hi Vac. Further confirmation of thickness was estimated by Tolansky's method using multiple beam Fizeau fringes [26]. The deposition rate was maintained 10-20 Å/sec throughout sample preparation. Before evaporation, the glass substrates were cleaned thoroughly using concentrated chromic acid, detergent, isopropyl alcohol and distilled water.

X – Ray diffractograms (Bruker, Germany) 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). Surface morphological studies of the thermally deposited CdInSe thin films were done using the Scanning Electron Microscope (Zeiss EVO 50) operating with an accelerating voltage 10 KV. The quantitative compositional analysis of the CdInSe films were carried out by EDAX (Energy dispersive X-ray Analyzer) technique attached with the SEM. Optical absorption was measured by UV-VIS spectrophotometer model no. Shimadzu-2450.

3. RESULTS AND DISCUSSIONS

3.1 XRD characterization

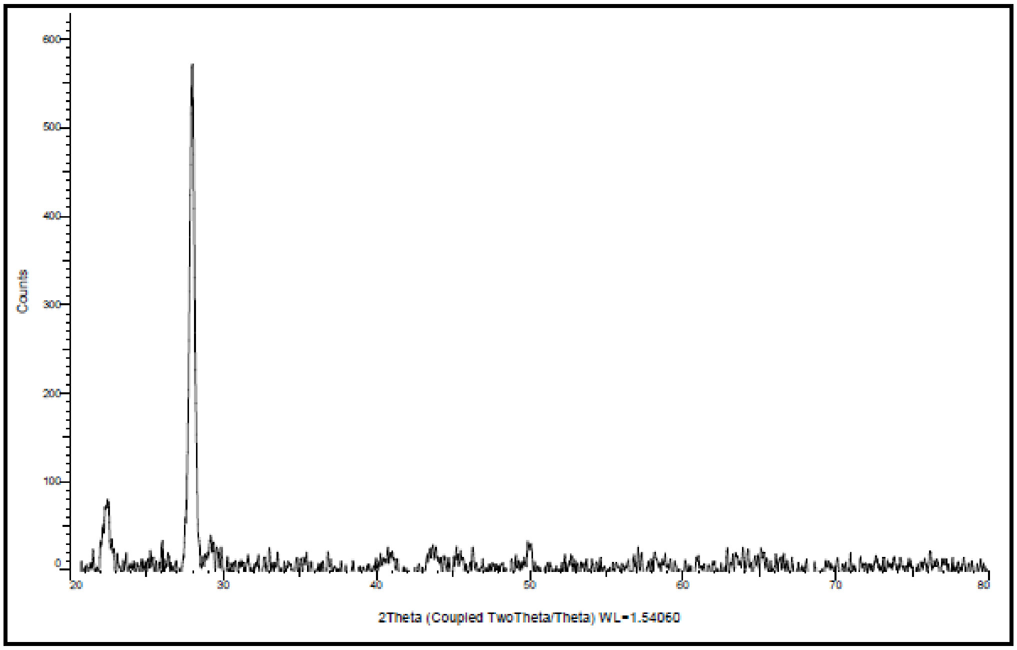
Fig. 1 shows the XRD pattern of CdInSe thin film prepared at substrate temperature of 303K. The 2θ peak observed at 22.403^0, 27.808^0, 40.265^0, 49.816^0, 49.873^0 exhibit the formation of the hexagonal phase of CdInSe which correspond to the (100), (002), (110), (110) and (103) planes of reflections. The presence of large number of peaks indicates that the films are polycrystalline in nature. It is observed that peak intensity increases with increasing thickness. As the thickness increases, the (002) diffraction peak becomes more and more dominant.

The average grain size is evaluated by well known Scherrer's formula and found to be 200.1 nm – 240.4 nm well agrees with already reported [12]

$$d = \frac{0.9\,\lambda}{\beta\cos\theta}$$

Where, λ the wavelength of X-ray used (λ = 1.54060Å), β is full width at half maxima (27.808^0).

The lattice parameters a and c in the prepared thin films have been determined as a = 3.9652 & c = 5.8270 Å respectively and are in good agreement with the values listed by the American society for testing materials (ASTM).



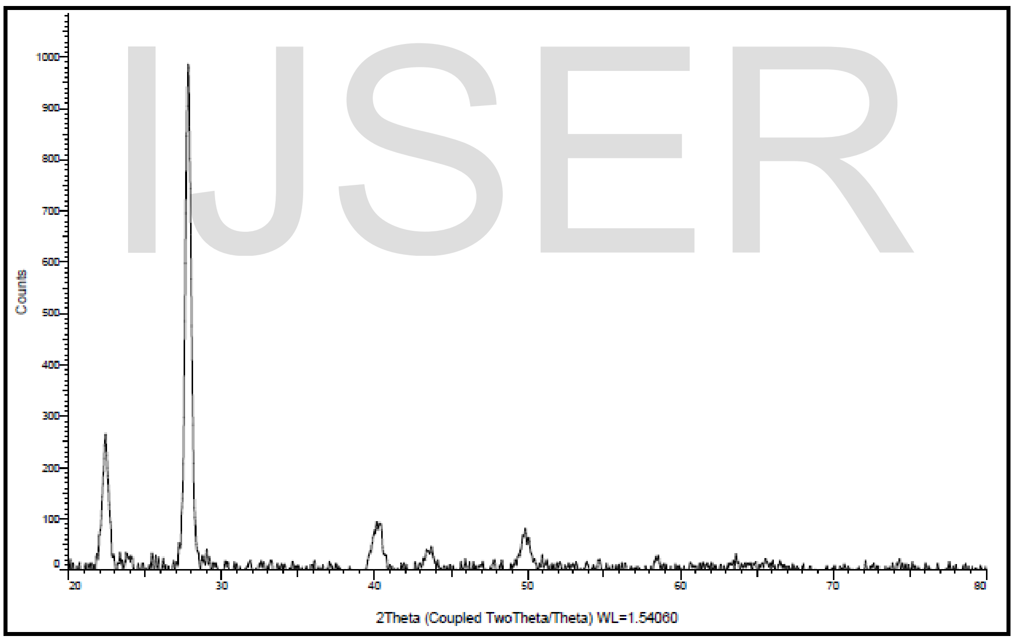


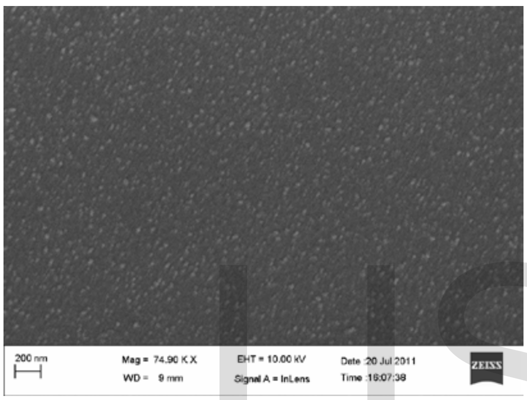
Figure 1: X-ray diffractograms of CdInSe thin films

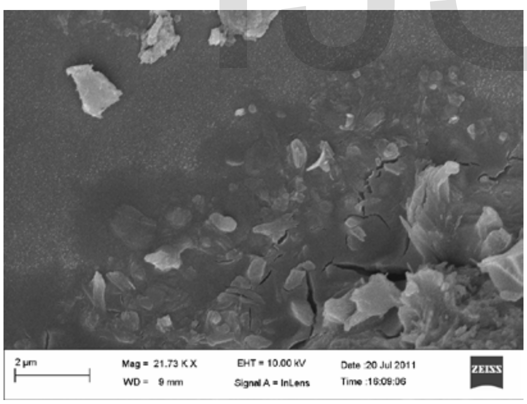
3.2 SEM Studies

Figure 2 (a, b, c) shows SEM images of CdInSe thin film with various magnifications 74.9K, 21.73K and 183K. The SEM image of CdInSe (Fig. 2 a, b) thin film shows that the film is uniform, polycrystalline, well cover on glass slide and free from microscopy defect like cracks or peeling. Nano size grains were uniformly distributed over smooth homogeneous background. The particle sizes were found to be 35-40 nm.

At low resolution the surface morphology is look like texture but as resolution increases the small grains are found. In higher resolution the nano tubes are clearly seen. The small gains in figure are the tips of nano rod seen in Fig. 2 c. It is clear that these nano rods are uniformly distributed over smooth substrate. The length of nano tube was varied in the range of 200 nm to 800 nm and diameter of the tube was 35 – 40 nm.

The grain size calculated by SEM is slightly less than the values of grain calculated by XRD. These values are in close agreement with other.





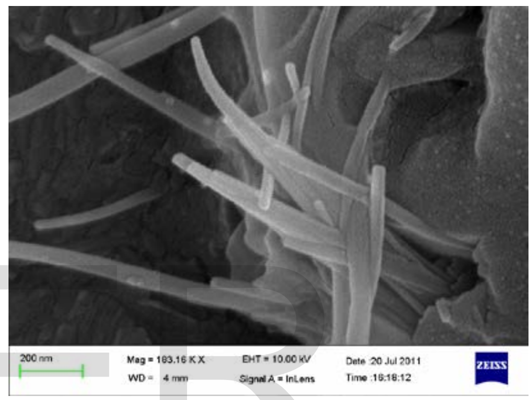


Figure 2 (a-c): SEM image of CdInSe thin film

3.3 EDAX studies

The elemental analysis of Cd, In and Se has been carried out EDAX in the binding energy region between 0 to 15 KeV shown in Figure - 3. This spectra shows the excepted elements detected. The spectrum peak reveals presence of Cd, In and Se at 0.4, 3.6, 1.6 and 11.2 KeV which confirms the presence of Cd, In and Se. Also there was no evidence for the appreciable amounts of impurities. The atomic percentage of Cd, In and Se were found to be 22.39%, 4.81 % and 72.80 %

respectively. It is seen that films were selenium rich due to difference in vapors pressure.

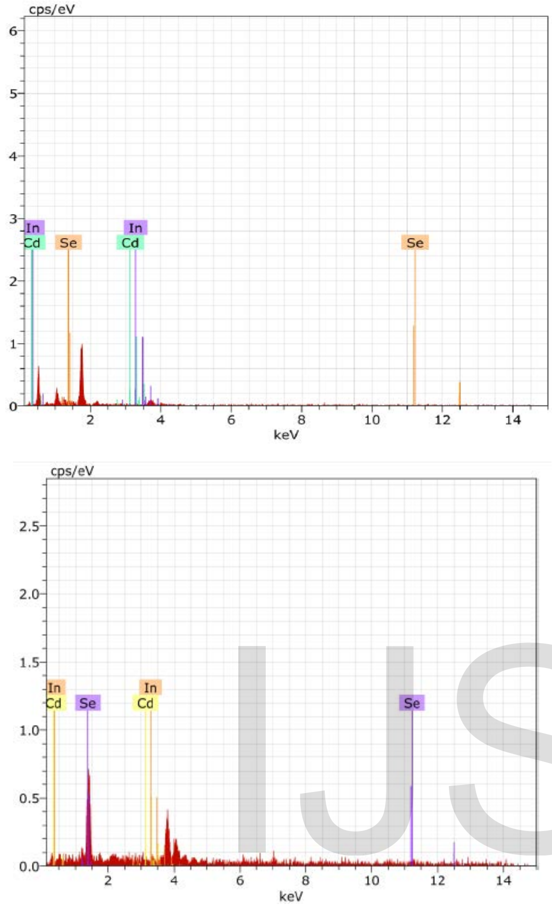
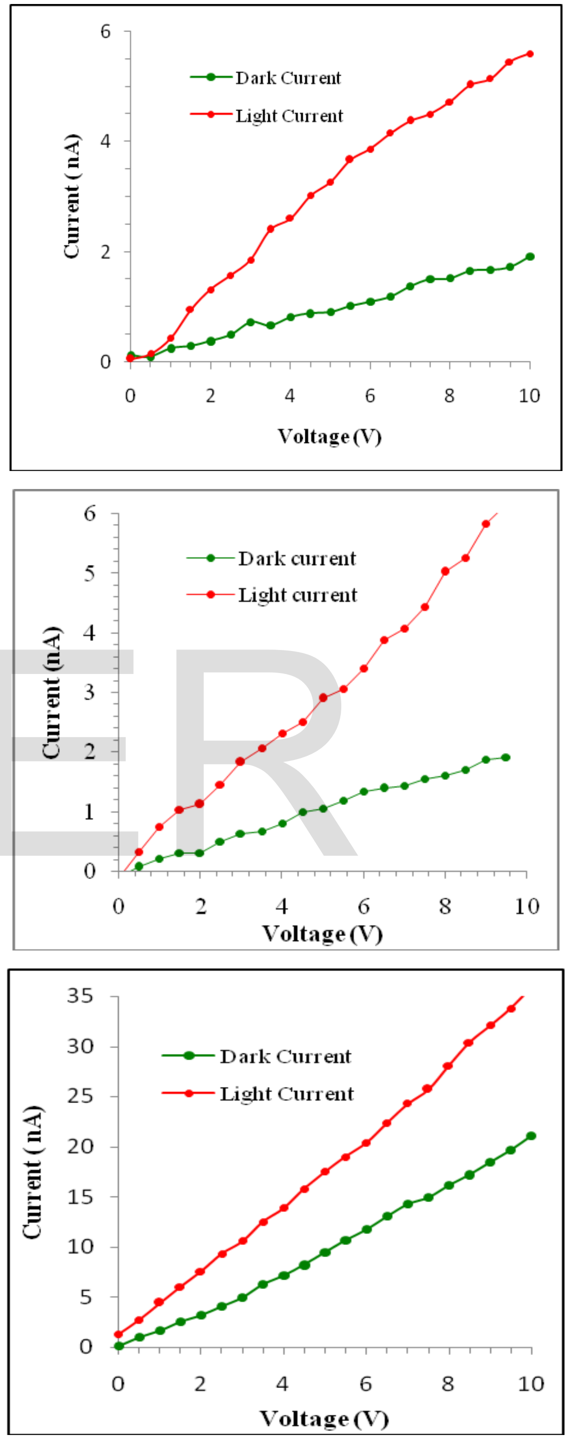


Figure 3: EDAX spectrums of CdInSe

3.4 Photo Sensing

Photo sensing is useful for fabrication of optical devices, photo sensor and PV modules. CdInSe can be used as window material in PV module. Figure 4a to 4d shows the I-V plots of CdInSe thin films with various thicknesses. I-V plot was obtained at room temperature under the dark condition and under the luminance of Xe - Lamp light (400 W).



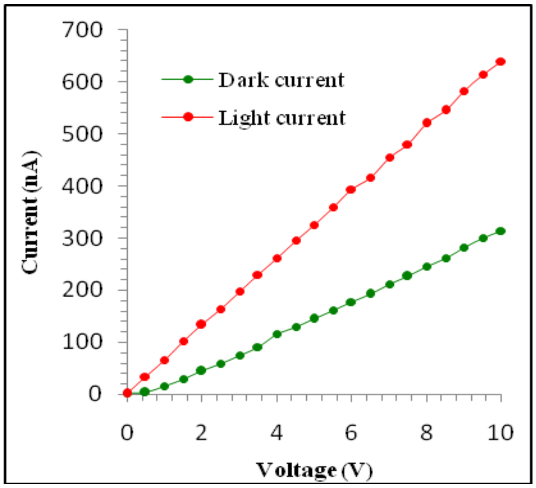


Figure 4: I-V Plots of CdInSe Thin Films for Photo Sensing

a) 1000 Å b) 2000 Å c) 2500 Å d) 3000 Å

The figures 4 a-d shows the improvement in current with respect to the voltage for both dank and luminance conditions. From the I-V plots it is observed that the recorded current in the presence light was relatively higher than the current measured in dark condition. It is know that the incident light excites the valence electrons, which in turn move across the energy band gap. This process creates electron – hole pairs and the observed current depends upon the number of charge carriers. Usually, photosensitive materials show increase in photocurrent on exposure to light. Photo sensitivity of grown CdInSe thin films calculated by:

$$S = \frac{I_l - I_d}{I_d}$$

Where I_l is the light current and I_d is dark current. The photo sensitivity of grown CdInSe thin films is motioned in the table 1. The photosensitivity is mainly depends upon crystallite size, absorption, band gap, chemical composition and resistivity of material etc. The thin film is found to be photosensitive which can be further utilized in various optoelectronic applications due to its charge carrier dynamics.

Table 1: Photo Sensitivity of CdInSe Thin Films

Thickness (Å)	Photo Sensitivity
1000	1.89
2000	1.48
2500	1.21
3000	1.48

3.5 Optical Properties

The optical absorption spectra were obtained in the 300 nm – 1100 nm wavelength range by employing a Shimadzu 2450 UV-Visible model of the spectrophotometer.

The spectra displayed in Fig. 5 (a, b) shows the absorbance and transmittance spectra. The film transmits well in the visible region of the solar spectrum. The optical band gap of these films has been calculated using the relation (Tauc 1974).

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

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Where, hυ is the photon energy, α is the absorption coefficient, E_g the band gap, A is constant and, n = 0.5 for direct band gap material, n = 2 for indirect band gap material.

The plot of $(\alpha h\upsilon)^2$ versus hυ for these CdInSe films is presented in figure – 5 c. This figure clearly shows the linear dependence for the value of P=1/2. This is attributed to an allowed and direct transition with direct band gap energies. The observed trend at absorption edge towards lower photon energies for the increasing film thickness could be attributed to the change in the grain size and the stoichiometric. The straight line portion is extrapolated to cut the x-axis, which gives the energy gap. All graphs show straight line portions supporting the interpretation of direct band gap for all the films.

The estimated band gap values were obtained as 2.05 -2.45 eV for indium doped CdSe as shown in figure 5c. Hence the CdInSe can be used in development of efficient photovoltaic application.

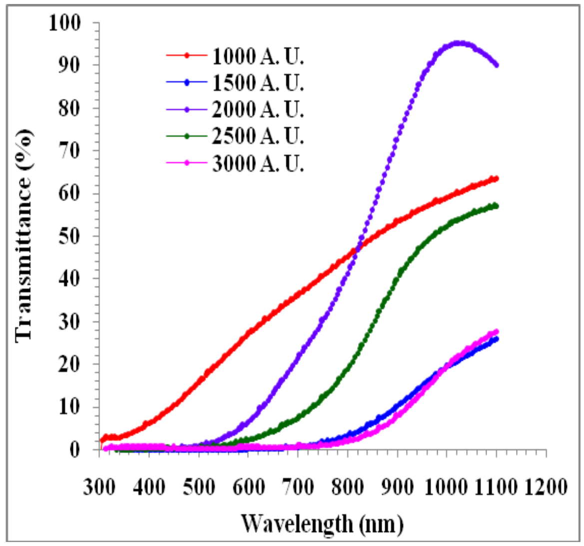

Fig.5 a: Transmittance Spectra of CdInSe Thin Film

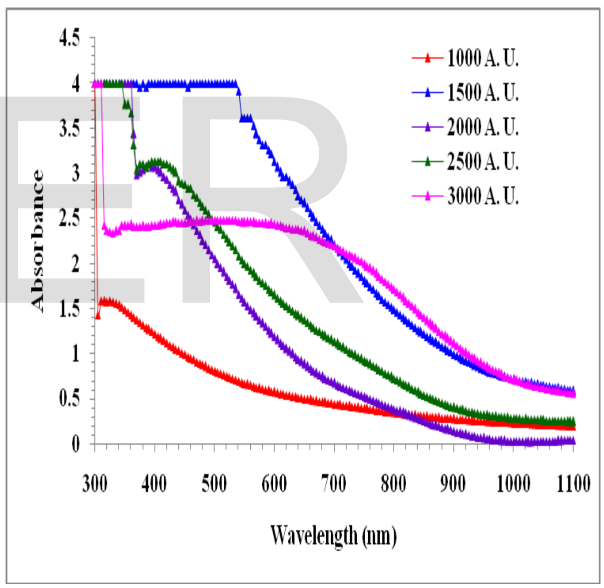

Fig.5 b: Absorbance Spectra of CdInSe Thin Film

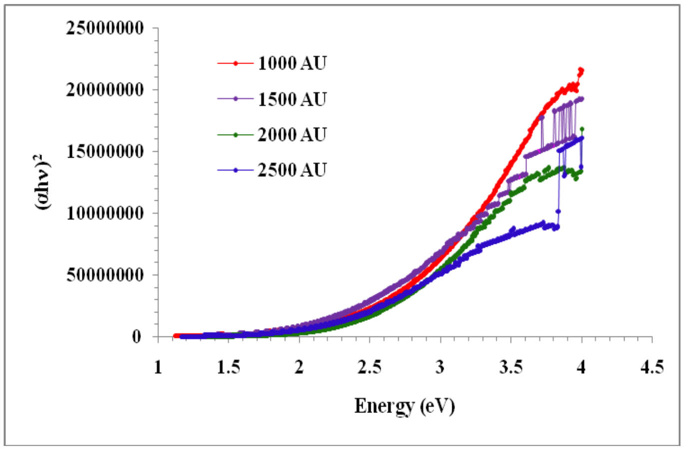

Figure 5 c: Plot of $(\alpha h\upsilon)^2$ versus $h\upsilon$

4. CONCLUSION

CdInSe thin films of different thicknesses have been deposited successfully on glass substrate. XRD confirms that the structure of the film is polycrystalline in nature and having hexagonal structure. From SEM study it is observed that deposited CdInSe film were homogenous and granular structure with nano crystalline in nature. Nano tubes are uniformly distributed over smooth substrate. The length of nano tube was varied in the range of 200 nm to 800 nm and diameter of the tube was 35 – 40 nm.

Analysis of the transmission data for CdInSe thin films, deposited at RT, showed the absorption coefficient, $a = 10^{-4}$ cm^{-1}, and the energy band gap, E_g, in the range of, 2.05 - 2.45 eV, hence the CdInSe can be used in development of efficient photovoltaic application in the next phase of work. The photosensitivity is mainly depends upon crystallite size, absorption, band gap, chemical composition and resistivity of material etc. The thin film is found to be photosensitive which can be further utilized in various optoelectronic applications due to its charge carrier dynamics. Sensitivity was found to be in the range of 1.21 – 1.89.

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