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COMPOSITIONAL AND ELECTRICAL RESISTIVITY STUDIES ON THERMAL EVAPORATION COPPER INDIUM DISELENIDE THIN FILMS

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Copper Indium diselenide thin films have been deposited on to well cleaned glass substrates in a vacuum of 10^{-5} Torr. The thicknesses of the films have been determined by micro balanced method and confirmed by multiple beam interferometric method. The EDAX results of the deposited $CuInSe_2$ films show that the composition of the films is almost the same as that of the source material. The resistivity is found to decrease with increase in temperature confirming the semiconducting nature of the deposited $CuInSe_2$ films. Two types of conduction mechanism namely variable range hopping and thermally activated process is found to be operative in the deposited $CuInSe_2$ films.

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1. Introduction

Semiconducting thin films have been extensively studied for a long time due to their significant role in modern science and technology. The ternary semi conductors of the type I-III-VI_2 have been intensively studied in recent years because of their potential applications in a variety of electro optic devices. Among these, copper indium diselenide is a promising material for the fabrication of thin film solar cells because of its high absorption coefficient, suitable band gap, and good thermal, environmental and electrical stability and also because of the potential low cost methods in its preparation [1]. Garcia et al [2] have prepared $CuInSe_2$ film by co- evaporation. They have reported the hole density and activation energy as $10^{13} – 10^{16}$ cm^{-3} and 0.03 to 0.5 eV in the temperature range 300K –400K respectively. Sakata et al [3] have deposited amorphous $CuInSe_2$ films by flash evaporation. The films were found to be of p-type semiconductor. The DC conductance and the activation energy were found to be in the range 1.2 –1.7 ohm cm^{-1} at 285 K and 55.5-301 meV respectively. The $CuInSe_2$ thin film has been vacuum co-deposited from the elements in two layers by Rommal Noufi et al [4]. They have reported that the resistivity of first layer, composite layer and second layer as $10^{-1} – 10$, 500-5 $\times 10^3$ and $2 \times 10^3 – 5 \times 10^3$ ohm cm respectively. Tell et al [5] have prepared $CuInSe_2$ compound and have reported that the compound's resistivity value is 1 ohm cm at room temperature. The present work deals with the compositional and electrical properties of copper indium diselenide thin films prepared by single source thermal evaporation.

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2. Experimental

The $CuInSe_2$ compound was prepared by taking stoichiometrically weighed pure Cu, In and Se. The mass of the elements has been measured using Metler AE 200 digital micro balance. The weighed high purity elemental copper, indium and selenium are taken in a pure quartz ampoule 65 mm long with 10 mm diameter. A pressure of $2x10^{-4}$ Torr is achieved in the ampoule along with the material. The vacuum sealing is done using oxy indane gas. The sealed ampoule is placed in a rotating furnace and the ampoule is gradually heated at the rate of 100°C/hour step by step up to a temperature of 1100°C. The ampoule is maintained at 1100°C for 24 hours and then cooled slowly to room temperature at a rate of 100°C/hour. The temperature required for synthesisation was determined from the phase diagram of $CuInSe_2$ alloy. During the course of heating and cooling the quartz ampoule is rotated continuously to ensure homogeneity in the molten mixture. After cooling, the alloy is taken by breaking the ampoule. Copper Indium diselenide thin films have been deposited on to well cleaned glass substrates in a vacuum of 10^{-5} Torr. Energy dispersive x-ray analyzer confirms the composition of constituent in the $CuInSe_2$ thin films. The electrical contacts required for resistance measurement has been made with silver. The electrical resistance of the deposited $CuInSe_2$ films has been measured in the temperature range 300 K to 450 K using Precision LCR meter (Chroma – 1075).

3. Results and discussion

The EDAX pattern of $CuInSe_2$ compound and $CuInSe_2$ thin film are shown in Figures 1 and 2 respectively. It is found that the elemental composition in the bulk is almost maintained in the film, as copper: 26.153 atomic%, indium: 24.288 atomic % and selenium 49.559 atomic%. The presence of high copper content increases the grain size, in turn yielding good poly crystallites [6, 7]. The results of X-ray diffraction studies and the energy dispersive analysis of X-rays (EDAX) carried out on $CuInSe_2$ thin films deposited by vacuum evaporation technique shows that the deposited films are of good quality suitable for the fabrication of $CuInSe_2$ based solar cells.

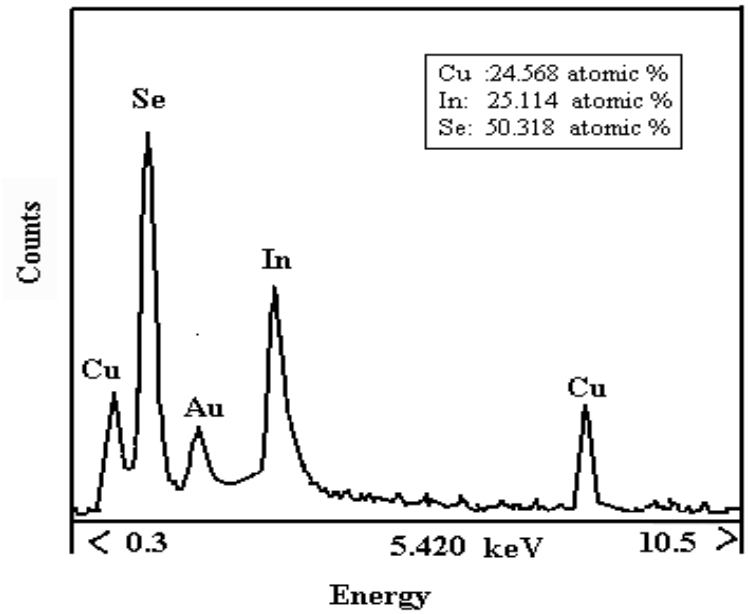

Fig. 1. EDAX pattern of the $CuInSe_2$ bulk

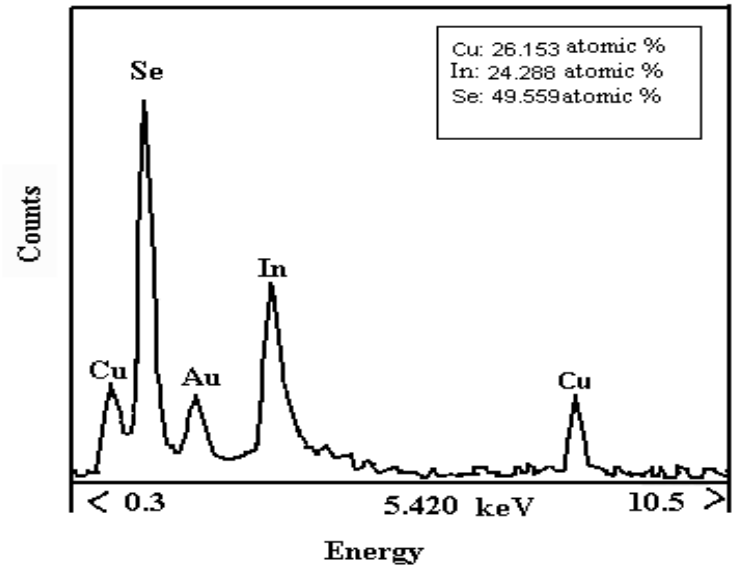

Fig. 2. The EDAX pattern of the $CuInSe_2$ thin film

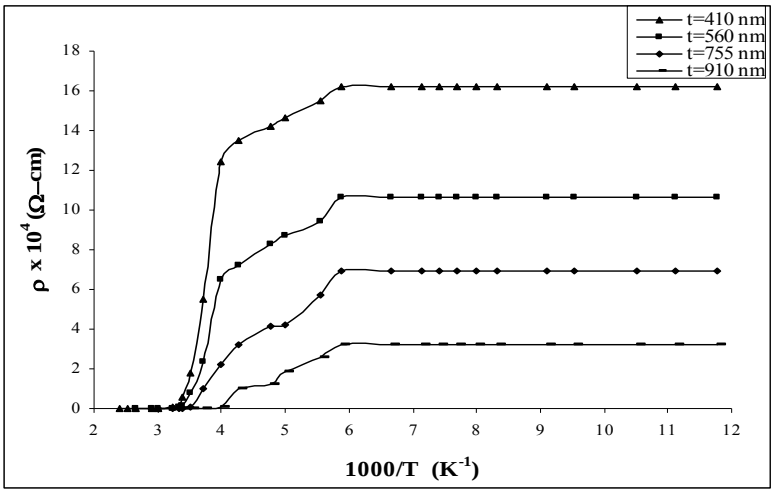

Fig. 3. Variation of resistivity with temperature of $CuInSe_2$ thin films of different thicknesses

The variation of resistivity with temperature of $CuInSe_2$ thin films of different thicknesses is shown in Fig. 3. The resistivity is found to decrease with increase in temperature confirming the semi conducting nature of the deposited films. The resistivity is also observed to exhibit a strong dependence on film thickness. The resistivity of thicker films is found to be comparatively less than those of thinner films. This may be due to the presence of large grains with less strain and dislocation in the thicker films.

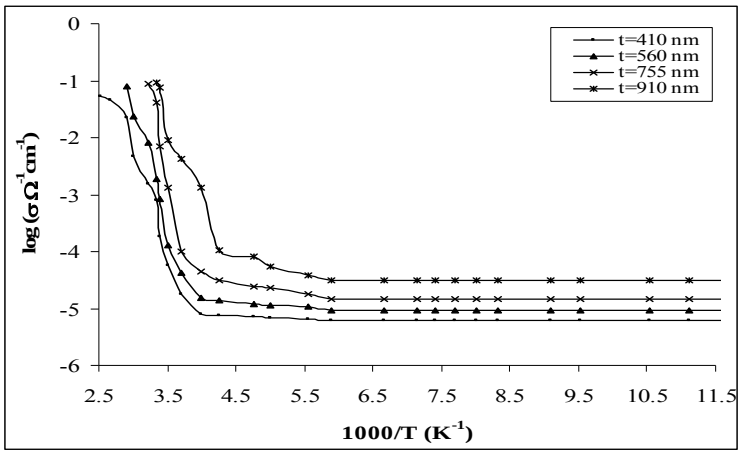

Fig. 4. Plot of logσ Vs. 1000/T of CuInSe2 thin films of different thicknesses

Fig. 4. shows the variation of electrical conductivity with the inverse of absolute temperature in $CuInSe_2$ films. The increase in conductivity is very gradual in the room temperature range. Similar observation has been reported by earlier workers [8, 9]. The log σ Vs. 1000/T plot is found to have two regions with two different slopes with the point of inflection around 250K. This characteristic reveals that there are two types of conduction mechanism present in the deposited $CuInSe_2$ films. In the temperature region below 250K the conduction mechanism is of variable range hopping process and in the temperature region above 250K the conduction is of thermally activated process.

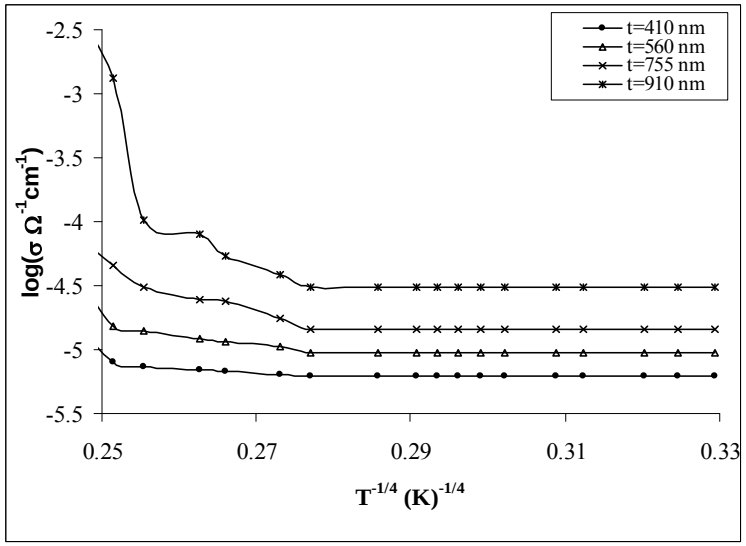

Fig. 5. Plot of log σ Vs.of $T^{-1/4}$ of $CuInSe_2$ thin films of different thicknesses

The plot of log σ Vs. $T^{-1/4}$ is shown in Fig. 5. The conductivity data below 250K are used in the plot. The plot is found to be a linearly varying one and is in accordance with Motts variable range hopping process [10]. Log σ is found to be proportional to $T^{-1/4}$. Abu et al [11] have reported a similar behavior in $CuInSe_2$ films.

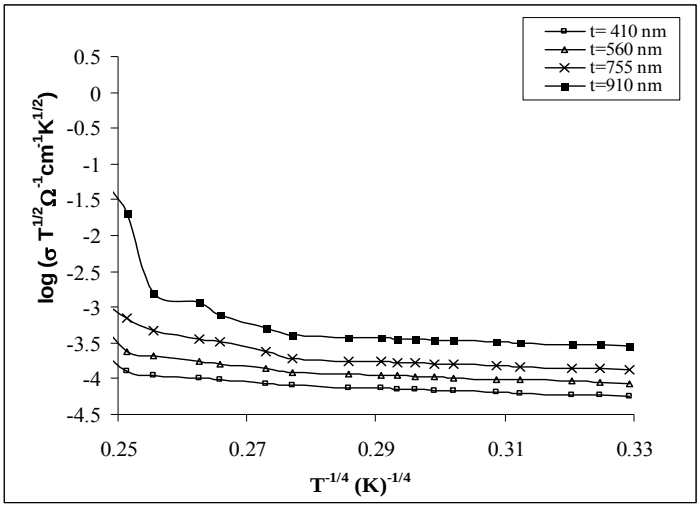

Fig.6. Plot of log ($\sigma T^{1/2}$) Vs.$T^{-1/4}$ of $CuInSe_2$ thin films of different thicknesses

The plot of log ($\sigma T^{1/2}$) Vs.$T^{-1/4}$ shown in Fig .6. represents the conductivity below 250K.The plot is a linearly varying one and experimental data are found to comply with the relation.

$$\sigma = \sigma_0 \; T^{-1/2} \exp \{ -(T_0/T)^{1/4} \} \qquad (1)$$

This confirms that the conduction mechanism in $CuInSe_2$ films in the temperature range below 250K is of variable range hopping conduction mechanism.

4. Conclusion

The EDAX results of the deposited $CuInSe_2$ films show that the composition of the films is almost the same as that of the source material. The resistivity is found to decrease with increase in temperature confirming the semiconducting nature of the deposited $CuInSe_2$ films. Two types of conduction mechanism namely variable range hopping (below 250 K) and thermally activated process (above 250K) are found to be operative in the deposited $CuInSe_2$ films.

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