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The Measurement of Conductivity of Copper Indium Disulphide Thin Films Against Temperature and Thickness

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ABSTRACTS

Ternary semiconductor copper indium disulphide ($CuInS_2$) thin films have been prepared by thermal evaporation. Three stacked layers of film starting with copper, indium and finally sulphur was deposited on glass substrate in the thickness ratio of 1:1:10. The films were then annealed in carbon block by method known as encapsulated sulphurization at 350°C for 4 hours. The XRD analysis for four samples of thickness of 449.5, 586, 612 and 654nm showed that stoichiometric $CuInS_2$ were formed at this annealing condition. The electrical conductivity of $CuInS_2$ thin films were measured against temperature from 150K to 300K. The conductivity values were between 76.6 Sm^{-1} to 631.26 Sm^{-1} and the result showed that it increase exponentially with temperature for the above temperature range. The resulting activation energies were found to be in the range 0.05 to 0.08 eV. This suggested that hopping mechanism predominant to the conducting process. It also found that the conductivity decreased with increasing film thickness.

KEY WORDS: Conductivity, $CuInS_2$, thin films, annealing.

INTRODUCTION

The properties of semiconductor materials either as bulk or thin films have been studying continuously. Ternary semiconductor such as $CuInS_2$, CuInSe and CuInTe are becoming current interest as these materials have photovoltaic device application potential[1,2] such as for application in heterojunction solar cells and photovoltaic detectors[3-6]. Attempts have also been made to make stable and high performance solar cells from these materials[7,8]. $CuInS_2$ is crystalline in chalcopyrite structure. A variety of techniques have been employed to prepare $CuInS_2$ thin films and their properties described by several workers previously[9-12]. In this work $CuInS_2$ thin films have been prepared by thermal evaporation and preliminary investigation of electrical conductivity against temperature and film's thickness are reported.

MATERIALS AND METHODS

The $CuInS_2$ were prepared by thermal evaporation on glass slide substrate. The evaporation was done in three stages starting with copper followed by indium and finally sulphur. The deposition was done at pressure 10^{-5} torr and the film's thickness ratio was 1:1:10. Sulphur film is the thickest because some of this material vaporizes during annealing. It is necessary to preheat the substrate for 30 to 45 minutes before copper deposition to avoid film being peel off after annealing. The deposition rate was kept at 0.5 nm/s for every material. During evaporation the thickness of the film was measured by means of quartz crystal monitor and was confirmed by Tolansky technique after evaporation.

The sample obtained in the form of three stacked layers that later put in a carbon block. Then this carbon block was placed in a glass tube inside a furnace as in Fig.1. The annealing process is known as encapsulated sulphurization[9]. Argon gas pressure 10^{-1} mbar continuously flow during annealing process. The annealing was done at temperature 350°C for 4 hours. These parameters were chosen as the optimum preparation condition of the previous results[9]. The sample was left to cool down slowly in the tube until the next morning and this producing a good quality film.

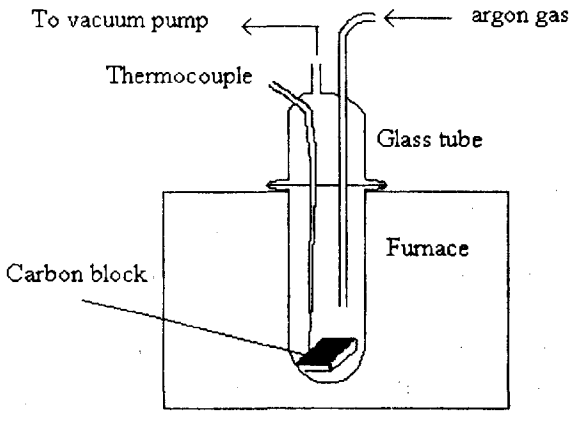

FIGURE 1: Annealing Sample in Carbon Block

The composition studied of the films were done using X-ray diffraction technique. The surface morphology of the films was observed from SEM micrograph taken on a selected samples. The electrical conductivity of the films was measured against temperature in the range of 150°C to 300°C. The measurements were done in a cryostat by Van der Paw technique.

RESULTS AND DISCUSSION

X-ray Analysis and SEM

Four samples of thickness 449.5, 586, 612, and 654 nm were analyzed by X-ray diffraction tecnique.using CuKα radiation. The spectrum showed a prominent peak corresponding to (112) plane as in Fig. 2. The results are in agreement of the previous

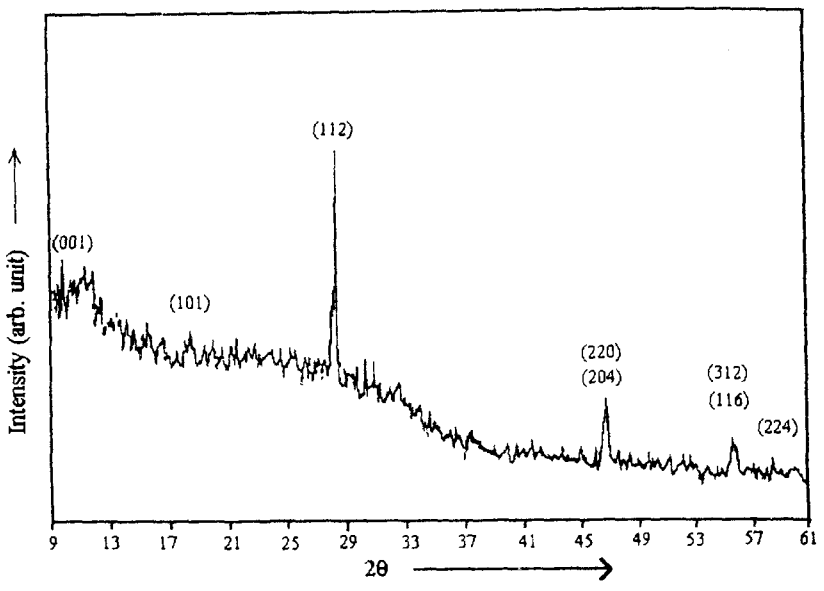

FIGURE 2:X-Ray Difraction Spectra of CuInS2 Thin Film (449.5 nm)

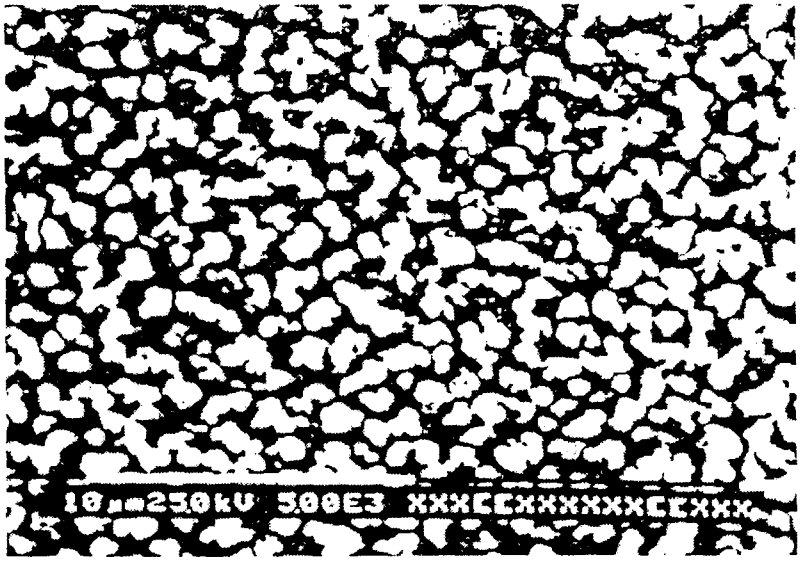

FIGURE 3: SEM Micrograph of $CuInS_2$ Thin Film (449.5nm)

results[9], Kazmerski et. al [10] and Hwang et. al[11] and that the $CuInS_2$ thin films are polycrystalline in nature. The surface topography of $CuInS_2$ films is shown in Fig 3. The grain size is about 1 μm.

Conductivity Measurement

The sample's ohmic contacts were made by deposited four tinny Al on the film. The d.c conductivity of $CuInS_2$ films was measured in the temperature range between 150-300°C. The lowest value is 76.6 Sm^{-1} for 654 nm film and the highest value obtained is 631.2 Sm^{-1} for the film of 449.5 nm thickness. It was found that the conductivity of $CuInS_2$ thin films increased exponentially with increasing temperature. A typical result is shown as in Fig. 4. The conductivity values were slightly higher order than previous results by other workers[10,12].

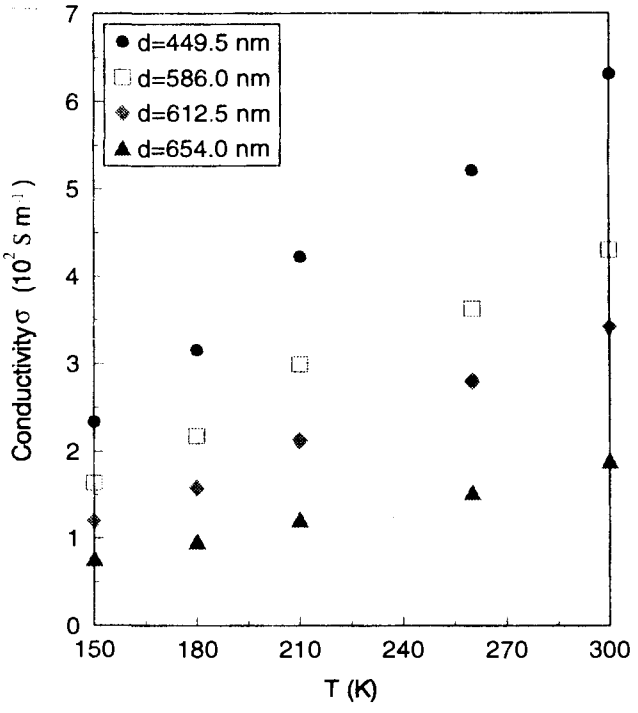

FIGURE 4: Temperature Dependence of Conductivity of $CuInS_2$ Thin Films

There results at low temperature suggest that the conductivity of $CuInS_2$ thin films exhibits an activation energy dependence in accordance with the relation [13]

$$\sigma \propto \frac{1}{T^{1/2}} \exp\left(-\frac{E_a}{kT}\right)$$

where E_a is the activation energy. A typical plot ln σ vs 1/T is shown in Fig 5. Hence the slopped of this plot gives the activation energy. The calculated activation energy is in the range 0.05 eV to 0.08 eV. The conducting process mainly by hopping mechanism due to the linearity of I-V graphs obtained. The values obtained suggested that the films are extrinsic semiconductor. The conductivity of $CuInS_2$ thin films were also found to be decreasing with film thickness as shown in Fig 6.

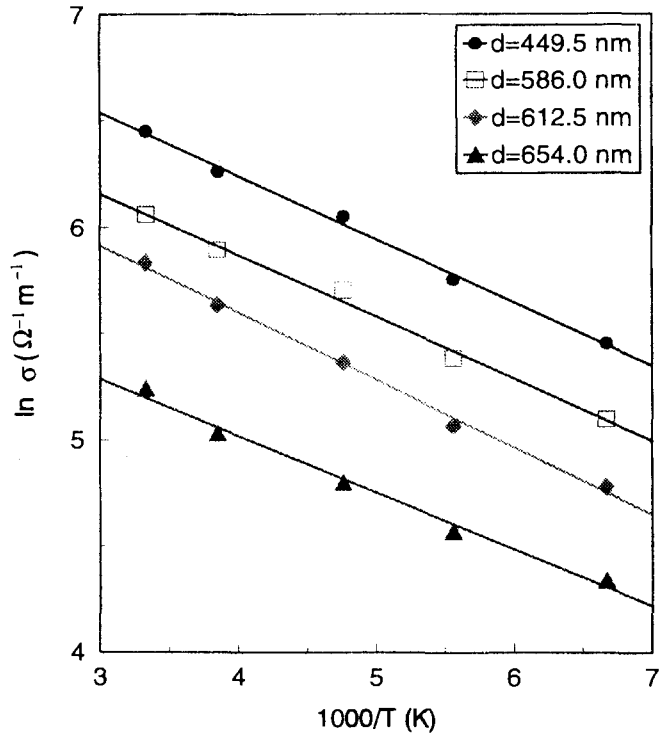

FIGURE 5: ln σ against 1/T for $CuInS_2$ Thin Films

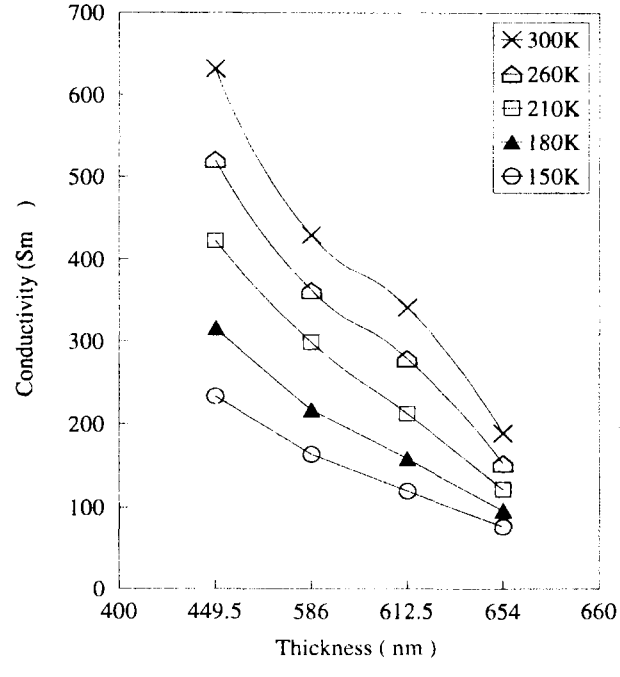

FIGURE 6: The Variation of Conductivity against Thickness for $CuInS_2$ Thin Films

CONCLUSIONS

The conductivity of $CuInS_2$ thin films prepared by encapsulated sulphurization has been measured. The values increased with increasing temperature but decreased with film's thickness and it was suggested the thin films are extrinsic.

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