

Copper Indium Gallium Telluride Films for Solar Cells

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Abstract: Copper indium Gallium Telluride films were deposited for the first time by the pulse electro-deposition technique at room temperature and at a constant potential of -0.75 V(SCE). The films exhibited single phase. Optical band gap of the films is in the range of range $0.9-1.5$ eV for various duty cycles. Atomic force microscopy studies indicated that the grain size in the range $300-500$ nm. Capacitance voltage measurements indicated the films to exhibit p-type behavior. The flat band potential was 0.75 V (SCE) and carrier density was in the range of 6.5×10^{16} cm.

Key words: Thin films, Solar cells, Pulse electrodeposits, I-III-VI₂ semiconductors, and chalcopyrite.

I. Introduction

Cu-III-VI₂ chalcopyrite semiconductors are feasible candidates for application as photo detectors [1], photo-voltaic cells [2] and light-emitting diodes [3]. Among Cu-based chalcopyrite, a high efficiency of 19.9% has been achieved for Cu(In,Ga)Se₂ (CIGS) based-thin film solar cells with small areas (1 cm²) [4]. There has been increasing interest in the material properties of I-III-VI₂ compounds whose energy gap lies between 0.9 and 3.5 eV, as they exhibit great potential for the manufacture of electro-optical devices [5]. Though I-III-Se₂ compounds have received much attention in recent years, there are relatively fewer studies on I-III-Te₂. Earlier no reports on CuInGaTe₂ show a direct band gap semiconductor with an energy gap of 1.23 eV. Bulk CuInGaTe₂ exhibited p-type conductivity due to shallow acceptors [6] with a hole concentration of about 10^{18} cm⁻³ at room temperature [7]. In this work, the pulse electrodeposition technique was employed for the first time [11] to deposit CuInGaTe₂ (CIGT) films for applications of solar cells.

II. Experimental methods

Copper Indium Gallium telluride were deposited on tin oxide coated conducting glass substrates at room temperature at a deposition potential of -0.75 V Vs Saturated Calomel Electrode (SCE) by pulse electrodeposition method[12]. The total deposition time was 60 min. 0.25 M CuCl₂, 100 mM TeO₂ and the concentration of GaCl₃ and InCl₃ was varied to get different composition. Thickness of the films estimated by Mitutoyo surface profilometer, it varied from Thickness of the films estimated by Mitutoyo surface profilometer varied in the range of 350 – 700 nm with increase of duty cycle. The films were characterized by Xpert panalytical x-ray diffraction unit with Cu ka radiation. Optical measurements were recorded using a Hitachi UV-Vis-IR spectrophotometer. Surface morphology of the films was studied by molecular imaging atomic force microscope.

III. Results and discussion

Fig.1 depicts the XRD patterns of the films deposited at different duty cycles. The films were polycrystalline with peaks corresponding to (112), (220) and (312) planes of crystalline CuInGaTe₂ at approximately $2\theta = 24.20^\circ$, 40.21° and 47.29° , respectively matches with (JCPDS card No.10-0421). As the duty cycle increased, the intensity of the peaks increased and the width of the peak decreased. The crystallite size was estimated from the Scherrer's equation to be 30nm-70nm

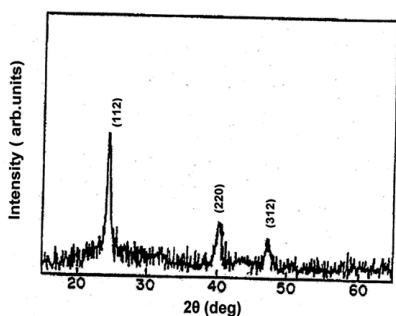


Fig. 1

Fig. 1 X-Ray diffraction pattern of Cu InGaTe₂ deposited at 50% duty cycles

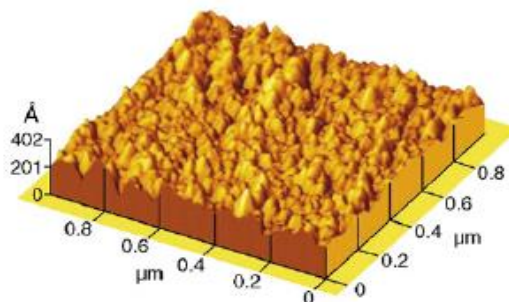


Fig. 2

Fig. 2 Atomic force micrographs of Copper Indium Gallium Telluride deposited at 50% duty cycles

The obtained stoichiometric composition from EDS study is close to the ideal composition of CuInGaTe_2 . The quantized stoichiometric composition is Cu (28.95 at %), Ga (27.80 at %) and Te (43.25 at %). Atomic force microscopy studies were made on the films. Fig.2 shows the Atomic force microscopy images. The grain size and surface roughness vary from 300 nm and 1.5 nm, respectively.

Optical absorption studies were made on the films deposited at 50% duty cycle. The films exhibited a high absorption co-efficient of the order of 104 cm^{-1} . A plot of $(\alpha h\nu)^2$ against $h\nu$, as indicated in Fig. 3, exhibited linear behavior near the band edge, the band gap of the deposited material was determined to be in the range 1.24 eV. The band gap was found to slightly increase with decrease of duty cycle, due to the small grain size. The band gap of CuInGaTe_2 in thin film prepared by other technique was not reported in previous literature. The band gap of thin films obtained in the present work is in fair agreement with the value of Cu(In,Ga)Se_2 [11,12,13]

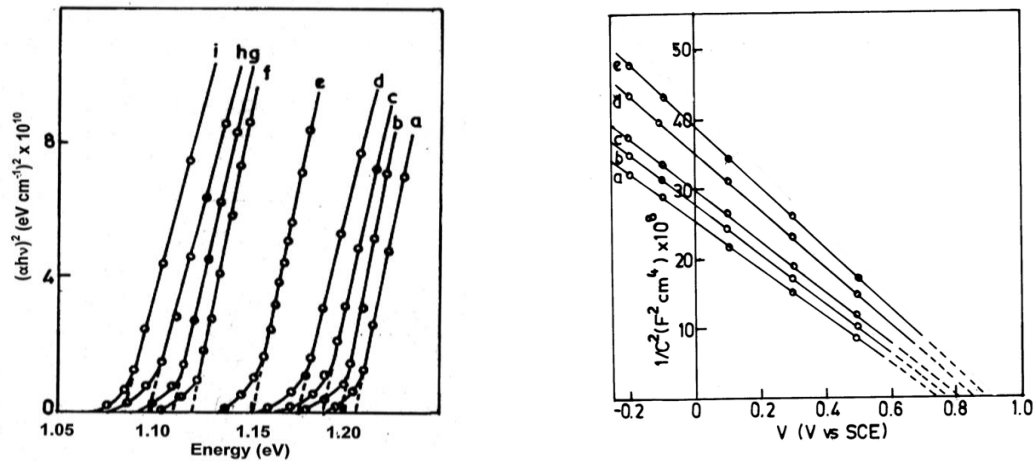


Fig. 3 $(\alpha h\nu)^2$ Vs $h\nu$ plot of CuInGaTe_2

Fig.4 Mott Schottky plots of CuInGaTe_2 films deposited at different duty cycles (a)15 % (b)33 % (c)50 %

. Fig. 4 shows the Mott-Schottky plot of the CuInGaTe_2 films deposited at different duty cycles. 1 M $\text{Na}_2(\text{SO}_4)_2$ blocking electrolyte was used, the AC frequency was 10 kHz. Linear plots were obtained. The nature of the plot with negative slope indicates p-type behavior. V_{fb} of 0.68 - 0.72 V (SCE) and a carrier density in the range of $2.5 \times 10^{16} \text{ cm}^{-3}$ were obtained.

Resistivity of the films deposited at different duty cycles was measured by the two probe resistivity technique. Evaporated gold dot contact at the center of the top of the film served as one contact, while the conducting glass substrate served as the other contact. The resistivity of the films decreased from $40 \Omega \text{ cm}$ to $20.0 \Omega \text{ cm}$ with increase of duty cycle. The resistivity decreases for lower duty cycles since the Cu/In ratio is greater than 1 for the films deposited at duty cycles lower than 50% (supported by the EDS data).

Using the value of carrier density obtained from the M-S studies and the resistivity value of $40 \Omega \text{ cm}$ for the films deposited at 50% duty cycle, a value of $20 \text{ cm}^2 \text{V}^{-1} \text{S}^{-1}$ was obtained for the mobility. The resistivity values for the films deposited at different duty cycles are shown in Table 1. The value of resistivity is higher than earlier report.

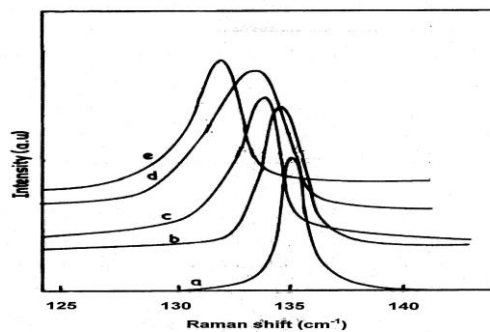


Fig. 5 Raman spectra of CIGT films deposited at different duty cycles 50 % (a) 33 % (b) 15 % (c) 9 % (d) 6 % (e)

Fig 5 shows the Raman spectra of CuInGaTe_2 films deposited at different duty cycles. It can be observed that A1 mode shifts to higher frequencies with increase of duty cycle. The width of the peak also decreases as the duty cycle increases.

IV. Conclusions

The results of this work clearly points to the possibility of depositing single phase nano crystalline CuInGaTe₂ films. Films with band gap in the range of 0.9 – 1.25 eV can be obtained. P-Type films with carrier density in the range of $2.5 \times 10^{16} \text{cm}^{-3}$ can be obtained. So this work shows CuInGaTe₂ can be used as a better alternate for CuGaSe₂ in solar cell applications.

References

- [1] Wagner S, Shay JL, Migliorato P. Applied Physics Letters 1974;25 434–5.
- [2] Shay JL, Wagner S, Kasper HM. Applied Physics Letters 1975; 27:89–90.
- [3] Phil WY, Park YS, Faile SP, Ehret JE. Applied Physics Letters 1975; 26:717–9.
- [4] Repins I, Contreras MA, Egaas B, DeHart C, Scharf J, Perkins CL, et al. Progress in Photovoltaic's: Research and Applications 2008;16:235–9.
- [5] J.L. Shay and J.H. Wernik, Ternary Chalcopyrite Semiconductors: Growth, Electrical Properties and Applications, Pergamon, New York, 1975.
- [6] H. Neumann, D. Peters, B. Schumann and G. Kuhn, Phys. Status Solidi (a), 52 (1979) 559.
- [7] W. Horig, G. Kuhn, W. Moller, A. Muller, H. Newmann and E. Reccius, Krist. Tech., 14 (1979) 472.
- [8] Ananthan MR, Kasi Viswanathan S. Solar Energy Materials and Solar Cells 2009;93:188–92.
- [9] Ishizaki T, Saito N, Fuwa A. Surface and Coatings Technology 2004;182:156–60.
- [10] Gremenok VF, Victorov IA, Bodnar IV, Hill AE, Pilkington RD, Tomlinson RD, et al. Materials Letters 1998; 35:130–4.
- [11] JM. SessaReddy, K.T. RamakrishnaReddy, B.S. Naidu, J. Reddy, Materials Chemistry and physics 44(1996)281
- [12] Dr. K. Srinivasan, C. Vinodhini, Material science in semiconductor processing 15(2012)194–198.
- [13] Du TB. British Corrosion Journal 2002;37:18–22.