Growth and Characterizations of Nanostructure $Cu_{0.5}$ $In_{0.5}$ Se Thin Films

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ABSTRACT

Thermal evaporation method was used to deposit Cu0.5 In0.5 Se thin films on top of the glass substrates. A scanning electron microscope was used to analyze the microstructure and assess the phase purity. Deposited thin films showed a monoclinic crystal structure with polycrystalline in nature. The optical transmittance spectra of Cu0.5 In0.5 Se thin films was analyzed and showing the fundamental band gap of 2.2 eV.

***KEYWORDS** : XRD, SEM, EDAX, UV-VIS Spectroscopy.*

INTRODUCTION

CuInse, a ternary compound, is known for being useful in PV devices because of the higher absorbing coefficient. [1, 2]. For thin-film solar cells, CuInse has been identified as a promising absorber material. [3]. Crystallinity and compositional balance should be essential factors for these devices for working optimally. Several deposition methods have been used to produce CuInse thin films, including: Epitaxy of molecular beams [5, 6] used as a pulse laser for thin-film deposition [7] used as a spray pyrolysis for thin-film deposition [8] used as a CBD RF sputtering for thin-film deposition [9] used as a CBD for thin-film deposition [10]. Thermal evaporation is a key method for depositing compound materials due to its informality and reproducibility. CuInSe thin films were deposited using this method by feeding source material onto a molybdenum boat and repeating the evaporation process to achieve the desired thickness. Despite these precautions, other preparative parameters, such as source to substrate distance, deposition rate, and substrate temperature, also plays a significant role. These growth parameters can lead to variations in structural, optical, and electrical properties. Therefore, it is necessary to study these properties and optimized it for favorable deposition of the film. The present study focus on preparation of optimized CuInse thin film, which was analyzed by XRD and SEM. Also, studied optical properties such as photo sensing, absorbance spectra, transmission spectra and energy band gap.

LITERATURE REVIEW

$CuInSe_2$ (CIS), a ternary semiconductor, has become a key material in large-scale thin-film solar cells thanks to its impressive optical and thermal properties. It is one of the most promising candidates for second-generation solar cells, with efficiencies beyond 19%. Polycrystalline nature structural characterization was carried out by XRD and SEM studies these studies confirm the polycrystalline nature $CuInSe_2$ thin films were deposited on glass substrate from single source thermal evaporation method. Energy band gap was between 1.02 eV to 1.04eV and high absorption coefficient values 1 to 2 $\times 10^5$ cm^{-1}.

METHODOLOGY

The melt quench process was used to create ternary alloy $Cu_{0.5}In_{0.5}Se$. The pure mixture of copper, indium and selenium was placed in evacuated quartz tube and heated to approximately 1000^{O}C for 24 hours before it was quelled in ice-cooled water. $Cu_{0.5}In_{0.5}Se$ films were created through thermal evaporation under a pressure of 10^{-5} torr the distance between source and substrate was maintained at 14cm.

The sample with varying thickness were deposited under similar condition. The thickness of the film was assessed using the Digital Thickness Monitor (DTM-101) using by Hind-Hi Vac. The rate of deposition was maintained at 8-10 Å/sec for all sample preparations. Prior to the evaporation process, the glass substrates were meticulously cleaned with chromic acid, detergent, and acetone.

RESULTS AND DISCUSSION

XRD Analysis

The XRD technique is used to study crystalline properties such as crystal structure, size, and nature. $Cu_{0.5}In_{0.5}Se$ samples were scanned at 2θ angles ranging from 0° to 80°. Figure 1 displays the XRD pattern of a thin film of $Cu_{0.5}$ $In_{0.5}$ Se with a thickness of 500 A .

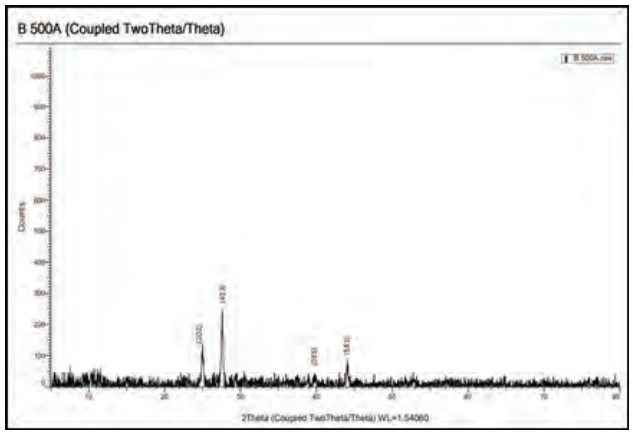


Fig. 1: XRD Spectrum of $Cu_{0.5}$ $In_{0.5}$ Se Thin Film

The hkl plans (202), (423), (035), and (551) show 2θ peaks at 24.992°, 27.588°, 39.827°, and 44.060°, respectively. The desires for reflection are in good agreement with the JCPDS data. The XRD pattern contains many peaks. It indicates the material's polycrystalline nature. [7-11]. The primary peak is of monoclinic shape. The average crystalline size (D) was calculated using the Scherrer equation.: where λ is the wavelength of X-ray, β is Full Width Half Maxima, and θ is the diffraction angle. The crystal size was found to be 3692 nm.

SEM Analysis

Analysis using FE Scanning Electron Microscope (SEM) can be used to study the surface morphology. FESEM (Zeiss EVO50) was used to assist with the SEM study. The SEM pictures of $Cu_{0.5}In_{0.5}Se$ thin films are displayed in Figure 2. It is evident from the SEM pictures that the film was uniform. The granules are evenly dispersed over the substrate's surface. The nanoparticles are stacked closely together [13]. Clusters are formed by the nanograins. It is discovered that the clusters have spherical forms. For both samples, the average cluster size is approximately 13 nm. There are no minute flaws in the samples, such as peeling or cracking. The films surfaces were adequately flat.

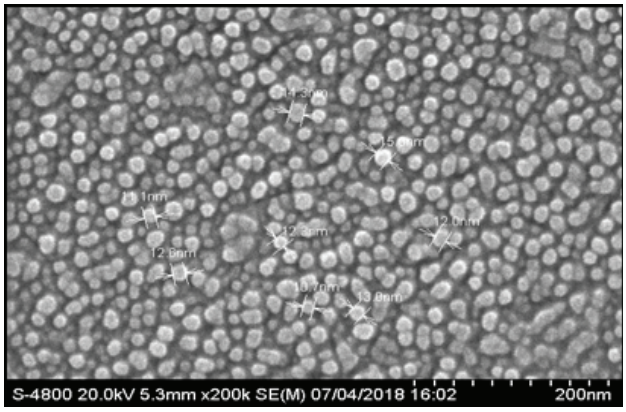


Fig. 2: SEM Image of Cu0.5In0.5Se Thin Film

Elemental Analysis of $Cu_{0.5}In_{0.5}Se$ Thin Films

The quantitative elemental analysis of Cu0.5In0.5Se thin films were done by EDAX. The EDAX spectrum of the $Cu_{0.5}In_{0.5}Se$ thin film is shown in Fig.3 for thickness 500 Å. The present elements were detected at 0.19, 9.1 and 10.30 KeV with atomic percentages of 1.46%, 55.44 and 43.10%. There is no evidence found of any type of impurities. It proves the purity of grown sample. The presences of other peaks are due to the glass substrate and gold coating during the characterizations.

UV – VIS Spectroscopy

The optical properties like absorbance transmittance of grown $Cu_{0.5}In_{0.5}Se$ thin film were studied by using UV – VIS Spectroscopy. The optical absorption patterns were obtained within the 400 – 800 nm wavelength ranges by using UV – VIS Spectrophotometer. Absorbance and transmittance spectra of grown $Cu_{0.5}In_{0.5}Se$ thin films are

plotted in figures 4 and 5 respectively. Higher absorbance is noticed within the 425-475 nm wavelength regions. The $Cu_{0.5}In_{0.5}Se$ thin films with various thicknesses have good absorbance. Hence the it can be used as absorber material in fabrication of solar cell.

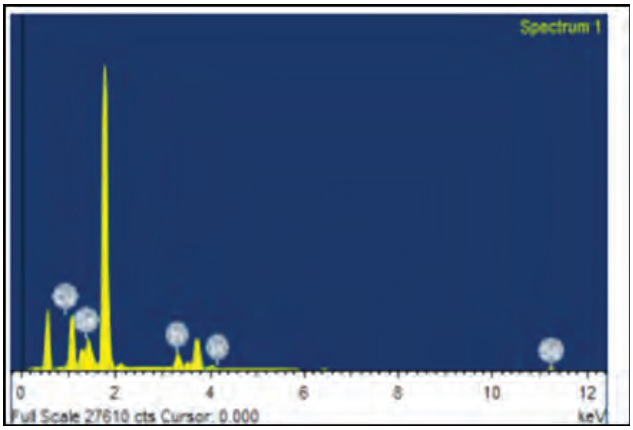


Fig. 3: EDAX Pattern of Cu0.5In0.5Se Thin Film

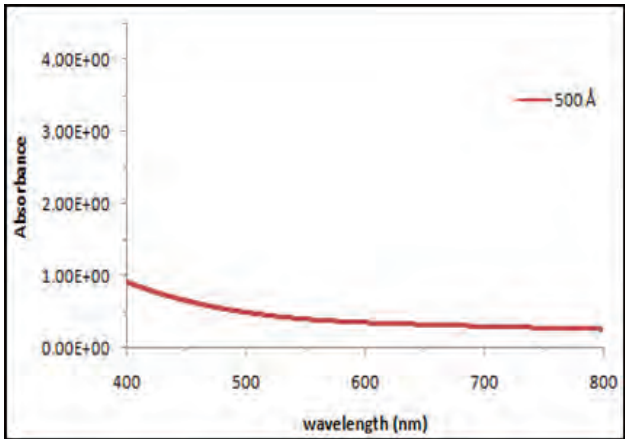


Fig. 4: Absorbance pattern

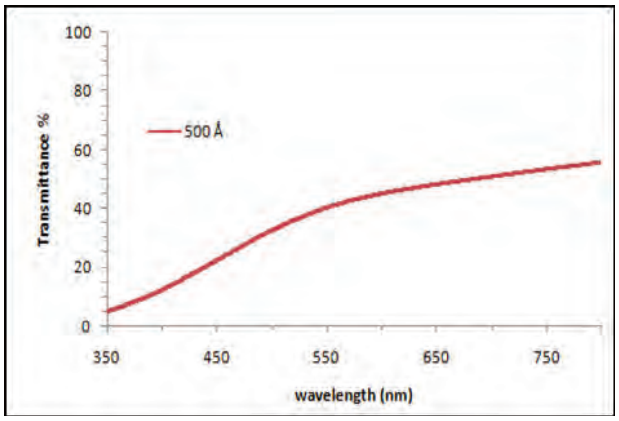


Fig. 5: Transmittance pattern

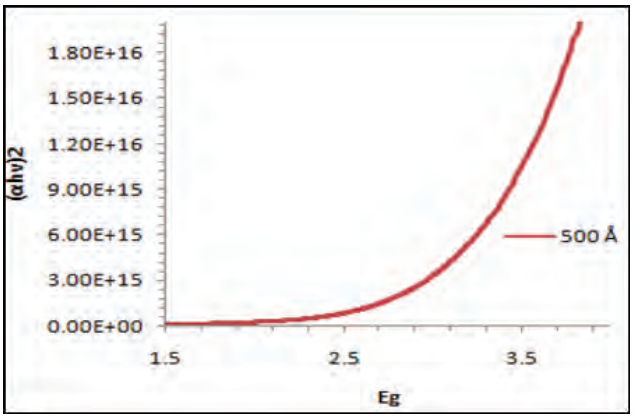


Fig. 6: Band Gap Pattern

The relation (Tauc 1974) has been used to compute the optical band gap (Eg) of the samples with the help of α and hv, the absorption coefficient and the photon energy respectively. The developed $Cu_{0.5}In_{0.5}Se$ thin films' optical band gap was calculated using a plot of (αhν)2 Vs Eg and Fig. 6 displays the band gap pattern. The material Cu0.5In0.5Se has a direct band gap. Figure 6 shows that the optical band gap of the Cu0.5In0.5Se thin films that were produced had a thickness of 500 Å and was approximately 2.2 eV.

Photo sensing

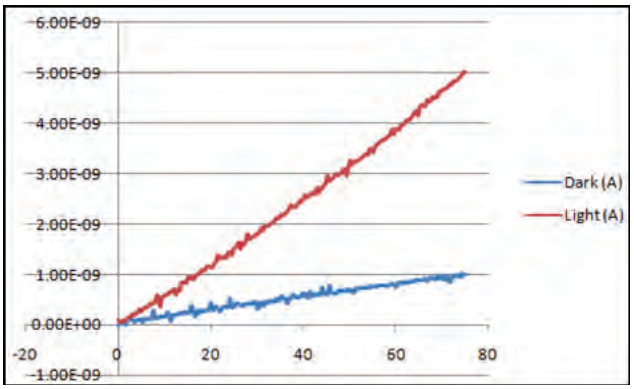


Fig. 7: I-V Plot of $Cu_{0.5}In_{0.5}Se$ Thin Film

The I-V plot of $Cu_{0.5}In_{0.5}Se$ thin film for 500 Å thicknesses recorded in both dark and bright conditions is displayed in Fig. 7. The I-V pattern shows that in both dark and bright situations, current increases in relation to voltage. Additionally, compared to the current measured in dark conditions, the recorded current in the presence of light was comparatively higher. When exposed to light, photosensitive materials often exhibit an increase in photocurrent. Using light current and dark current, the

photosensitivity of grown $Cu_{0.5}In_{0.5}Se$ thin films was determined to be 3.20 as follows:

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

CONCLUSIONS

The XRD study reveals the polycrystalline nature of $Cu_{0.5}$ $In_{0.5}$ Se thin film having monoclinic crystal structure. The SEM revels that grains are spherical in shape and uniform distribution over the substrate. Presence of required constituent elements and stoichiometry was confirmed using EDAX analysis. Further band gap of the material was calculated to be 2.2eV. Hence, the material is very suitable for manufacturing efficient photovoltaic devices. Photosensitivity of grown $Cu_{0.5}$ $In_{0.5}$ Se thin films was determined to be 3.20.

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