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Synthesis and Characterization of $CuMS_2$ (M= Bi, Sb) Thin Films Prepared by CBD Method*

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Abstract: $CuMS_2$ (M= Bi, Sb) thin films (0.1 M) were deposited by chemical bath deposition (CBD) method and characterized by X-ray diffraction (XRD) and UV-Visible (UV) analyses. The XRD pattern confirms the formation of orthorhombic structured $CuBiS_2$ with Cu_2S phases as an impurity and orthorhombic structured $CuSbS_2$. UV studies show higher optical absorption in the visible region, which indicates that the resulting material can be used as an absorbing material in solar cells.
Keywords: $CuBiS_2$, $CuSbS_2$, CBD, XRD, Orthorhombic, Absorbing materials.

Introduction

Metal-based ternary chalcogenide semi-conductors ABX_2 (A= Cu, Ag; B= Bi, Sb, In; X= S, Se, Te) have considerable applications for a wide variety of IR detectors, p-n junction solar cells and thermoelectric materials [1]. $CuSbS_2$ and $CuBiS_2$ are semi-conducting materials having the capability of covering maximum part of the visible region and infra-red region in the electromagnetic spectrum (E_g = 1.5 to 2.2 eV), higher optical absorption coefficient (>10^4 cm^{-1}) [2] and can be easily obtained in the form of thin films. The advantages of these materials are: 1) earth abundance 2) low cost when compared to Ag, In and Te and 3) lower toxicity. Hence, the present study aims to deposit $CuMS_2$ (M= Bi, Sb) thin films by simple CBD method and to study their structural and optical properties.

Experimental Details

AR grade chemicals were used in this study. $CuMS_2$ (M = Bi, Sb) thin films have been prepared by CBD technique. For the preparation of $CuBiS_2$ thin films, 0.1M of $Cu(NO_3)_2$ and 0.1M of $Na_2S_2O_3$ were dissolved in double distilled water and added into ethylene glycol dissolved 0.1M of $Bi(NO_3)_3$ solution at room temperature under vigorous stirring. Then, ultrasonically cleaned substrates were immersed in the prepared solution at rest for 24 h. The preparation of $CuSbS_2$ thin film process was similar to that of $CuBiS_2$; here, 0.1 M of acetone dissolved $SbCl_3$ was used instead of $Bi(NO_3)_3$. After dipping for 24h, the substrates were taken out of the bath, rinsed with double distilled water and dried in room temperature. The prepared films were annealed at 200 °C in air atmosphere for 1h and characterized by X-ray diffraction (XRD) and UV-Visible (UV) analyses.

Results and Discussion

Film thickness was calculated by using Swanepoel method [3] and found to be 1191 nm for $CuBiS_2$ and 303 nm for $CuSbS_2$ thin films. Fig. 1 shows the XRD patterns of $CuBiS_2$ and $CuSbS_2$ thin films. The $CuBiS_2$ film shows the prominent peaks at 2θ = 30.09° and 54.05° corresponding to the reflection of (013) and (216) planes, respectively, for orthorhombic

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$CuBiS_2$ [JCPDS Card No. 65-1300 and 89-2670]. An additional peak is observed at 2θ=37.88° belonging to (102) plane of hexagonal structured Cu_2S [JCPDS Card No. 89-2670]. In the case of $CuSbS_2$, the peaks at 2θ =28.78° and 25.33° correspond to the planes of (111) and (011), which confirms the formation of orthorhombic $CuSbS_2$.The low intensity of the peaks indicates that the films consist of coarsely fine grains/or are nanocrystalline in nature. Crystalline size was calculated using Scherrer formula and found to be 68 nm and 20 nm for $CuBiS_2$ and $CuSbS_2$, respectively.

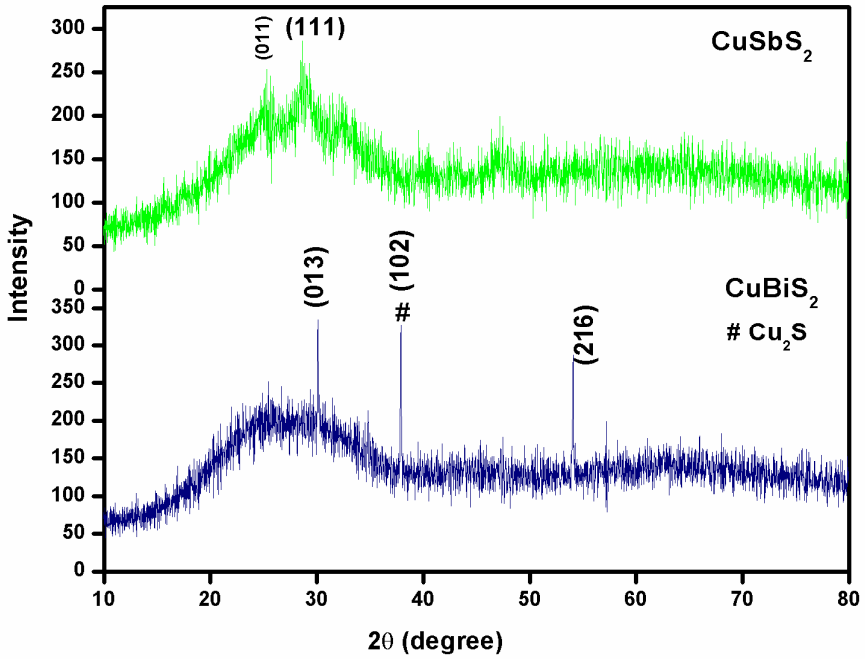

FIG. 1. XRD patterns of $CuBiS_2$ and $CuSbS_2$ thin films.

Fig. 2 shows the optical absorption spectra of $CuBiS_2$ and $CuSbS_2$ thin films. It can be seen from the spectra that the $CuBiS_2$ film showed better absorption in the visible region (300 -700 nm) compared to $CuSbS_2$ film. Optical absorption coefficient ***(α)*** was calculated and found in the range of 10^5 cm^{-1}. This higher ***α*** value confirms that the deposited films are potential candidates for solar cell applications. Eg plot (Fig. 2 inset) was drawn using Tauc's plot [1] and found to be 1.69 eV and 1.8 eV for $CuBiS_2$ and $CuSbS_2$ thin films, respectively, which is comparable to earlier literature (1.5 - 1.9 eV) [1,2]. ON the other hand, the thin films are having direct bandgap energy [4-7]. In the case of $CuBiS_2$, the band gap is comparatively lower than in the case of $CuSbS_2$ because of Bi^{3+} having higher anisotropic electronic behaviour, low conduction band effective mass and high electron mobility [8]. The Eg values lie closer to optimum value for solar cells.

Conclusion

In this work, $CuMS_2$ (M= Bi, Sb) thin films (0.1 M) were deposited by chemical bath deposition method. The XRD pattern confirms the polycrystalline nature of orthorhombic structured $CuBiS_2$ and $CuSbS_2$. UV studies show higher optical absorption coefficient (***α*** $>10^4$ cm^{-1}). Band gap energy was found to be 1.69 and 1.8 eV for $CuBiS_2$ and $CuSbS_2$ thin films, respectively, which indicates that the materials have potential applications in the field of solar cells.

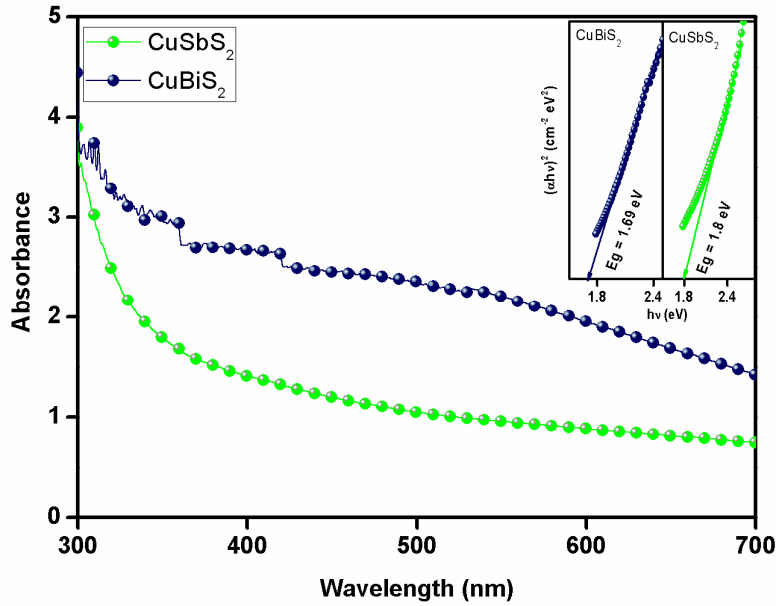

FIG. 2. UV-visible spectra of $CuBiS_2$ & $CuSbS_2$ thin films; inset: Eg plotplot.

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