Rod-Like CuS Thin Films Deposited Using Chemical Spray Pyrolysis Technique

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Abstract

Covellite CuS thin film was prepared using chemical spray pyrolysis technique. It was prepared using non-toxic solvent and cost-effective method. The CuS thin film formation was conformed with (102), (103), (105) and (110) phases of X-ray diffraction pattern. The SEM images appeared as rod-like shapes on the surface of the film. The optical band gap measured from Tauc's plot was found to be 2.4 eV. The direct optical band gap was useful in heterojunction photovoltaic cells. The Photoluminescence emission spectrum gives a sharp emission at 722 nm.

Keywords

Covellite, spray pyrolysis, 2-methoxyethanol, absorber material

Introduction

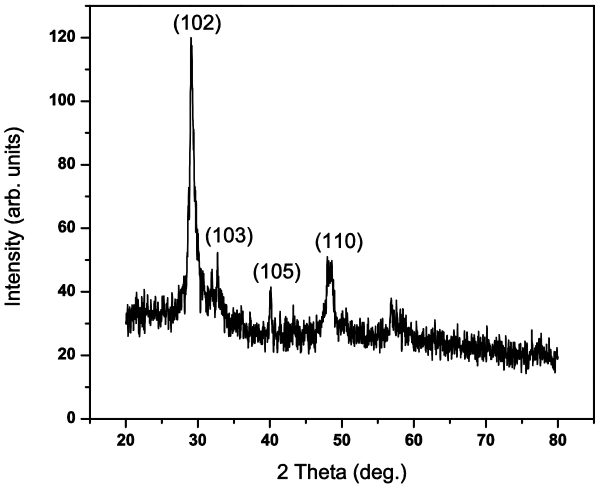
Covellite CuS thin film is of interest in the photovoltaic heterojunction cells and photo detectors. It received attention due to its cost effective and non-toxic nature with earth abundant precursor materials. It exists in different phases like Covellite, digenite, chalcocite, etc. The existence of different phases muddles the formation of a particular phase in a system. Suitable experimental conditions are to be identified to prepare a particular phase. The formation of films consists of different shapes such as spheres, rods, tubes, flowers, cubic, hexagonal, etc. It is prepared using a variety of physical and chemical deposition techniques including vacuum evaporation [1], chemical bath deposition [2], ALD [3], electrodeposition [4], Spray pyrolysis [5]. Among these techniques spray pyrolysis is the simple and large scale usable technique. In this present work, CuS thin film was prepared with solvent used precursor solution to get rod-like structures.

Experimental procedure

The precursor solution was prepared using $CuCl_2.2H_2O$ (0.2 M) and NH_2CSNH_2 (0.1 M) dissolved in 2-methoxyethanol solvent in the ratio of 2:1. The solution was stirred for 30 min. in the magnetic stirrer at room temperature to get a homogeneous solution. The prepared solution was sprayed onto preheated glass substrates. The substrate temperature was maintained at 300 °C and the pressure was 1.4 Kg/cm^2 at a flow rate of 5 ml/min. The process of deposition was done 8 times with 2 min. spraying and resting time consecutively to achieve the required thickness. The deposited film was characterized with (Bruker D8 Discover) X-ray diffractometer with the $CuK\alpha_1$ source radiation (=1.54051 Å) to study the structural property. The surface morphology was studied using (Carl Zeiss) Scanning Electron Microscope with 10 KV Extra-High Tension (EHT) voltage. The optical property was studied using (Perkin Elmer Lambda 576) UV-Visible-NIR spectrophotometer. The photoluminescence emission was studied using (Lambda 55) spectrometer.

Results and Discussion

Structural and morphological studies



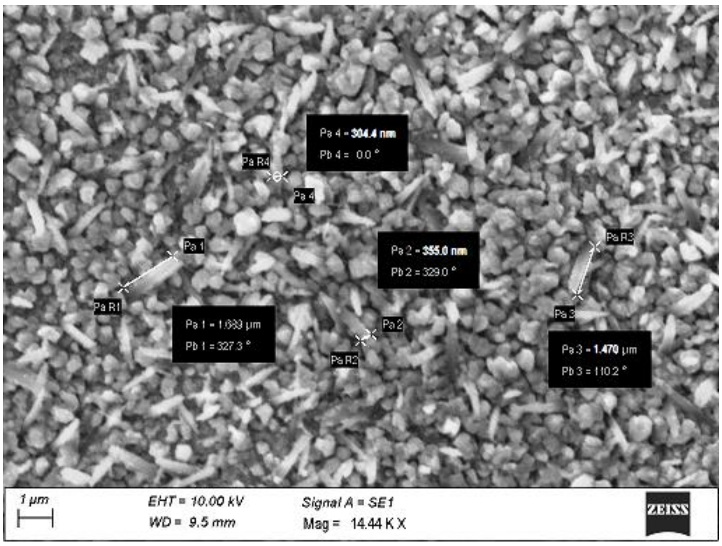


Fig. 1: (a) XRD pattern of CuS thin film, (b) rod-like SEM image of CuS thin film

Figure-1(a) gives the XRD pattern of Covellite CuS thin films with intensed peak at $2\theta = 29.05°$ and minor peaks at 32.02°, 40.1° and 48.2° corresponding to (102), (103), (105) and (110) planes respectively. This indicates the formation of hexagonal CuS (JCPDS card no. 6-464) [6, 7]. The polycrystalline nature of the film is confirmed with multiple diffraction peaks. The crystallite size was calculated using Debye-Scherrer's formula and it is found to be 6.5 nm.

$$D = \frac{0.9\lambda}{\beta \cos\theta}$$

where D is the crystallite size, λ is the wavelength of the target CuKα (=1.54051), β is the full-width half maximum value and θ is the position of respective Bragg peaks.

Figure-1(b) represents the SEM image of CuS thin film. The rod-like shapes formed on the surface of the film can be clearly seen [8, 9]. The rod length is 1.470 μm and the rod width is about 304 nm. Since, the deposition is done consecutively it appears to be rod like structure on the surface. The rod length is larger so maximum amount of light can be absorbed.

Optical studies

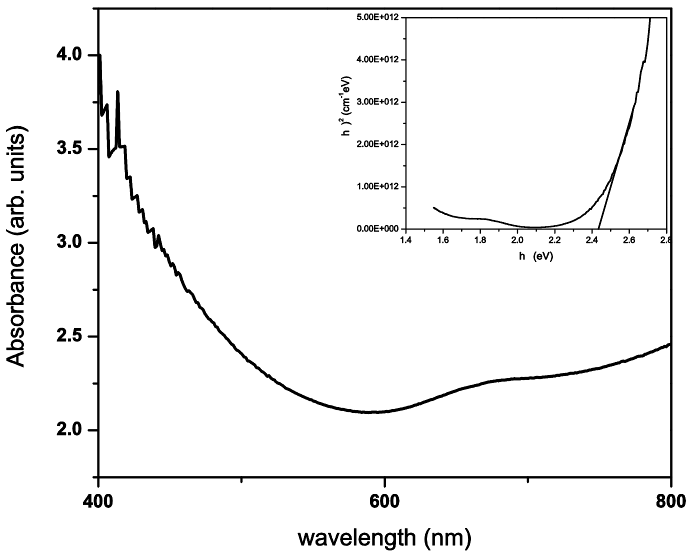


Fig. 2. (a) Absorbance spectrum of CuS thin film and inset is the Tauc's plot

Figure 2(a) shows the optical absorbance spectrum taken by UV-Visible spectrophotometer. It absorbs in the UV-Visible region with a cut off wavelength around 590 nm [10]. The inset gives the optical band gap calculated using Tauc's plot. The optical band gap is calculated using the formula [11]:

$$\alpha h\nu = A[h\nu - E_g]^n$$

where absorption coefficient, A is a constant, Eg is the band gap energy and $n = ½$ for direct allowed transitions.

The optical band gap is found to be 2.4 eV and absorption coefficient is 10^5 cm^{-1}. It indicates that it is an eminent material for heterojunction thin film solar cell [12].

Figure-2(b) provides the emission spectrum of CuS thin film using Photoluminescence spectrometer. The PL emission gives an intensed peak at 722 nm and a weak peak at 623 nm [13]. The excitation wavelength used is 480 nm to get the emission peaks. Xenon lamp was used as a source with optical filters to filter the specified wavelength light. For blue light wavelength excitation (480 nm), the emission is in the red wavelength region.

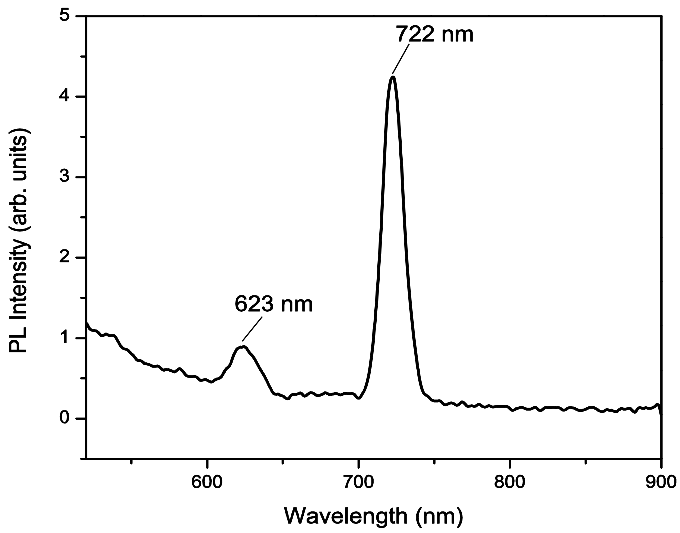


Fig. 2(b): Photoluminescence spectrum of CuS thin film

Conclusion

The Covellite structure of CuS thin film was achieved using 2-methoxyethanol as solvent in the material ratio of 2:1. The CuS structural property was studied using XRD which confirmed the polycrystalline nature of the film. The rod-like shape observed from the SEM image was useful for photovoltaic absorbers. The optical absorbance in the UV-Visible region was pertinent for photovoltaic application. The PL emission shows emission in the near IR region. The material possessed an optical band gap of 2.4 eV which is optimum for heterojunction Photovoltaic cell.

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