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Transmittance Spectra of CuS Thin Film at Varying Concentration of Complexing Agent

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Abstract

We have fabricated CuS thin film using chemical bath deposition technique. Transmittance data of the films were obtained using a Janway 6405 UV/Visible spectrophotometer. Structural and surface morphology of the films were carried out using an x-ray diffractometer with Cukα radiation and Olumpus Optical microscope. Transmittance spectra of CuS thin film fabricated at varying concentration of ligand show moderate transmittance in the visible region, relatively low transmittance in the UV and NIR region. The highest transmittance of approximately 46% was obtained in the UV region while the Vis and NIR region has approxiately 52% and 42% respectively. XRD measurements indicate one prefered orientation corresponding to (112) atomic plane. A lattice constant of 5.434Å was calculated for CuS thin film in the [112] plane at maximum intensity of 2θ = 27.8757 There was no clear cut effect of the varying concentration of ligand on the transmittance of the deposited films in the UV and visible region, but there appears to be some effect on the transmittance of CuS thin film in the infrared NIR region of the electromagnetic spectrum as a result of varying concentration of complexing agent.

Keywords

Copper Sulphide, Chemical Bath Deposition, Complexing agent, Transmittance Spectra

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1. Introduction

Because of the novel physical properties and potential applications, semiconductor thin films have attracted much attention to researchers during the past years. Copper sulphide (CuS) belong to I-IV compound semiconductor materials. It has various application which include: application in selective radiation filters on architectural windows for solar control in warm climate [1], as gas sensors [2], devices for photovoltaic conversion of solar energy [3], useful for photo-thermal conversion of solar energy [4], useful in coating of windscreens, driving mirrors and in p-n junction solar cells [5].

There are various technique for the deposition of semiconductor thin films, they include chemical spray pyrolysis, molecular beam epitaxy, thermal evaporation, sputtering, chemical vapour deposition, chemical bath deposition etc. Various researchers have deposited CuS thin film using the various techniques, [6] deposited CuS thin films using spray pyrolysis, [7] deposited CuS using chemical bath method, [8] deposited CuS thin film using successive ion layer adsorption and reaction.

In this work, we report the successful deposition of copper sulphide (CuS) thin films at room temperature, using a simple, reproducible and cost effective technique called the chemical bath deposition [9].The study focuses on the fabrication of CuS thin film and the correlation of the transmittance spectra with the concentration of complexing agent.

2. Materials and Methods

The reaction bath for the deposition of copper sulphide was composed of cupric sulphate ($CuSO_4.5H_2O$), thiourea, triethanolamine (TEA) and ammonia solution. Cupric

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sulphatewas used as copper ion source, thiourea was used as sulphide ion source, TEA served as complexing agent and ammonia solution was used for pH adjustment.

In this experiment, five reaction baths (50ml beaker) were used. 5ml of cupric sulphate was measured into a 50ml beaker and various volumes of TEA was then added as indicated in Table 1. 5ml of thiourea solution was added, followed by 5ml of ammonia solution. Each bath was topped to 50ml mark by adding distilled water and stirred to ensure uniformity of the mixture. Glass slides were then dipped vertically into the bath and left to stand for one hour, after which they were removed and dried in air. A pH range of 10.9 ~ 11.1 was maintained.The experiment was conducted at room temperature. Janway 6405 UV/visible spectrophotometer was used to determine the spectra transmittance. Structural and surface characterization of the films was carried out using an x-ray diffractometer with Cukα radiation and Olumpus optical microscope respectively. Other solid state and optical properties of the films had been investigated in our earlier publication [10].

Table 1. Bath constituents for the deposition ofCuS thin film.

Slide NO.	Volume of complexing agent (TEA) (ml)	Volume of CuSO4.5H20 (ml)	Volume of thiourea (ml)	Volume of ammonia solution	Time (hours)
Cu6	2.50	5.00	5.00	5.00	1.00
Cu7	5.00	5.00	5.00	5.00	1.00
Cu8	7.50	5.00	5.00	5.00	1.00
Cu9	10.00	5.00	5.00	5.00	1.00
Cu10	12.50	5.00	5.00	5.00	1.00

The reaction mechanism is of the form.

$$(CuSO_4.5H_2O) + TEA \rightleftharpoons Cu[TEA]^{2+} + (SO_4)^{2-} + 5H_2O$$

$$Cu[TEA]^{2+} \rightleftharpoons Cu^{2+} + TEA$$

$$(NH_2)_2\,CS + OH^- \rightleftharpoons CH_2N_2 + H_2O + HS^-$$

$$HS^- + OH^- \rightleftharpoons H_2O + S^{2-}$$

$$Cu^{2+} + S^{2-} \rightleftharpoons CuS$$

3. Results and Discussion

From the transmittance spectra shown in Figure 1, it can be seen that the transmittance is low in the UV region. The highest peak at 245nm and 290nm has transmittance of 22%. In the visible region, the highest peak at 650-740nm has transmittance of 38%. In the NIR, the highest peak at 1100nm has 27% transmittance. In Figure 2, the highest peak at approximately 245nm has transmittance of 40%. In the visible region, the highest peak at 605-695nm has transmittance of 51%, while in the infrared region, the highest peak at 1010-1100nm has transmittance of 30%. In Figure 3, the highest peak in the UV region at approximately 245nm has transmittance of 46%. In the visible region, the peak transmittance was approximately 52% at 695-740nm. In the NIR region, the transmittance obtained was approximately 42% at 1010-1100nm. In Figure 4, peak transmittance of 26% at approximately 210nm is observed in the UV region. In the visible region, peak transmittance value of 40% was obtained at 600-700nm, while at wavelength range of 1000-1100nm in the NIR region, the transmittance was18%. Figure 5 shows peak transmittance of 47% at approximately 250nm in the UV region, which decreased to approximately 405 at 600-700nm in the visible region. This further decreased to 18% at 1000-1100nm in the NIR.

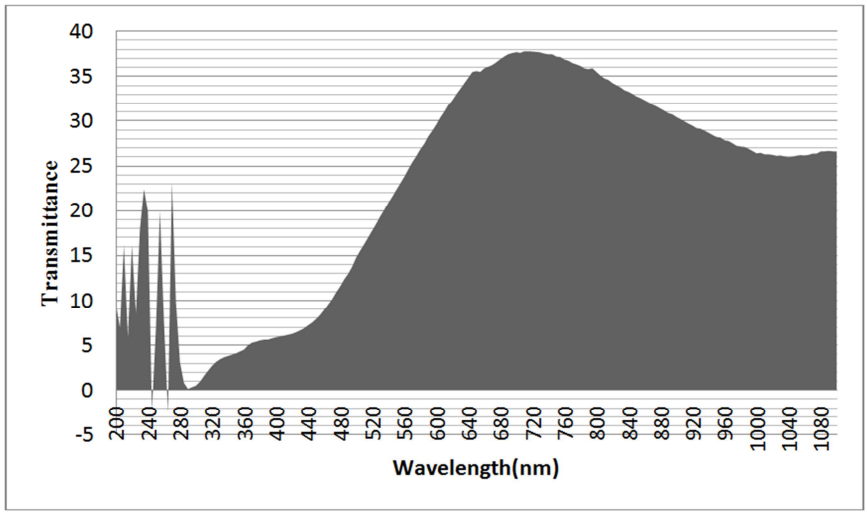

Figure 1. Graph of transmittance versus wavelength at 2.5mls volume of complexing agent.

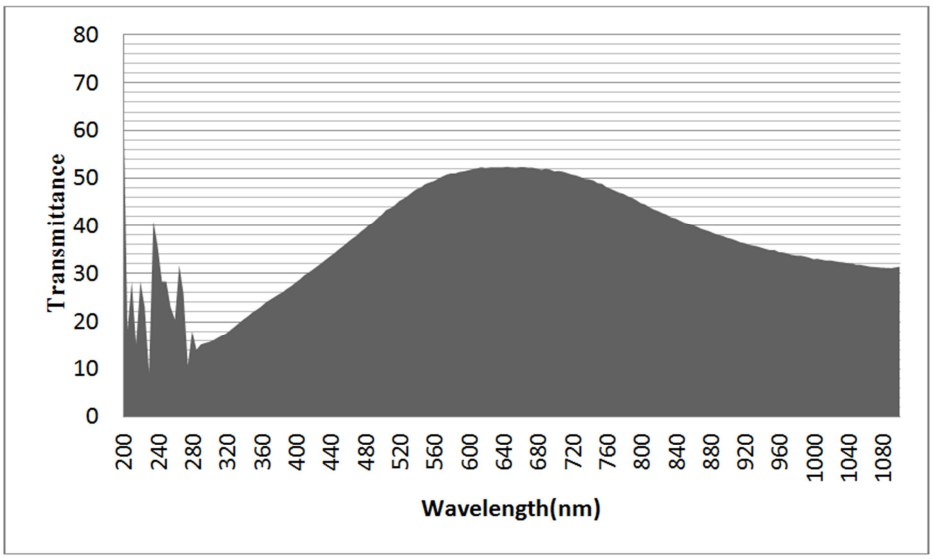

Figure 2. Graph of transmittance versus wavelength at 5mls volume ofcomplexing agent.

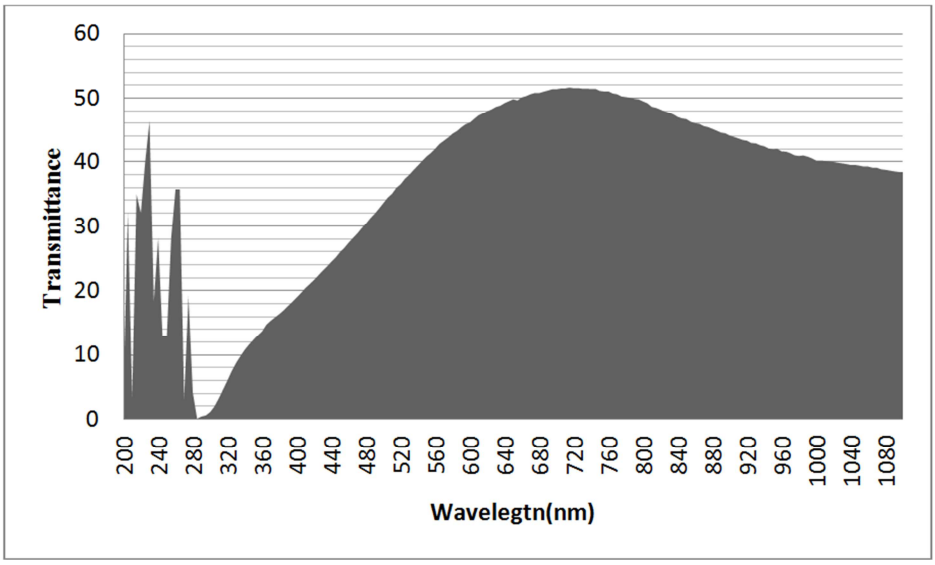

Figure 3. Graph of transmittance versus wavelength at 7.5mls volume ofcomplexing agent.

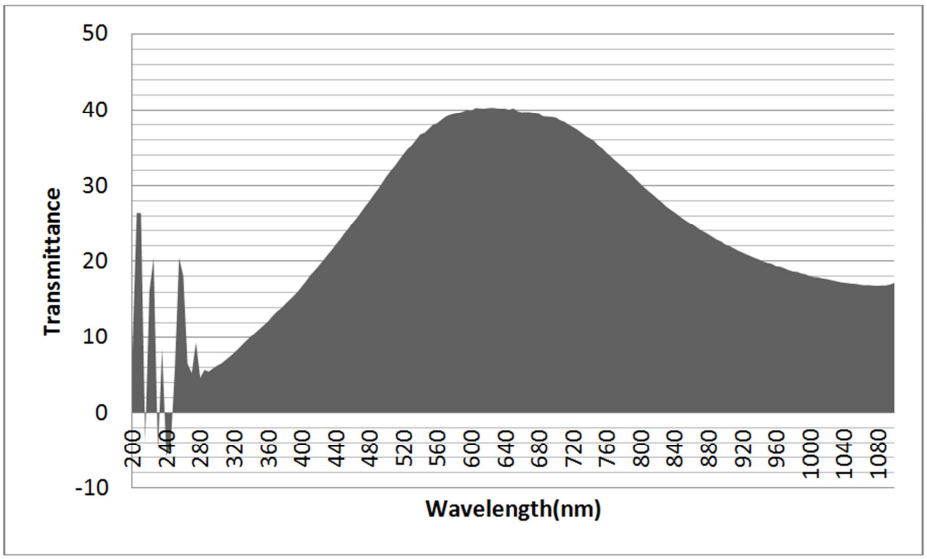

Figure 4. Graph of transmittance versus wavelength at 10mls volume ofcomplexing agent.

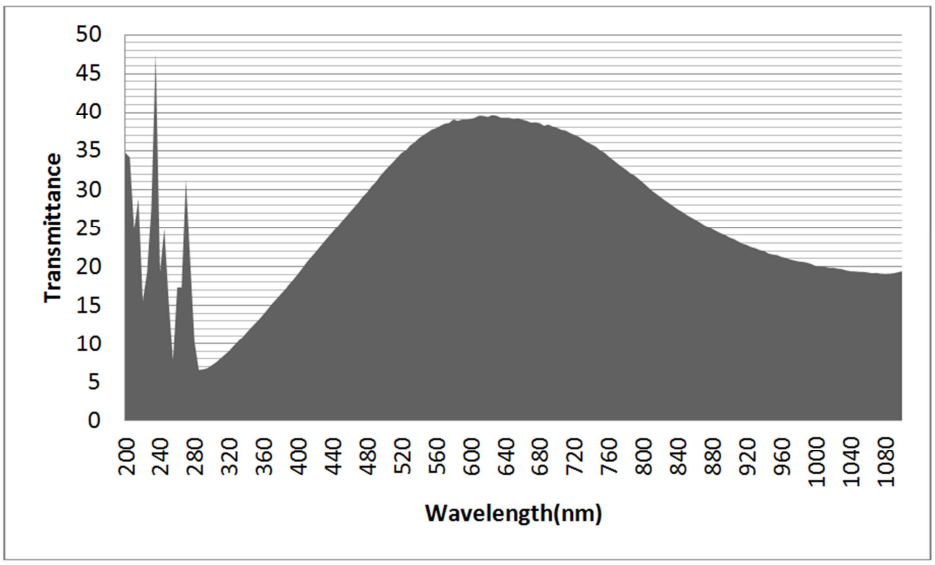

Figure 5. Graph of transmittance versus wavelength at 12.5mls volume ofcomplexing agent.

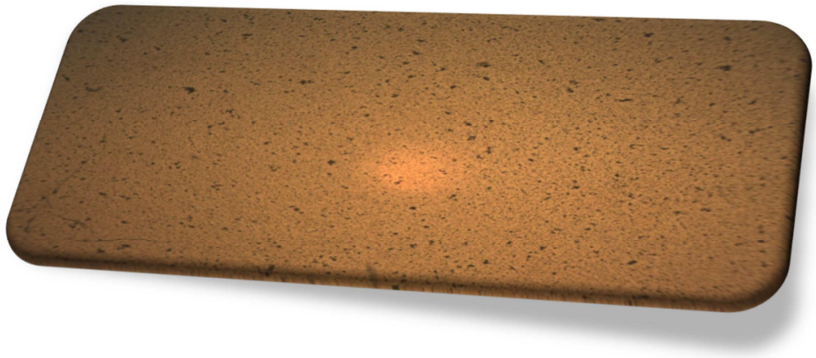

Figure 6. Micrographs of CuS thin film.

A careful look at the transmittance spectra of all the fabricated films indicate that there is no clear cuteffect that can be attributed to the varying complexing agent concentration in the UV and visible region. In the visible region, the % transmittance was almost to a certain degree equal. In the NIR, the transmittance increased slightly and then remained constant as concentration of complexing agent increased. From the foregoing, one can infer that the varying concentration of complexing agent have effect on the transmittance of CuS thin film in the infrared NIR region of the electromagnetic spectrum.

Figure 6 shows the optical micrograph of our deposited CuS thin film. The optical micrograph shows that the substrate is covered completely indicatingthatnucleation sites have formed. The grains are very small, the size of each granule does not differ very much from each other.XRD measurements indicate oneprefered orientation corresponding to (112) atomic plane. From the XRD results, a lattice constant of 5.434Å was calculated for CuS thin film in the [112] plane at maximum intensity of $2\theta = 27.8757$ from Braggs law, given by: $n\lambda = 2d\sin\theta$.

Table 2. X-ray result of deposited CuS thin film.

17 reflections in pattern. Wavelength 1.5406 was used to calculate the diffraction angles.									
2θ	**Int.**	**h**	**k**	**l**	**2θ**	**Int.**	**h**	**k**	**l**
17.9051	10	1	0	1	50.2264	1	3	0	1
27.8757	100	1	1	2	54.6880	6	1	1	6
28.9473	4	1	0	3	55.0796	12	3	1	2
32.0898	6	0	0	4	55.4772	1	2	1	5
32.3761	8	2	0	0	57.5193	4	2	2	4
37.2486	4	2	1	1	60.5026	1	1	0	7
43.7602	1	1	0	5	60.9874	1	3	2	1
44.0065	2	3	1	3					
46.2339	25	2	0	4					
46.4847	10	2	2	0					

4. Conclusion

We have fabricated CuS thin film using chemical bath deposition technique.Transmittance data of the films were obtained using a Janway 6405 UV/Visible spectrophotometer. Structural and surface morphology of the films were carried out using an x-ray diffractometer with Cukα radiation and Olumpus Optical microscope. Transmittance spectra of CuS thin film fabricated at varying concentration of ligand show moderate transmittance in the visible region, relatively low transmittance in the UV and NIR region. XRD measurements indicate one prefered orientation corresponding to (112) atomic plane. From the XRD results, a lattice constant of 5.434Å was calculated for CuS thin film in the [112] plane at maximum intensity of 2θ = 27.8757. There was no clear cut effect of the varying concentration of ligand on the transmittance of the deposited films in the UV and visible region, but there appears to be some effect on the transmittance of CuS thin film in the infrared NIR region of the electromagnetic spectrum as a result of varying concentration of complexing agent

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