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Optimal Growth and Characterization of Cobalt Sulphide Thin Films Fabricated Using the Chemical Bath Deposition Technique

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Abstract
In this work, chemical bath deposition technique was used to deposit thin films of cobalt sulphide on glass substrate from the aqueous solution containing 1M of cobalt chloride, 1M of thiourea, 1M of ammonia and 1M of ethylene diamine tetra acetate (EDTA) which served as the complexing agent. The optical measurement was carried out on the deposited films using M501 single beam scanning UV/visible spectrophotometer. The results show that the films have high absorbance towards the UV-region whereas it recorded low transmittance value in the same region. The films also exhibited poor reflectance value towards the UV-region. The band gap energy value was found to be 1.72eV. The films were observed to have thickness value range of 1.122µm to 1.152µm. These properties made the material to be a good candidate for photovoltaic and opto-electronic applications.
Keywords: Cobaltsulphide, absorbance, transmittance,reflectance, solid state property, band gap energy, thin film

1.1 Introduction

Thin films of semiconducting compounds have been studied extensively in recent years due to their applications in photovoltaic and opto-electronic devices. Thin films are thin material layers ranging from fractions of a nanometer to several micrometers in thickness. Depending on how the atoms/molecules/ions/clusters of species are created for the condensation process, the method for depositing thin film are divided into two major part namely physical vapour deposition techniques and chemical deposition techniques. Chemical bath deposition techniques have proven to be useful and important deposition technique for the synthesis of various functional metal chalcogenide devices [1-3]. This technique is novel in the sense that it possesses a number of advantages over conventional thin-film deposition method. It is cheap, easily reproducible and can be used to coat large surface area of material. The technology is based on the controlled release of the metal ions ($m^{2+)}$ and sulphide ions (S^{2-}) in aqueous solution of relevant compounds into which the substrates are immersed [2]. The basic principle involved is that for a given compound to be precipitated from a solution, its ionic product (IP) must exceed its solubility product (SP). When this condition is satisfied, the thin film of a particular compound is formed on the immersed substrate by an ion-by-ion condensation process [4-5].

In this paper, chemical bath deposition technique was employed to deposit the thin film of cobalt sulphide on microscopic glass which served as substrate. The deposition parameters were optimized to obtain good quality films. The optical and solid state properties studied include absorbance, transmittance, reflectance, band gap energy, absorption coefficient and thickness of thin films

1.2 Experimental Details

The apparatus such as beakers, measuring cylinders, stirring rod, syringe and glass slides were first washed with detergent and rinsed with distilled water and dried in open air. The essence is to ensure clean surfaces which are prerequisite for thin film deposition. The step-wise process is as follows; 5ml of 1M cobalt chloride was put into a 50ml beaker and was added 3ml of 1M ethylene diamine tetra acetate (EDTA). The mixture was stirred for about 2mins for the formation of homogenous solutions. Thereafter; 5ml of ammonia was added to the resulting solution. This mixture was also stirred, and finally 5ml of 1M thiourea solution was added to the mixture. Distilled water was used to make up the solution to 50ml mark on the beaker. Thereafter, a clean microscopic glass slide was clamped vertically into the beaker with synthetic foam as cover. This is to avoid dust and unwanted particles from entering the reaction bath. The bath was allowed to stay for 12hrs (S_1) after which the glass slide was removed, rinsed and dried in open air. Three other baths were prepared in this way and allowed to stay for 24hrs (S_2), 36hrs (S_3), and 48hrs (S_4) respectively. After deposition, the optical measurement was carried out on the deposited films using M50l single Beam scanning UV/visible spectrophotometer in the wavelength range of 200-800nm.

The chemistry of reaction is as depicted below

$$CoCl_2 + EDTA + 2NH_4OH = Co(NH_3)_2Cl_2 + EDTA + H_2O$$

$$Co(NH_3)_2Cl_2 = Co^{2+} + 2NH_3Cl^-$$
$$(NH_2)_2CS + OH^- = CH_2N_2 + H_2O + HS^-$$
$$HS^- + OH^- = H_2O + S^{2-}$$
$$Co^{2+} + S^{2-} = CoS \quad (1)$$

1.3 Results and discussion

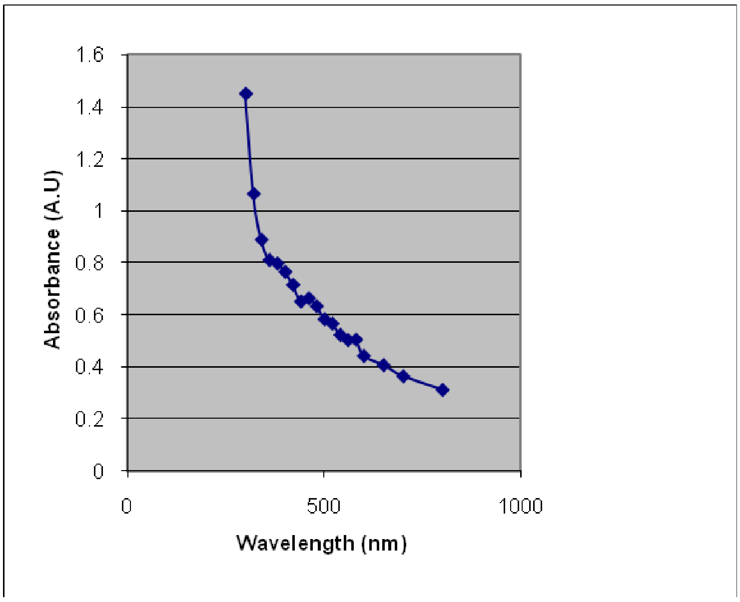

Figure:1.1 Plot of Absorbance against Wavelength For sample 4

Figure 1.1 is the plot of absorbance against wavelength. It shows that the films have high absorption value in the ultra-violet region than in any other region of the electromagnetic spectrum. This means that CoS material is a good absorber of UV-radiation and can be used in devices where ultra-violet ray could pose a problem. That is, it could serve as a ultra-violet filter.

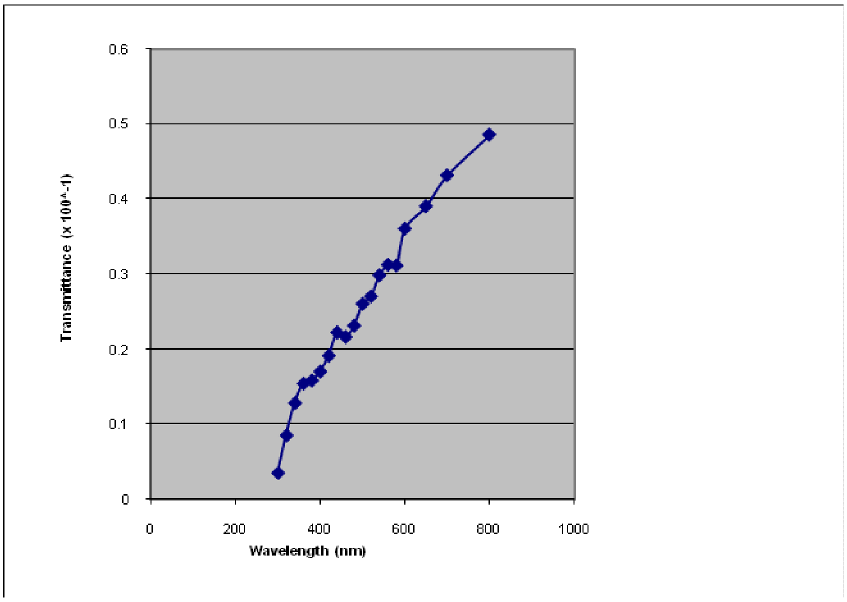

Figure: 1.2:Plot of Transmittance with Wavelength for sample 4

The plot of transmittance against wavelength is reflected in figure 1.2. The figure shows that the film has high transmittance value in the infra-red region of electromagnetic spectrum.

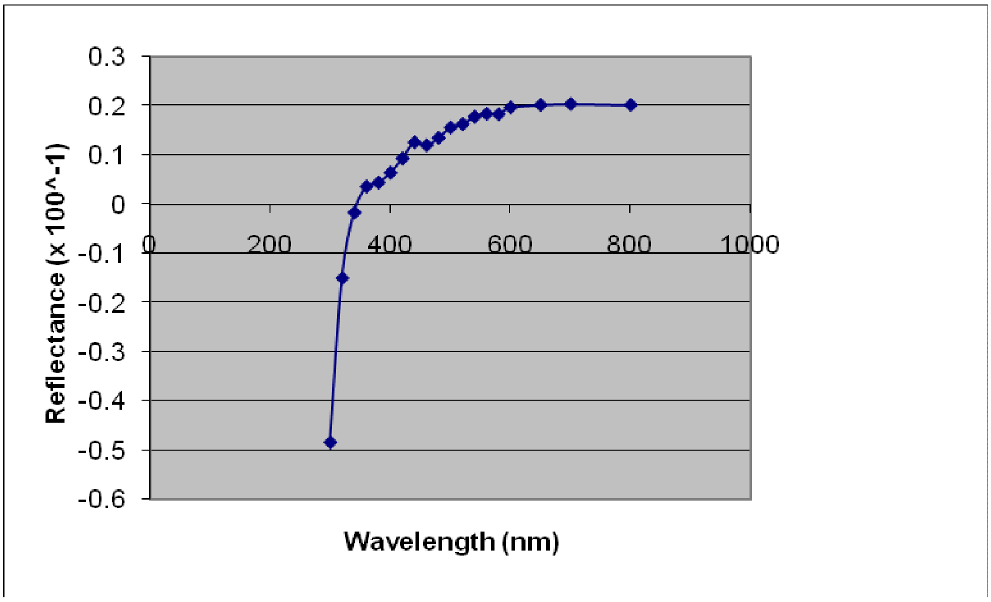

Figure 1.3: Plot of Reflectance against Wavelength

The variation of reflectance with wavelength is illustrated in figure 1.3. The graph shows that the film exhibited very low reflectance and therefore can be deployed in fabricating anti-reflectance devices.

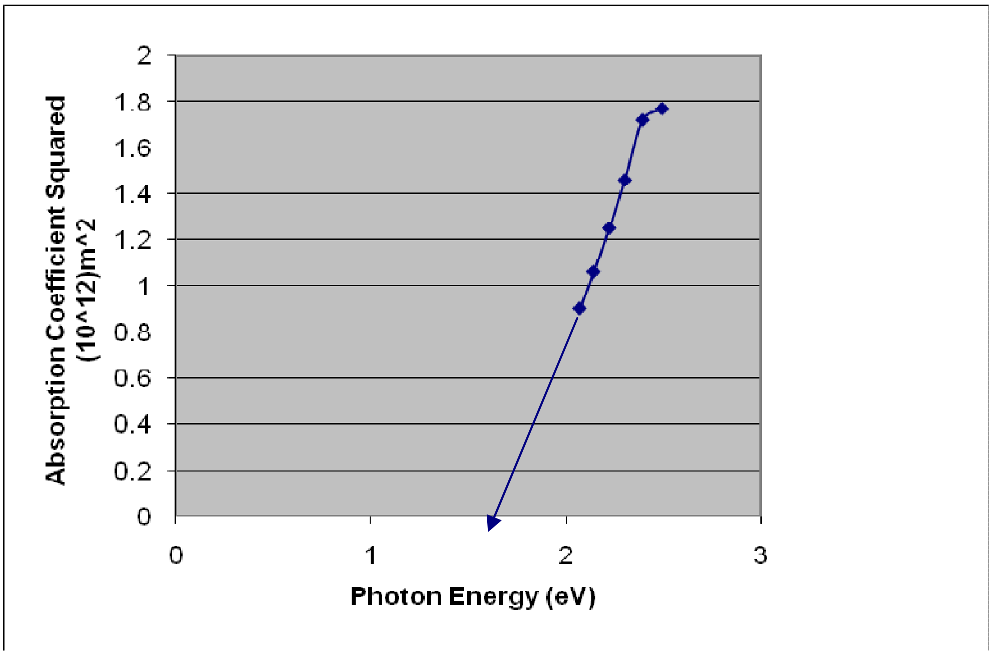

Figure 1.4 : Plot of Absorption Coefficient Squared against Photon Energy

Figure1.4. is the plot of absorption coefficient squared against photon energy. By extrapolating the linear portion of the curve to the point on the photon energy axis; the band gap energy of CoS was found to be 1.72eV.

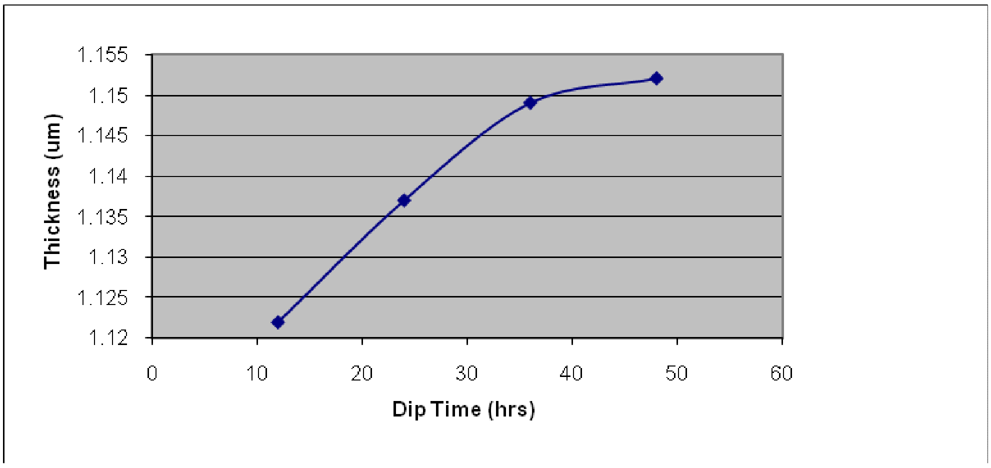

Figure 1.5: Plot of Thickness against Dip Time.

Figure 1.5 is the plot of film thickness against the Dip time (hrs). The graph shows that thickness of the film increases as the dip time increases until optimum point is reached beyond which the curve remains constant.

1.4 Conclusion

Thin films of CoS were successfully deposited on microscopic glass slide using a cost-effective and easily reproducible technique known as chemical bath deposition technique. The optical studies conducted on the films show that the films have high absorbance and moderate transmittance of solar radiation in the UV-region and towards the visible-infra region respectively. The films also exhibited poor reflectance of solar reflection and therefore can be used as anti-reflectance coating for solar cell devices.

A direct band gap of 1.72eV was obtained for the deposited film in this research. This band gap energy is somewhat high when compared with band gap energy of 1.15eV as reported by Zhenrui et al[6].This difference can be attributed to environmental factors especially the temperature. All these properties made the CoS thin film to be a good candidate for applications in photo-voltaic and opto-electronic devices.

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