Optical Properties of Chemical Bath Deposited Ag 2 S Thin Films

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ABSTRACT

The chemical bath deposition technique has proven to be a novel method for the growth of different types of semiconducting materials in thin film form. The CBD is simple, cheap, reproducible, and convenient for large area deposition. In this article, thin films of Ag_2S were deposited at room temperature on glass substrates immersed in a bath mixture containing aqueous solutions of 5ml of 0.1M $AgNO_3$, 5ml of 0.2M $(NH_2)_2CS$, and 4ml of 0.2M NaOH in which EDTA was employed as complexing agents. The films were studied for its optical properties using Camspec M501 and the results showed averaged absorbance of 71.0% in the UV-region, poor averaged transmittance and reflectance values of 19.8% and 9.2%, respectively in the same region. The optical band gap energy was found to be 1.56eV. Also the films exhibited averaged refractive index of 2.52, averaged extinction coefficient of 0.038 and averaged optical conductivity of $5.81\text{x}10^{13}S^{-1}$. The films have averaged dielectric functions of 6.364 in the real part and 0.188 in the imaginary part. All these properties made the Ag_2S thin films to be a good candidate in opto-electronic, solar-cells and electrochemical cells applications.

(Keywords: optical properties, photovoltaic, Ag_2S thin films, chemical bath deposition technique, complexing agent)

INTRODUCTION

There has been increasing interest in the optical properties of semiconductor thin films because of their wide range of applications in science and technology. In recent years much attention has been shown in Ag_2S thin films due to its applications in optical and electronic systems such as photovoltaic cells, solar selective coatings, photoconducting cells, IR detectors, and high resolution optical memories [1-4]. Various methods have been employed in depositing Ag_2S thin films [5-6]. In this paper, we report the optical properties of chemical bath deposited Ag_2S thin films.

EXPERIMENTAL DETAILS

Thin films of Ag_2S were deposited at room temperature on glass substrates immersed in a bath containing the aqueous solutions of 5ml of 0.1M $AgNO_3$, 5ml of 0.2M $(NH_2)_2CS$, and 4.0ml of 2.0M NaOH in which EDTA was employed as complexing agent. Before introducing the substrates into the reaction bath, it was degreased with HNO_3 solution, washed with detergent and dried in open air. The essence of this is to ensure a clean surface prerequisite for the formation of nucleation centers [7] for thin film deposition. Having obtained a cleaned surface, the substrate was then immersed into the reaction bath and allowed to stand for 48hours. Two other baths were set-up in this way with concentration of EDTA varied. The substrates were labeled S_1, S_2 and S_3 with the volume of EDTA being 2.0ml, 4.0ml, and 6.0ml, respectively.

The reaction equation for the deposition is stated as:

$$AgNO_3 + EDTA \longleftrightarrow [Ag\ EDTA]^+ + NO_3^-$$

$$[Ag\ EDTA]^+ \longleftrightarrow Ag^+ + EDTA$$

$$NaOH \longleftrightarrow Na^+ + OH^-$$

$$NO_3^- + Na+ \longleftrightarrow NaNO_3$$

$$(NH_2)_2CS + OH- \longleftrightarrow CH_2N_2 + H_2O + HS^-$$

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

$$Ag^+ + S^{2-} \longleftrightarrow Ag_2S$$

After 48 hours these substrates were removed, rinsed with distilled water and dried in open air at room temperature (300K). Thereafter, a Camspec

M501 single beam scanning UV/VIS spectrophotometer was used for optical measurement on the deposited Ag_2S thin films using a similar blank substrate as a reference frame.

RESULTS AND DISCUSSION

The variation of absorbance of the films with the wavelength of incident radiation is shown in Figure 1. It was observed that towards the visible region of electromagnetic spectrum that sample S_2 which was prepared at 4.0ml concentration of EDTA and pH of 5.53 has better averaged absorption coefficient of incident radiation than the other two samples S_1 and S_3 which were prepared at 2.0ml, 2.44 pH, and 6.0ml, 5.66 pH, respectively. This high absorption of radiation in UV region by this Ag_2S thin films shows that it can be used for coating of eye glasses to prevent cases of sunburns.

Figure 2 shows the transmittance spectra of the three samples (S_1, S_2 and S_3). It was discovered that sample S_3 has better averaged transmittance of incident radiation in the UV region than the other two samples (S_1 and S_2). This indicates that the increase concentrations of the complexing agent in this bath were responsible because fewer ions coalesced to form a thinner film of Ag_2S thin film on the substrate at the stipulated time. This thinner nature of the films formed allowed greater passage of incident radiation hence higher transmittance as shown by sample S_3.

The plot of reflectance against the wavelength of incident radiation for the three samples was shown in Figure 3. Sample S_2 has much lower averaged reflectance in the UV region than the other two samples (S_1 & S_3). This lower reflectance as exhibited by this film can be exploited in fabricating systems where reflection losses are a problem, for example in photovoltaic devices.

The refractive index (n) of the deposited films was calculated using the relation;

$$n = 1+R^{0.5}/1-R^{0.5} \quad \textbf{(1)}$$

where, n= refractive index
R= reflectance

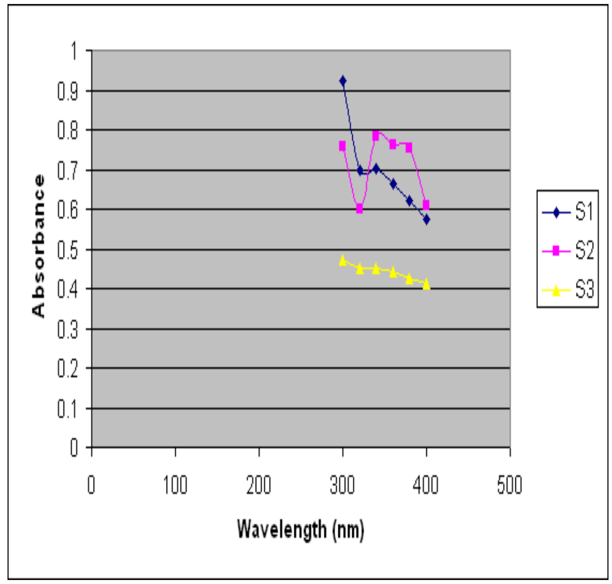

Figure 1: Plot of Absorbance against Wavelength for the Three Samples towards the Visible-region.

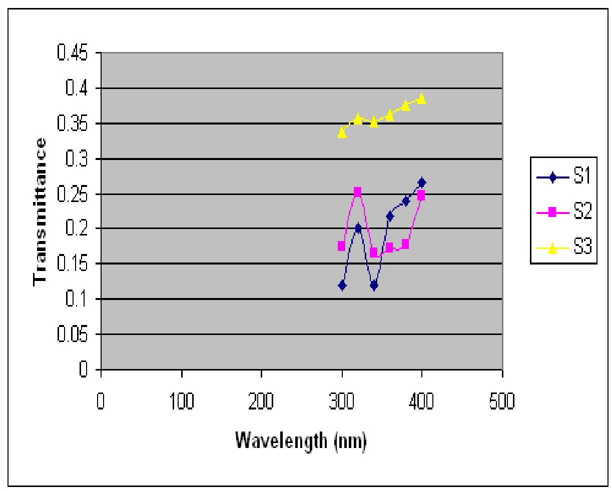

Figure 2: Plot of Transmittance against Wavelength for the Three Samples towards the Visible region.

and the results show that sample S_3 has higher averaged refractive index of 2.62 than the other two samples (S_1 & S_2) which recorded averaged refractive index of 2.52 and 2.23 respectively. This shows that sample S_3 is more optically denser than the other two samples. This high refractive index of this film can be exploited as coating material for internal layer of optical systems for instance optical fibers.

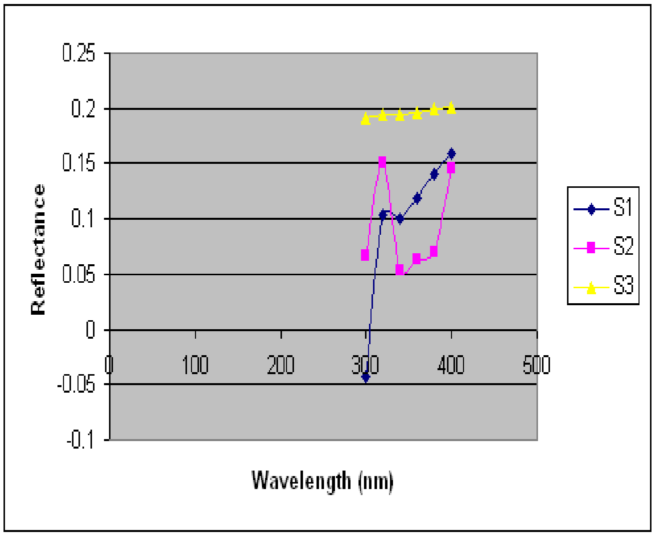

Figure 3: Plot of Reflectance against Wavelength for the Three Samples towards the Visible Region.

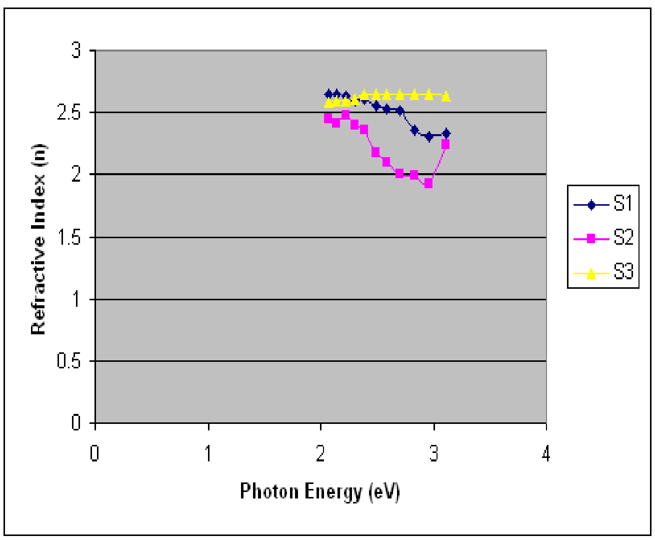

Figure 4: Plot of Refractive Index against the Photon Energy for the Three Samples.

Thereupon, the extinction coefficient (k) of this film was computed employing the relation:

$$K = \alpha \lambda / 4\pi \quad \textbf{(2)}$$

where, K= extinction coefficient
α= absorption coefficient
λ= wavelength of incident radiation

The plot of extinction coefficient (k) against the photon energy for the three samples (S_1, S_2&S_3) is shown in Figure 5.

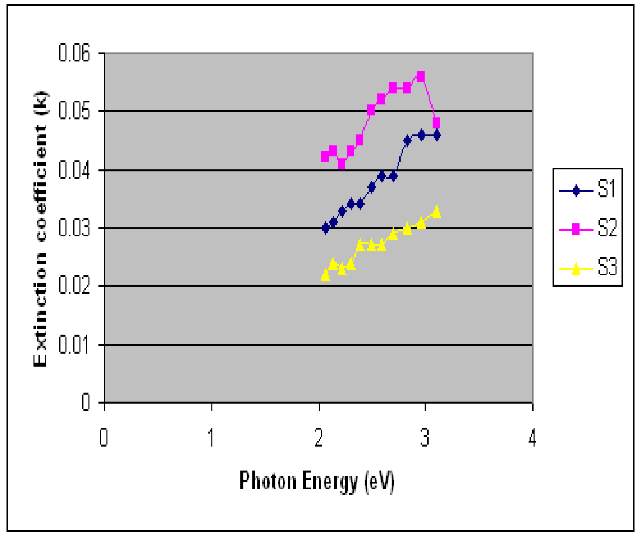

Figure 5: Plot of Extinction Coefficient against the Photon Energy for the Three Samples.

The averaged extinction coefficient of 0.048 for sample S_2 was higher than that of other two samples S_1 &S_3 which recorded averaged extinction coefficients of 0.038 and 0.027, respectively.

Figure 6 depicted the spectral analysis of the optical conductivity of the three samples. Sample S_2 shows higher optical conductivity value of 6.485 x $10^{13}S^{-1}$ than the other two samples. This shows that sample S_2 contains more electrons in the conduction band than the other two samples.

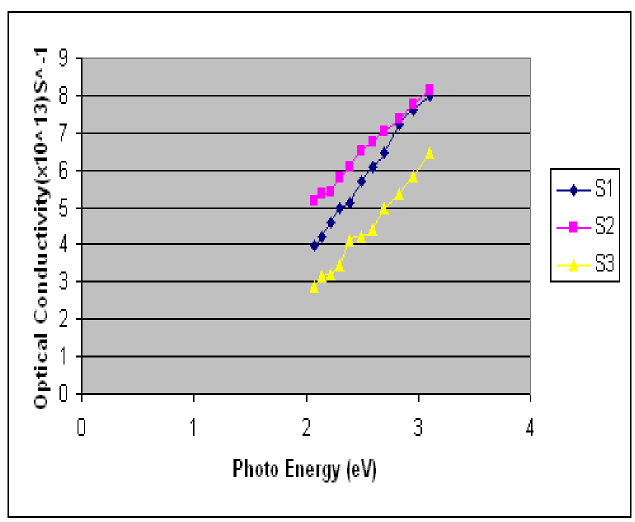

Figure 6: Plot of Optical Conductivity against Photon Energy for the Three Samples.

The electronic structure as a function of dielectric function was analyzed through the computation of the real and imaginary part of the dielectric function of Ag_2S thin films using the relation

$$E_1 = n^2 - k^2 \qquad \textbf{(3)}$$

where, E_1= real part of the dielectric function
n= refractive index
k= extinction coefficient

and

$$E_2 = 2nk \qquad \textbf{(4)}$$

where, E_2= imaginary part of the dielectric function
n= refractive index
k=extinction coefficient

Where n is the refractive index and k is the extinction coefficient. Figure 7 shows the plot of real part of dielectric function as a function of photon energy for the three samples. Sample S_3 exhibited higher averaged real part dielectric function of 6.888 than the other two samples S_1 and S_2 which recorded 6.364 and 5.005, respectively.

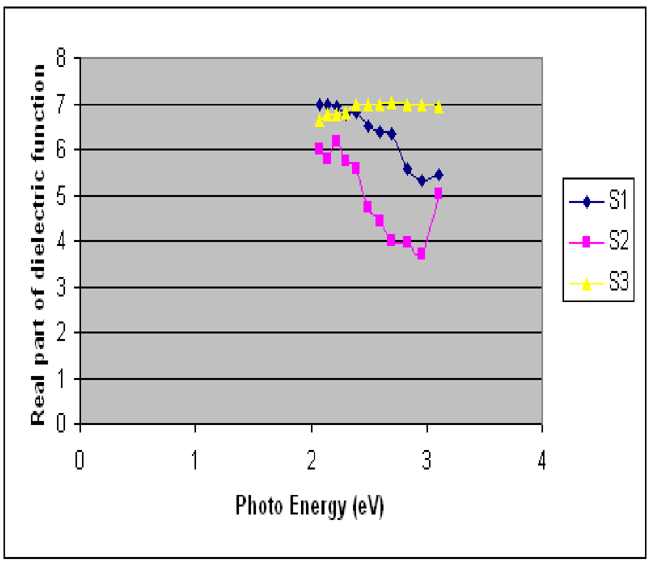

Figure 7: Plot of Real Part of Dielectric Function against the Photon Energy for the Three Samples.

Also, the imaginary parts of dielectric function of these samples were plotted against the photon energy.

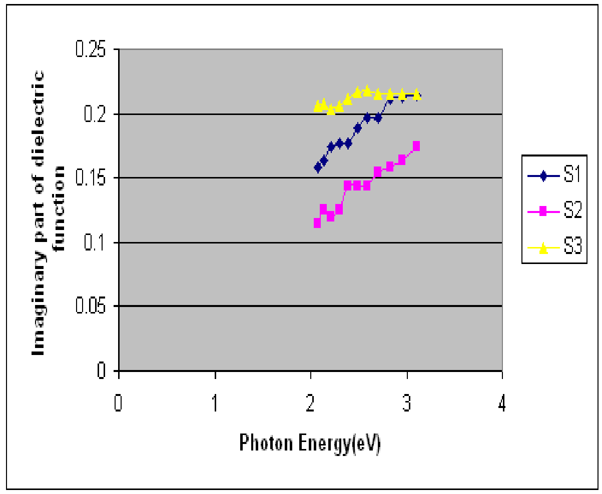

Figure 8: Plot of Imaginary Part of Dielectric Function against the Photon Energy for the Three Samples.

The results show that sample S_2 exhibited higher averaged imaginary dielectric function of 0.212 than the other two samples S_1 and S_3 which recorded 0.188 and 0.142, respectively. Finally, the band gap energy of the deposited film was obtained by plotting the absorption coefficient squared against the photon energy as shown in Figure 9. The result shows that the material (Ag_2S thin film) shows a band gap energy of 1.56eV as the straight part of the graph intersects the photon energy axis at this point. Materials with this type of band gap energy and high optical conductivity can be used as absorber material for photovoltaic applications.

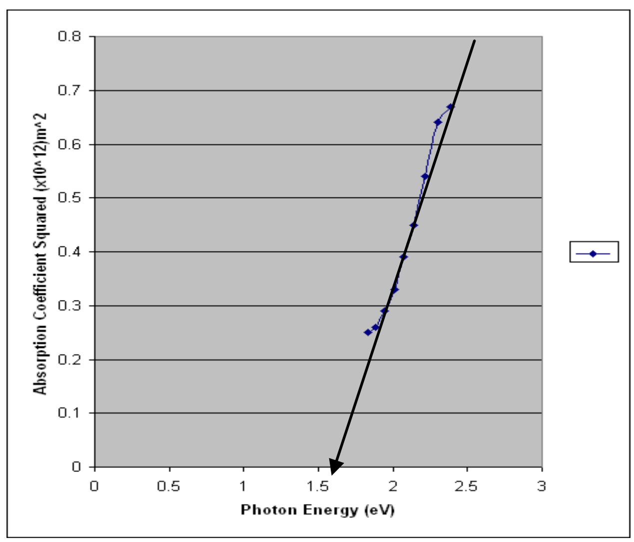

Figure 9: Plot of Absorption Coefficient Squared against the Photon Energy,

CONCLUSION

Thin films of Ag_2S were successfully grown using a chemical bath technique which has been classified as the most cost effective thin film deposition method. This is because the technique does not involve the usage of sophisticated machine and large area of the film can be deposited on substrates of interest using this method. On characterization, the optical properties of the film were determined .These properties made the material to have wide range of applications especially in optical and electronic systems.

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