Influence of Complexing Agent (TEA) On the Optical Properties of Bismuth Sulphide Thin Films Deposited By Chemical Bath Deposition Technique

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Abstract: ***Thin films of Bismuth Sulphide were successfully deposited on glass substrate using chemical bath deposition technique at different concentrations of complexing agent (TEA) and at room temperature (300K). The deposited films were optically characterized using M501 Single Beam Scanning UV/VIS Spectrophotometer. The results show that the deposited films were generally affected by the concentration of complexing agent (TEA) in the reaction bath. The film deposited at 10ml concentration was found to possess highest values in the following optical properties; absorbance (16.7%), reflectance (15.39%) , refractive index (2.29), optical conductivity (2.52 x*** $10^{13}S^{-1}$***), extinction coefficient (0.013528), real part dielectric function (5.249506) and imaginary part dielectric function (0.061992). The film deposited at 2ml concentration of TEA was found to have highest transmittance value of 90.36% at wavelength value of 300nm. And the film deposited at 6ml TEA concentration exhibited highest band gap energy value of 2.60eV.***

Keywords: Substrate, Chemical bath deposition, Characterization, Spectrophotometer, Optical properties, and Complexing agent

1. Introduction

Bismuth Sulphide is a binary semiconductor material that is made up two elements of Bismuth and sulphur. The compound is recently attracting wide interest due its desirable properties and applications in photovoltaic and opto-electronic devices. Bismuth Sulphide (Bi_2S_3) possesses moderate band gap energy of 1.7eV which lies in the visible region of electromagnetic energy spectrum [1]. It has found applications in photodiode arrays, photovoltaic converters, thermoelectric cooling technologies based on the Peltier effect and photoconductors [2, 3, 4]. Thin films of Bismuth Sulphide (Bi_2S_3) had been prepared by various Scientists using different methods such as Vacuum evaporation [5], Spray pyrolysis [6], Ultrasonic method [7], hydrothermal synthesis [8], Cathodicelectrodeposition [9] and Chemical deposition [10].

In this paper Chemical Bath Deposition technique was employed to prepare thin films of Bismuth Sulphide at different concentrations of complexing agent (TEA) while other parameters of deposition were left unchanged.

2. Experimental Details

The glass substrates were clinically cleaned by initially immersing them in a dilute solution of HCl and after staying in the solution for twenty minutes (20mins), they were removed, washed with detergent, rinsed with distilled water and dried in impurity free environment. The essence of this treatment is to form nucleation centers on the substrate necessary for the deposition of thin film. The beakers used in this research work were equally cleaned in this manner. Various molar solutions of different compounds like Bismuth Sulphateand Thiourea were prepared. Other compounds like ammonia and complexing agent (TEA) were already in solution form when purchased from the marketing company.

The deposition procedure was as follows: 5ml of 0.1M Bismuth Sulphate solution was put into the 50ml beaker (bath) and this was followed with the addition of 2ml TEA and the resulting solution was stirred for 2minutes. Thereafter, 5ml of ammonia solution was put into the bath and resulting solution was also stirred. Finally, 5ml of 0.1M thiourea was added and resulting solution was top with distilled water to make up the solution to 50ml mark on the bath.

The cleaned substrate was vertically clamped in the bath through a thick cardboard sheet to avert dirt from entering the bath. The set-up was allowed to stay for 12hours and after which the substrate was removed, rinsed with distilled water and allowed to dry in dirt free environment.

Two other set-ups were prepared in this way but the concentration of complexing agent (TEA) was varied, that is, 6ml and 10ml respectively while other parameters remain constant. After the deposition of Bismuth sulphide thin films was achieved, M501 Single Beam Scanning UV/VIS Spectrophotometer was used to obtain the absorbance data of the films. Other optical properties of the deposited films were calculated using relevant equations.

3. Results and Discussion

1.1 The Effects of Complexing Agent on the Optical Properties of Deposited Bismuth Sulphide Thin Films

Figure 1 shows the plot of absorbance against wavelength for the deposited films at different concentrations of complexing agent (TEA). From figure 1, the absorbance property of the films were generally low with the film deposited at 10ml concentration having highest peak absorbance value of 0.167(16.7%) of incident electromagnetic radiation at a wavelength of 360nm.

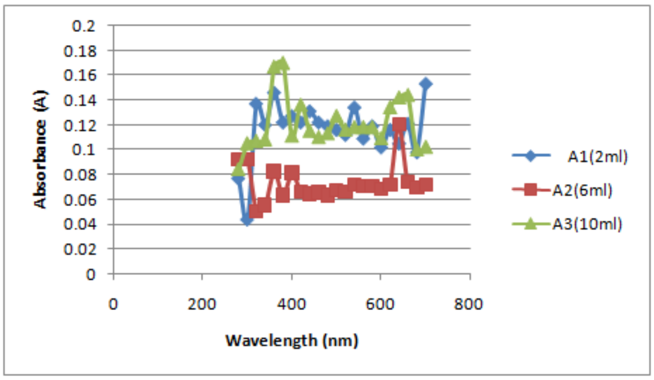

Figure 1: Plot of Absorbance against Wavelength for the films deposited at different concentrations of TEA

The transmittance spectra of the deposited films were illustrated in figure 2. From figure 2, the transmittance of the films to incident radiation was found to be generally high with the films deposited at 2ml and 6ml concentrations of TEA having peak transmittance values of 0.9036 (90.36%) and 0.8913 (89.13%) respectively within the wavelength interval of 300-320nm. This high transmittance value made the material a good candidate for application in photovoltaic devices.

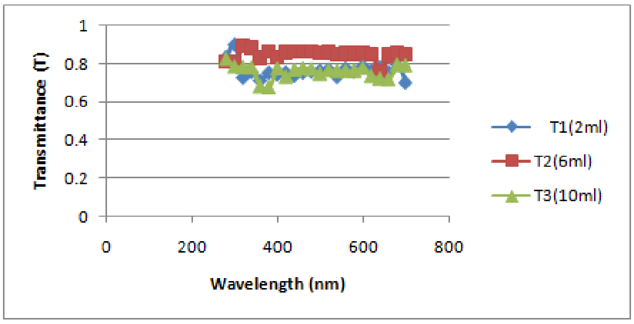

Figure 2: The transmittance spectra of the deposited films at different concentrations of TEA

The reflectance property of the films to incident radiation is shown in figure 3. The reflectance of the films to incident light energy was found to be generally low with film deposited at 10ml concentration of complexing agent (TEA) exhibiting highest peak value of 0.1539 (15.39%) at a wavelength of 380nm. This shows that Bismuth Sulphide semiconductor material can serve as anti-reflectance coating for fabrication of solar cells.

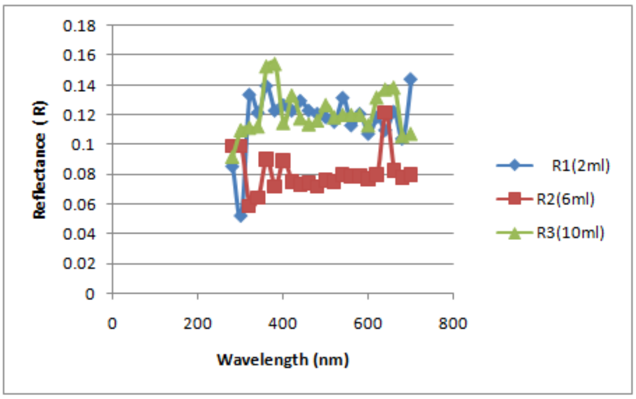

Figure 3: The plot of Reflectance against Wavelength for the deposited films at different concentrations of TEA

Figure 4 shows the plot of refractive index against photon energy for the films deposited at different concentrations of Complexing agent (TEA). The films were observed to possess moderate refractive index value range of 1.59-2.29. The film deposited at 10ml concentration of TEA was found to exhibit highest refractive index value of 2.29. This high refractive index value is an indicative that the thin film of Bismuth Sulphide can be used in fabricating photonic devices.

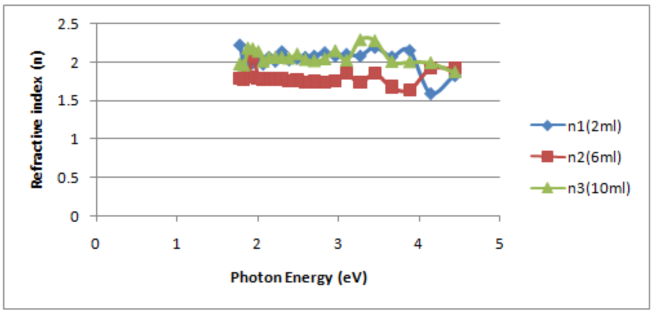

Figure 4: The variation of Refractive index with Photon Energy for the deposited Films at different concentrations of TEA

The optical conductivity spectra of the deposited films at different concentrations of complexing agent (TEA) are illustrated in figure 5. The films were observed to exhibit high optical conductivity of incident electromagnetic radiation which increases as the photon energy increases. From figure 5, the film deposited at 10ml concentration of complexing agent (TEA) was found to possess highest optical conductivity value of 2.52 x $10^{13}S^{-1}$ at photon energy of 3.45eV. This high optical conductivity value suggests that the Bismuth Sulphide semiconductor material can be used as window layer in solar cells devices.

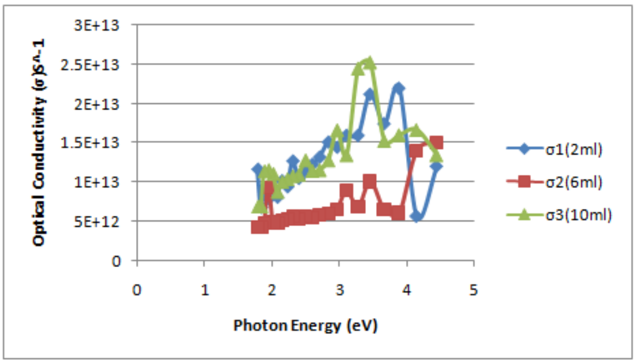

Figure 5: The optical conductivity spectra of the deposited films at different concentrations of TEA

The extinction coefficient spectra of the deposited films are illustrated in figure 6. From figure 6, the films were found to exhibit low extinction coefficient values with the maximum value of 0.013528 observed for film deposited at 10ml concentration of complexing agent (TEA) at photon energy of 3.27eV.

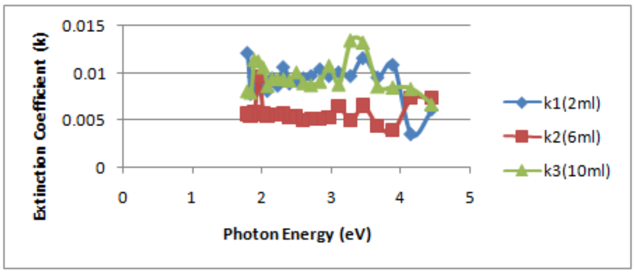

Figure 6: The extinction coefficient spectra of the deposited films at different concentrations of TEA

The real part dielectric function spectra of the deposited films are shown in figure 7. From figure 7, the films were observed to exhibit high real part dielectric function values with the film deposited at 10ml concentration of complexing agent (TEA) possessing highest peak value of 5.249506 at photon energy of 3.27eV.

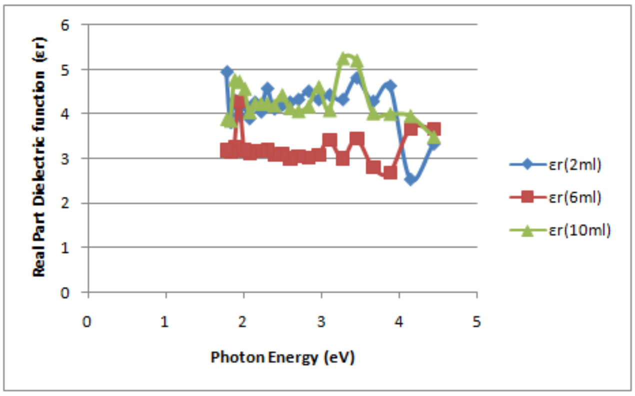

Figure 7: Real part dielectric function spectra of the films deposited at different concentrations of TEA

The imaginary part dielectric function spectra of the deposited films are depicted in figure 8. From figure 8, the imaginary dielectric function of the films were found to be of low values with the film deposited at 10ml concentration of TEA having the maximum value of 0.061992 at the photon energy of 3.27.

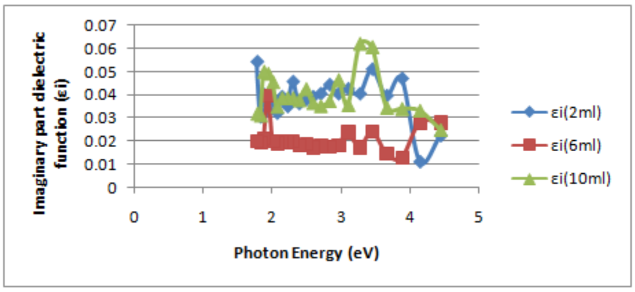

Figure 8: Imaginary part dielectric function spectra of the deposited films at different concentrations of TEA

Figures 9-11 show the plot of absorption coefficient squared against photon energy for the deposited films at different concentrations of complexing agent (TEA). Fromfigures 9-11, the band gap energies of the films were obtained at the point where the straight part of the graph meets the photon energy axis. The films exhibited band gap energy range of 1.95eV – 2.60eV with the film deposited at 6ml concentration of complexing agent possessing the highest band gap energy of 2.60eV.

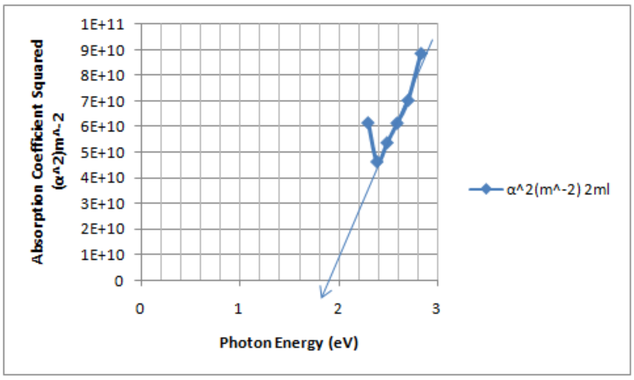

Figure 9: Plot of Absorption coefficient Squared against photon energy for film deposited at 2ml concentration of TEA

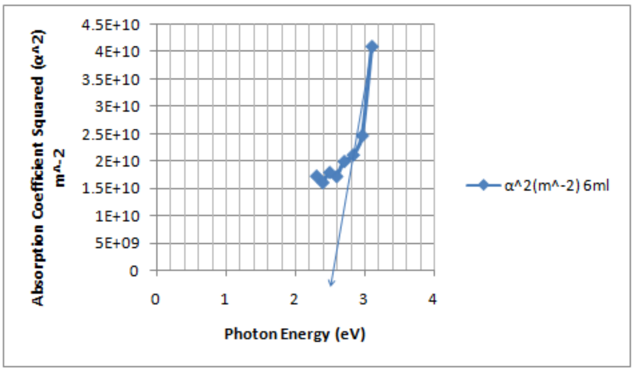

Figure 10: The plot of Absorption Coefficient Squared against Photon energy for the film deposited at 6ml concentration of TEA

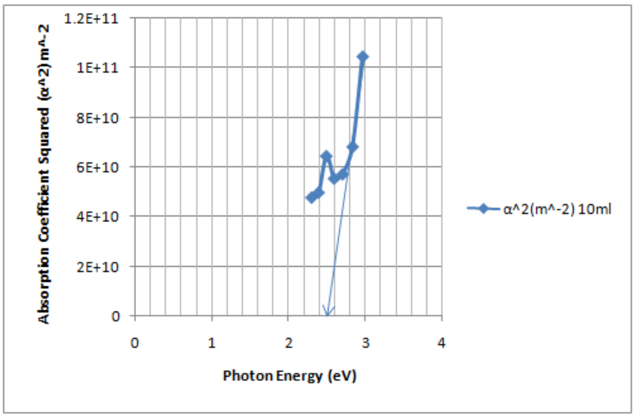

Figure 11: Plot of Absorption Coefficient Squared against Photon Energy for film deposited at 10ml concentration of TEA

4. Conclusion

Thin films of Bismuth Sulphide were successfully deposited on glass substrate using a Chemical Bath Deposition Technique which has been adjudged to be most cost effective way of depositing thin films. The technique is reproducible and with it large area of an object can be coated with thin films of desirable semiconductor materials. From the work it was observed that the concentration of complexing agent (TEA) has potential effect on the optical properties of the deposited films. The film deposited at 10ml concentration of TEA was found to be affected most and this goes to illustrate that high concentration of complexing agent has substantial effect on optical properties of semiconductor material. All these desirable properties of Bismuth Sulphide semiconductor material confirmed in this research show that the material is a good candidate for applications in photonics, opto-electronic and photovoltaic devices.

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