Optical Properties of Chemical Bath Deposited Magnesium Sulphide Thin Films

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Abstract
Thin films of Magnesium Sulphide were deposited on a glass substrate at room temperature (300K) from aqueous solution of Magnesium Sulphate ($MgSO_4.7H_2O$), Ammonia (NH_3), Thiourea $(NH_2)_2CS$ in which Ethylene diamine tetra acetate (EDTA) as complexing agent. Distilled water was used to make up the solution to the required volume. After the deposition, the films were optically characterized using M501 Single Beam Scanning UV/Vis Spectrophotometer. The results indicate that films exhibited low absorbance values (0.055-0.244) and reflectance values (0.067-0.186) respectively within the visible region of electromagnetic spectrum. The films show corresponding high transmittance value of 57%-91% within this region. The calculated absorption coefficient values of 0.683×10^5- 7.630×10^5m were recorded for the films with high optical conductivity values of $0.256 \times 10^{13}S^{-1} – 4.579 \times 10^{13} S^{-1}$ in the visible region. The films were observed to possess low extinction coefficient values of 0.003-0.019 and poor imaginary dielectric function values of 0.010-0.097. The calculated refractive index value was found to range from 1.56- 2.51. The films also exhibited direct wide band gap energy value of 3.85eV. All these desirable properties made the material a good candidate for photo-voltaic and photonic applications.
Keywords: Absorbance, reflectance, transmittance, optical conductivity, extinction coefficient, absorption coefficient, refractive index, dielectric function and band gap energy.

1.1 Introduction

The need to make human existence more comfortable has led Scientists to increase research efforts towards discovering semiconductor materials that can be used to fabricate opto-electronics devices which can add value to human life. The production of flat screen TV (Plasma display Panel), Air Condition that runs on low energy , fast transmission communication cables and photovoltaic panels for generation of electricity are some of the research products emanating from researches in semiconductor materials. Due to differences in properties of thin films and bulk films especially in terms of fabrication cost and desirable properties, thin film deposition techniques are now employ for the fabrication of large area arrays solar selective coatings, solar cells, photoconductors, antireflection systems, polarizers etc. For instance, different thin film deposition techniques have been used by Scientists to fabricate thin films of II-VI semiconductor compounds like Magnesium Sulphide (MgS). Thin films of II-VI semiconductor compounds like Magnesium Sulphide (MgS) have been prepared using Electrodeposition [1], Chemical Bath Deposition[2], SILAR [3], Sol-gel [4], Thermal evaporation[5] and so on. In this paper, Chemical bath deposition technique was used to prepare thin films of Magnesium Sulphide at different dip-times and at room temperature (300K).

1.2 Experimental Details

Magnesium sulphide thin films were deposited on a clean glass substrate by Chemical Bath Deposition technique. This was done in a reactive solution prepared in 50ml beaker by sequential addition of 5ml of 1M Magnesium sulphate (MgSO4.7H2O), 5ml of 1M EDTA and the resulting solution was stirred, 5ml of ammonia solution was added , this was followed with addition of 5ml of thiourea and the finally 30ml of distilled water was added and the solution was stirred. The glass substrate was clamped vertically in the bath and allowed to stay for 12hours. After this period, the substrate was removed, rinsed with distilled and allow to dry in open air. Three other set-ups were prepared in this way and allowed to stay for 24hours, 36hours and 48hours at room temperature. At the end of the deposition times, the substrates were removed and rinsed with distilled water and allow to dry naturally. The substrates were found to be coated with greyish deposits.

In order to investigate for the optical properties of the deposited magnesium sulphide thin films, the optical absorption measurement was carried out using M501 Single Beam Scanning UV/Vis spectrophotometer. The film coated glass substrate was placed across the sample radiation path way while the uncoated glass substrate was used as reference frame. The absorbance data was obtained directly from the spectrophotometer and other parameters were calculated using the relevant known equations.

The equation of reaction is shown below;

$$MgSO_4.7H_2O + EDTA \longleftrightarrow Mg(EDTA)^{2+} + SO_4^{2-} + 7H_2O$$

$$Mg(EDTA)^{2+} \longleftrightarrow Mg^{2+} + EDTA$$

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

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

$$Mg^{2+} + S^{2-} \longleftrightarrow MgS\downarrow$$

1.3 Results and Discussion

The films deposited were optically characterized and results were as stated below. The absorbance was obtained directly from UV/VIS spectrophotometer. The absorbance of the films to incident solar radiation was found to be of low value 0.055-0.244 and decreases from ultra-violet region to visible region of electromagnetic spectrum. The plot of absorbance as a function of wavelength is shown in figure 1 below for the four samples at different dip-times.

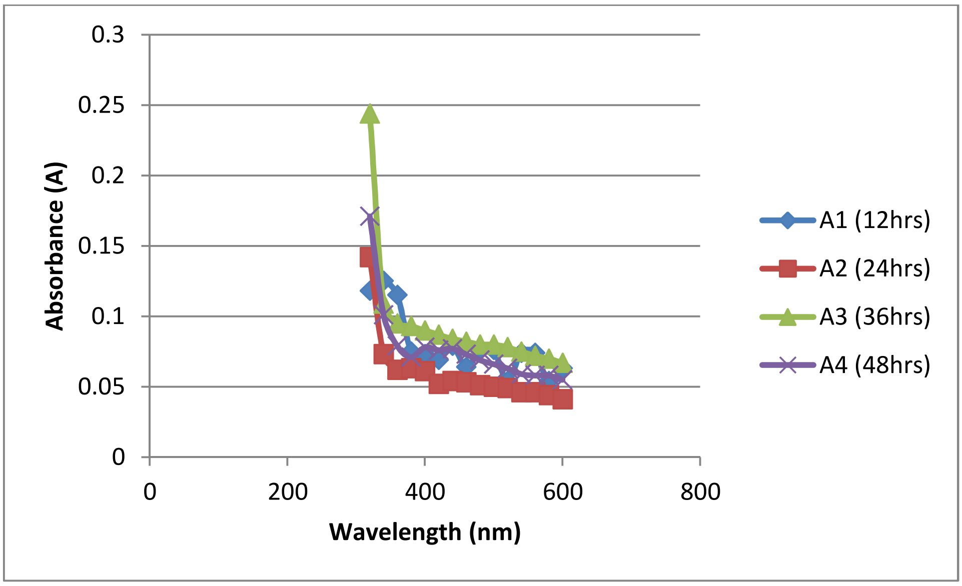

Figure 1: Plot of absorbance as a function of wavelength for the four samples at different dip-times.

The transmittance of the film to incident radiation was calculated using the relation,

$$T = 10^{-A} \qquad (1.1)$$

where A is the absorbance in arbitrary unit. The films were observed to possess high transmittance percentage value of 57% - 91%. The plot of transmittance as a function of wavelength is depicted in figure 2 below.

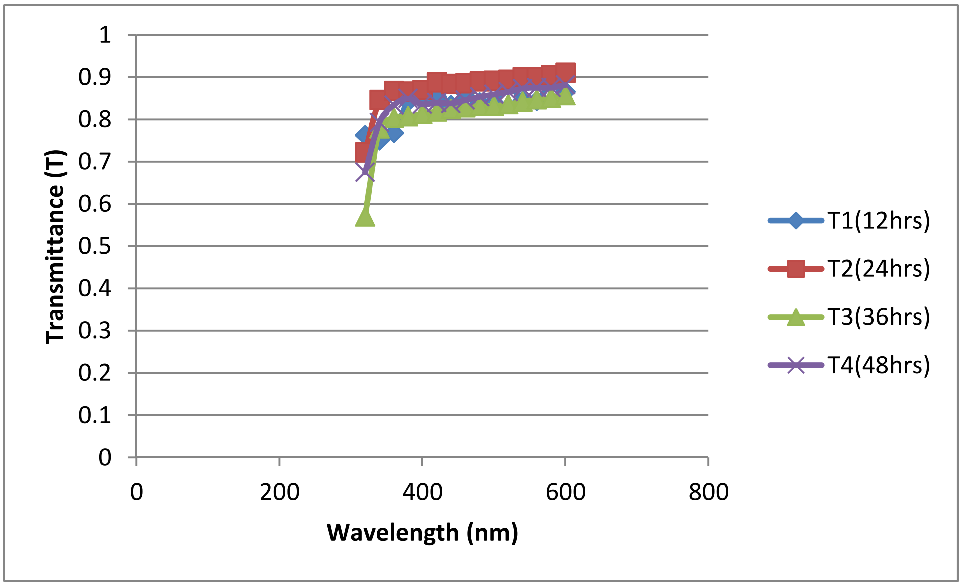

Figure 2 : Plot of transmittance as a function of wavelength for the four samples at different dip-times.

The reflectance of the films to incident solar radiation was calculated using the relation,

R = 1- (A+T) (1.2)

Where A is the absorbance and T is the transmittance. The reflectance performances of the films were found to be generally of low value (0.067-0.186) for the four deposited samples. This is shown in figure 3 below.

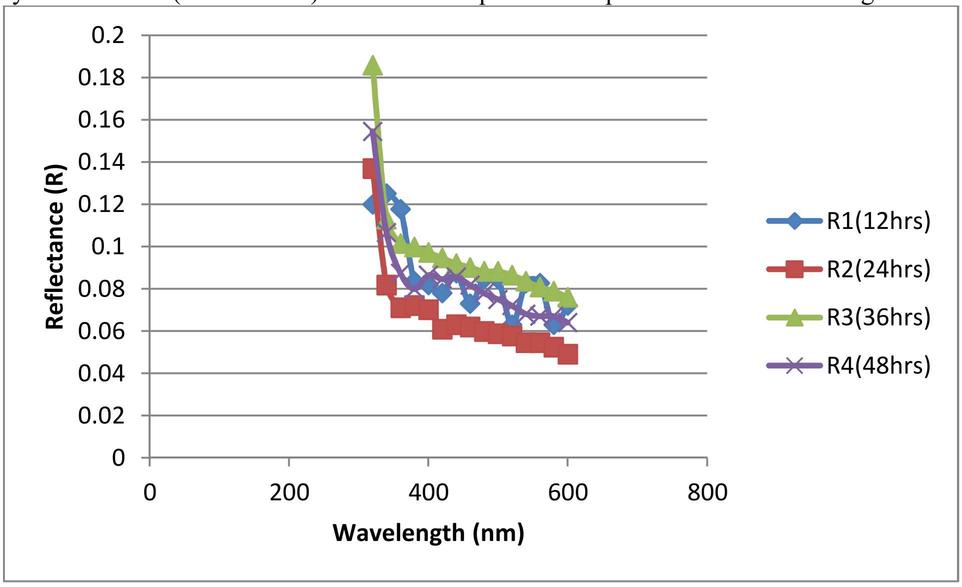

Figure 3: Plot of Reflectance as a function of wavelength for the four samples at different dip-times.

From the graph, it was observed that the reflectance deceases from ultra-violet region to infra-red region of electromagnetic spectrum. The film deposited at 36hrs exhibited higher reflectance ability than the other samples at room temperature (300K).

Figure 4 is the plot of absorption coefficient as a function of Photon energy for the four samples at different dip-times. Absorption coefficient is the decrease in the intensity of a beam of photons or particles in its passage through particular substance or medium. The absorption coefficient was calculated using the relation;

Absorption coefficient (α), = Ax $10^9/\lambda$ (1.3)

Where A is the absorbance and λ is the wavelength in meters.

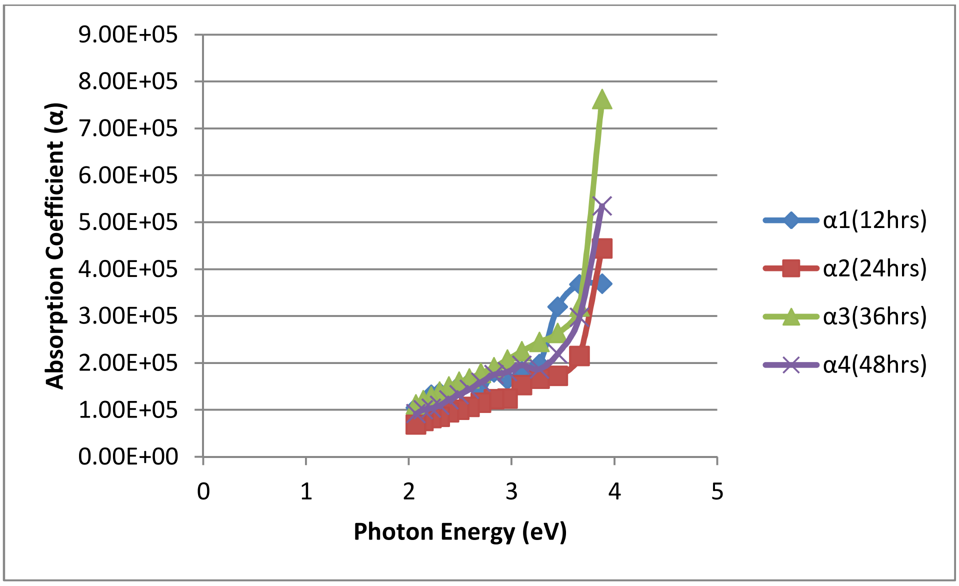

Figure 4: Plot of Absorption Coefficient as a function of Photon energy for the four samples at different dip-times.

The absorption coefficient of the deposited films was observed to be of high value $0.683 \times 10^5 - 7.630 \times 10^5$m. The film deposited at 36hrs exhibited better performance than the rest of the films.
The optical conductivity spectra of the films are shown in figure 5 below. The optical conductivity of the film was computed using the relation;

$$\sigma_{op} = \alpha nc/4\pi \qquad (1.4)$$

where α is the absorption coefficient, n is the refractive index and c is the velocity of light .

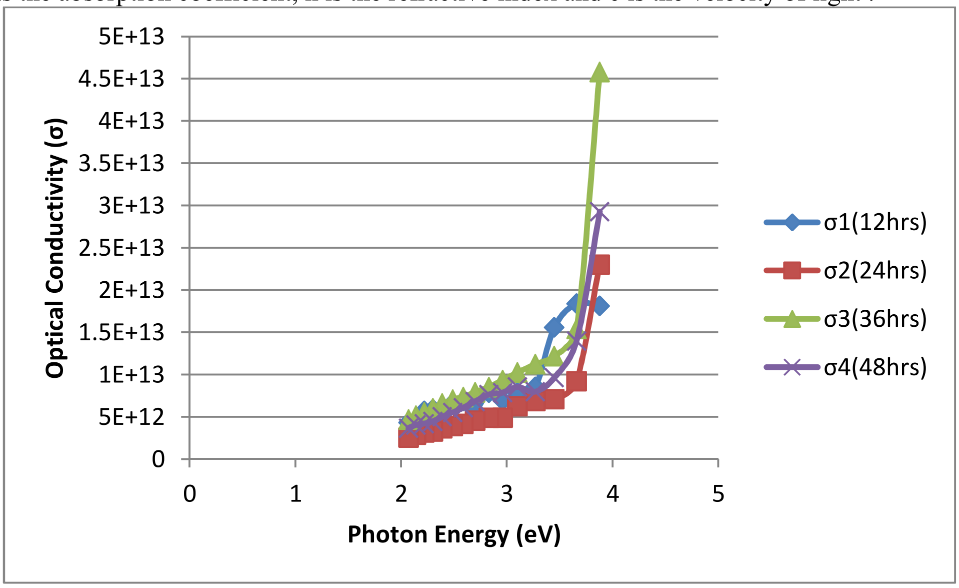

Figure 5: Optical Conductivity spectra of the deposited films at different dip-times.

The calculated value of optical conductivity of the films to incident solar radiation was found to be high, that is, $0.256 \times 10^{13}S^{-1} - 4.579 \times 10^{13}S^{-1}$. The optical conductivity is the response of a transparent solid to incident radiation [6]. The film deposited at 36hrs at room temperature (300K) exhibited better performance than the rest of the films.
The refractive index of the deposited films was computed using the expression;

$$n=1+R^{0.5}/1-R^{0.5} \qquad (1.5)$$

where R is the reflectance. The plot of refractive index as a function of photon energy is shown in figure 6 below.

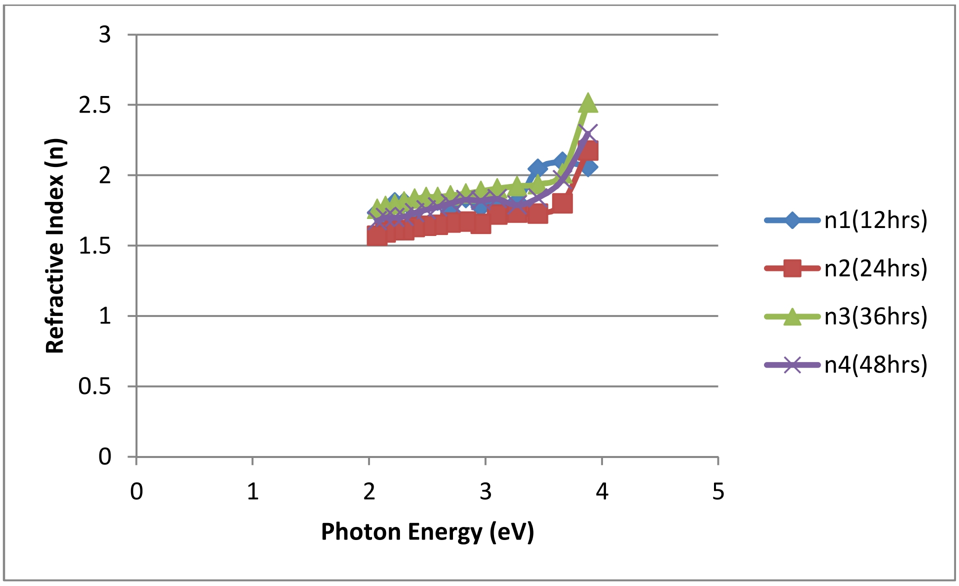

Figure 6: Plot of refractive index as a function of Photon energy for the four samples at different dip-times.

From the graph it was observed that the refractive index tends to increase towards the visible region of the electromagnetic spectrum and it ranges from 1.56-2.51. Refractive index is of critical importance for photonics applications such as optical waveguides and ophthalmic devices. Based on the unique refractive index characteristics and optical clarity; the thin films of Magnesium sulphide can be used in fabrication of contact lenses and photovoltaic devices.
Extinction coefficient of the films was computed using the relation;

$$K = \alpha\lambda/4\pi \qquad (1.6)$$

Where α is the absorption coefficient and λ is the wavelength of incident radiation. The plot of extinction coefficient is shown in figure 7 below;

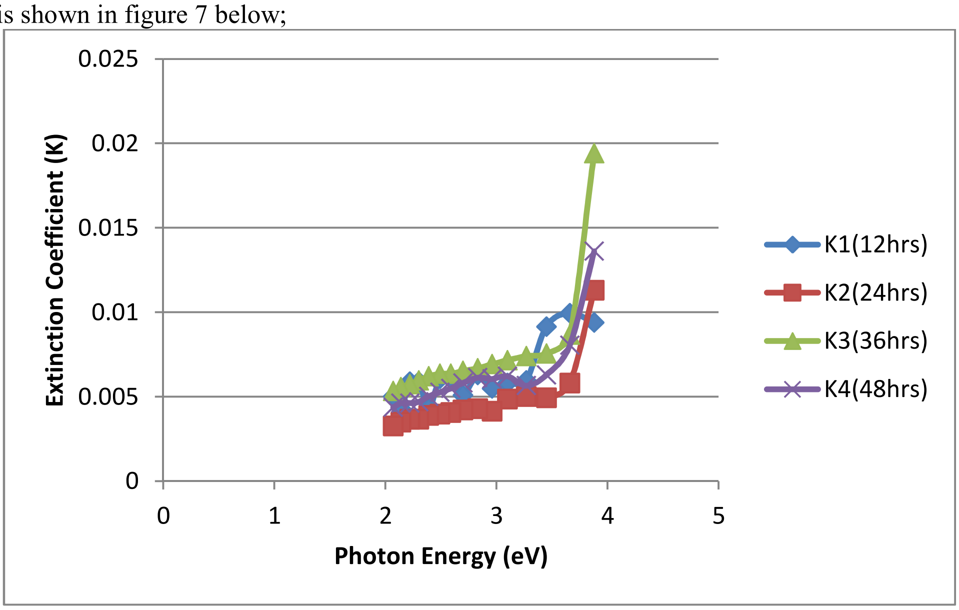

Figure 7: Plot of extinction coefficient as a function of Photon Energy for the four deposited films at different dip-times.

The value of the extinction coefficient of the deposited films was observed to be generally low, that is , 0.003-0.019. The film deposited at 3hrs room temperature (300K) was found to exhibit better extinction coefficient properties than the rest of the films.

Figure 8 is the plot of real part of dielectric function of the deposited films for the four different samples at different dip-times.

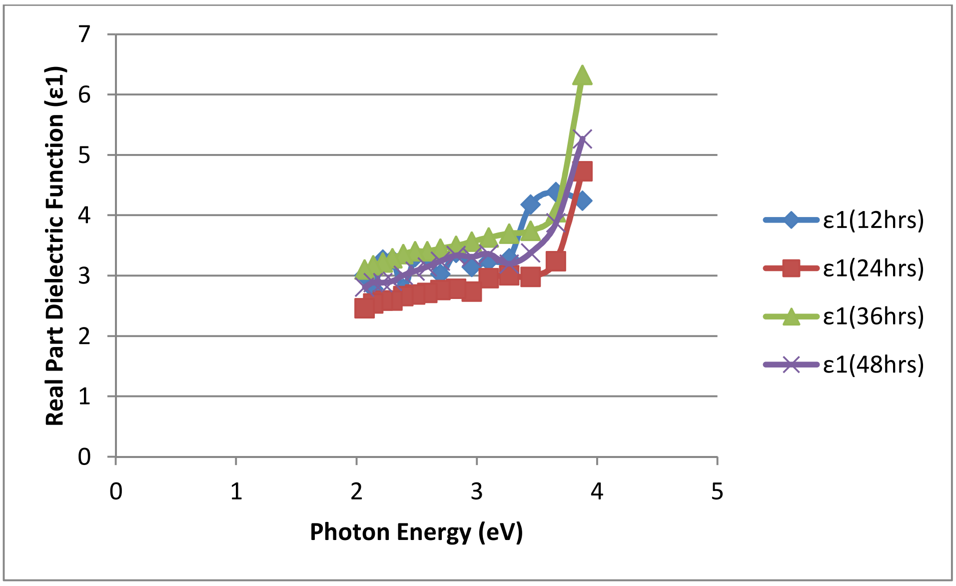

Figure 8: Plot of real part of dielectric function of the films as a function photon energy.

From the figure 8, it was observed that the real part of dielectric function increase as photon energy increases. The spectra of Imaginary part of dielectric function of the films are shown in figure 9 below.

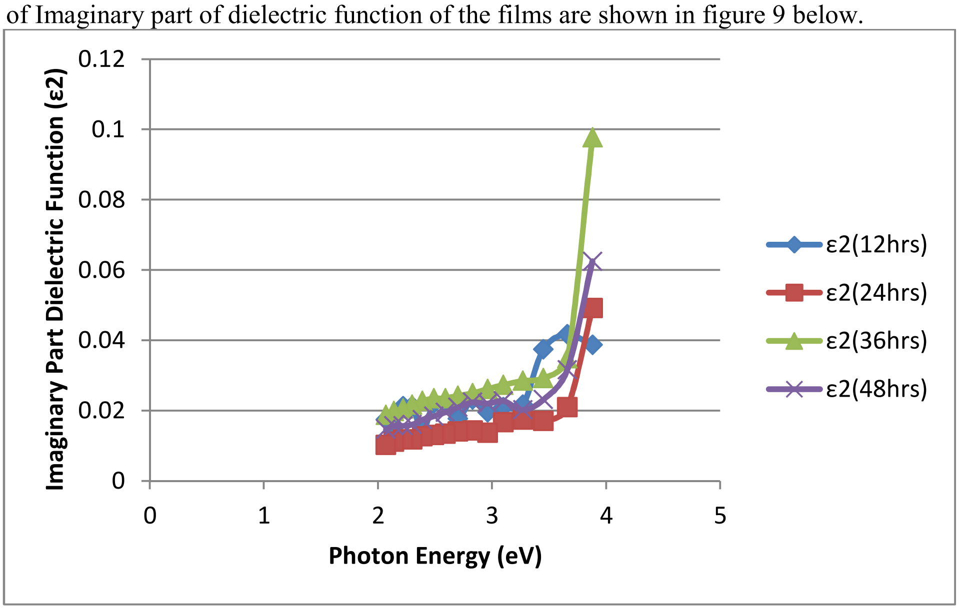

Figure 9: The plot of imaginary part of dielectric function as a function of Photon energy for the four samples at different dip-times.

The film deposited at 36hrs room temperature (300K) was found to exhibit the highest peak at photon energy value of 3.8eV.These optical constants were computed using the Wooten relation [7];

$\varepsilon_1 = n^2 - k^2$ (Real part) (1.7)

and

$\varepsilon_2 = 2nk$ (Imaginary part) (1.8)

where n is the refractive index and k is the extinction coefficient.

Figure 10 is the plot of absorption coefficient squared as a function of photon energy.

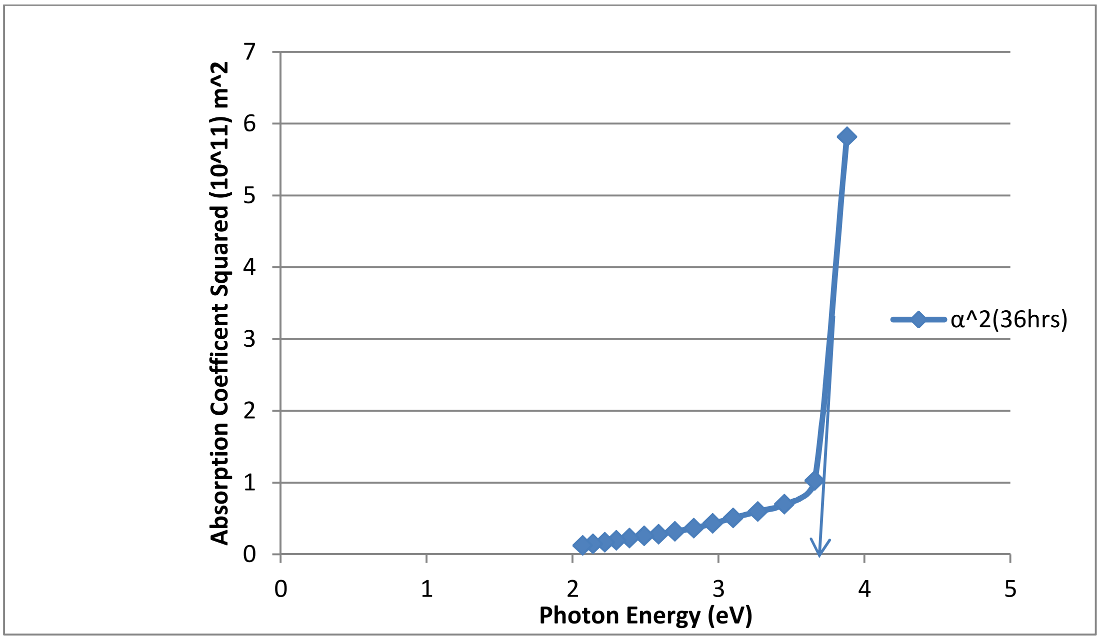

Figure 10: Plot of absorption coefficient squared as function photon energy for sample deposited at 36hrs room temperature.

From the figure, it was observed that the film exhibited a band gap energy of 3.85eV.That is the point where the straight portion of the graph extrapolated intercepted the photon energy x-axis. This high value of 3.85eV makes Magnesium Sulphide thin film to be a wide band gap semiconductor material that can find applications in photonic and photovoltaic devices. This band gap value of 3.85eV was found to be in close agreement with the value obtained by 3.9eV obtained by Nnabuchi [8].

1.4 Conclusion

The thin films of Magnesium sulphide thin films were successfully deposited on a glass substrate from the aqueous solution of Magnesium Sulphate ($MgSO_4.7H_2O$), Ammonia (NH_3), Thiourea $(NH_2)_2CS$ in which Ethylene diamine tetra acetate (EDTA) was used as complexing agent. Distilled water was used to make up the volume to the required mark. The deposited films were optically characterized using Camspec Single beam UV/VIS spectrophotometer at wavelength range of 320-600nm for its optical properties. The films were observed to possess low absorbance and reflectance values of 0.055-0.244 and 0.067-0.186 in arbitrary units respectively. The computed values of optical conductivity and absorption coefficient were found to be generally high with values of $0.256x10^{13}S^{-1} – 4.579 \times 10^{13}S^{-1}$ and $0.683x10^5$m- 7.630×10^5m respectively recorded for the films. The extinction coefficient of the films studied was found to be low with a value range of 0.003-0.019. Films exhibited high refractive index value of 1.56-2.51 with a wide band gap energy of 3.85eV. All these desirable properties made the Magnesium Sulphide thin films to be a good material for application in Photonic and Photovoltaic industries for fabrication of blue-emitters, photo detector and barrier material.

1.5 Reference

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