Optical Analysis of Aluminum Nickel Sulphide Ternary thin Films for Device Applications

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Abstract

The solution growth technique was used to deposit ternary thin film on substrates at different bath parameters which include temperature, concentration of solution, volume of solution and water, time of deposition and pH, from bath composition of aluminum chloride ($AlCl_3$), Nickle Chloride ($NiCl_2$ $6H_2O$), thiourea ($CS(NH_2)_2$, distilled water, ethylene diamine tetracetic acid (EDTA) and ammonia (NH_3). Ethylene diamine tetra acetic acid and ammonia served as the complexing agents. A UN-VIS-NIR spectrophotometer was used to measure transmittance, while absorbance and reflectance were determined by calculation. The GBC enhanced mini material analyzer (EMMA) X-ray diffractometer was used to measure the elemental compositions of the films. The optical properties revealed that films of Aluminum Nickel sulphide ($Al_{4.5}Ni_7S_3$) have high absorbance and reflectance but moderate transmittance throughout the ultraviolet, visible and infrared regions. The above results show that $Al_{4.5}Ni_7S_3$ could be applied in solar cells, photo-thermal solar energy devices etc. It could also be used as anti-reflection coatings.

Key words: solution growth technique, optical properties, anti-reflection coatings.

INTRODUCTION

$Al_{4.5}Ni_7S_3$ is the ternary thin films which are important in optoelectronics semiconductor materials. They are found between group II-VI are greenish in colour. Ternary compounds are found to be promising materials for optoelectronic device applications such as green-emitting devices. They are

recommended as good materials foe window layer of solar cells (Woon-Jo and Gye-Choon, 2003). The deposition and the measurement of the characteristics of ternary chalcogenide compounds and their possible applications in solar cells, light emitting diode and other non-linear optical devices has been increasing in recent years (Ortega-Lopoz *et al.,* 2003). Some of the ternary compounds have been examined for specific applications in super ionic conducting materials (Sasaki *et al.,* 2003). Because of the interest on ternary compounds, they are being studied for efficient solar energy conversion through photo-electrochemical solar cells (Padam and Rao, 1986).
Many of the deposition techniques of advanced technologies have been used in the preparation of ternary thin films, but a low cost and simple solution growth technique improves much better (Padam and Rao, 1986). It is a new and interesting technique which gives high quality semiconductor thin films. This technique is simple and requires low temperature. It produces good quality films (Wang *et al.,* 1999). This technique has been employed in the production of emerging materials for solar cells, protective coatings, solar thermal conversion in buildings and is being accepted by some industries (Chopra *et al.,* 1985; Nnabuchi, 2005 and Ezema *et al.* 2009). It is more convenient for the production large area device.

2.0 Literature Review

2.1 Thin Films as the Semiconductor Materials

Thin film is a crystalline or non crystalline material developed into two dimensional on a substrate surface by either physical method or chemical methods. It also low dimensional materials created by condensing one to one; atomic/molecular/ionic species (Alhassan, 1991). The chemical methods of deposition of thin films include chemical vapour deposition (Chopra and Das, 1983), electrochemical deposition, solution growth technique and anodization (Ndukwe, 1993; Ezema, 2005). Solution growth technique used in growing these ternary thin films is the technique in which films can be grown on either metallic or non metallic substrates by inserting them in suitable solutions without the application of any electric field. It is the most popular today because of large number of conducting and semiconducting thin films can be possible. In this technique, it is possible to deposite films on different microscopic slides (substrates) like glass, ceramics, metallic etc. Also the growth rate and degree of crystallinity depends upon the temperature of the solution in this method. The factors governing this technique are bath deposition, deposition temperature, deposition time and PH value. These chemical methods depend on a specific chemical reaction (Ohring and Mitton, 2002). The physical methods of depositing thin films include sputtering method, thermal evaporation, electron beam evaporation, activated reactive evaporation electron beam epitaxy and ion plating (Campbell, 1967 and Dulta, 1985). The physical methods depend on the evaporation or ejection of the material from a source.

2.2 Optical and solid state properties of thin films

The optical and solid state characteristics of thin films are always studied using spectrophotometer, which include transmittance (T), Absorbance (A), Reflectance ®, Absorption Coefficient (α), Extinction coefficient (K), Band gap (Eg), refractive index (n), dielectric constant (real part ($_{Er)}$ and Imaginary part ($_{Ei}$), optical conductivity (δo), and Electrical Conductivity (δe). In this paper, the optical and solid state properties determined include transmittance which determined directly from the spectrophotometer, absorbance, reflectance and refractive index which are determined by calculation. The optical properties determined in this paper are discussed below:

Transmittance (T) is the ratio of the transmitted flux (It) to the incident flux (Io) (Wooten,1972; Pankove, 1971 and Lothian, 1958). Absorbance (A) is the fraction of the radiation absorbed from the radiation that strikes the surface of the material. Reflection (R) is the fraction of the incident radiation of a given wavelength that is reflected when it strikes a surface. The relationship between transmittance (T), optical absorbance (A) and optical reflection (R) are stated below according to the law of conservation of energy given as:

$A + T + R = 1$

$R = 1 \quad A \quad T$.

2.3 Spectrophotometer as a measure of optical properties of the thin films grown.

UV VIS Spectrophotometer is also known as absorption or reflectance spectroscopy in the ultraviolet visible spectral region. It is the instrument that measures the ratio of intensity of two beams of light in the UV- Visible region, that is, it compares the intensity of the light passing through a sample (I) to the intensity of light before it passes through the sample (Io) which is known as transmittance. It also compares the intensity of light reflected from a sample (I) to the intensity of the reflected from a reference material (Io). It is used to determine the thickness of the films and a map of the film thickness across the entire wafer can also be used quality control purposes. (Fujiware, N.; Kokubo, M. and Kondo, N. (1994). It also determines the quality of molecular species absorbing the radiation. It could be analyzed using forouhi- bloomer dispersion equations to determine refractive index (n) and extinction coefficient. It is widely used in many industries including semiconductors, laser and optical manufacturing, printing and forensic examination, as in laboratories for the study of the chemical substance (Hall, 2006).

3.0 Methodology

The Aluminum Nickel Sulphide ternary thin films were deposited on the substrates was decreased with concentrated HNO_3) for 24 hours, cleansed with distilled water and dried in air. The $Al_{4.5}Ni_7S_3$ ternary thin films were deposited using solution growth technique. The films are grown at different concentrations of 0.1, 0.2, 03, 0.4 and 0.5mol respectively. The films are grown at two different temperatures 300k and 333k. the substrates were clip vertical on the reaction bath containing $AlCl_3$, $NiCl_2.6H_2O$, $CS(NH_2)_2$, EDTA and Aqueous ammonia in each. The films were deposited for two different dip times 24hours and 2hours. The films grown were washed with distilled water and dried in air. The reaction bath contained 16mls of 0.1m of $AlCl_3$, 16mls of 0.1m of $NiCl_2.6H_2O$, 16mls of 0.1m of EDTA, 16mlls of 0.1m of CS $(NH_2)_2$ and 10mls of aqueous ammonia for concentration of 0.1M. The same procedure and the same volume of solution in mls were used for 0.2m, 0.3m, 0.4m and 0.5m.

The reaction equations were given below

$AlCl_3 + EDTA \qquad [Al(EDTA)]^{3+} + 3Cl^-$

$[Al(EDTA)]^{3+} \qquad Al^{3+} + EDTA$

$NiCl_2.6H_2O + EDTA \qquad [Ni(EDTA)]^{2+} + 2Cl^-$

$[Ni(EDTA)]^{2+} \qquad Ni^{2+} + EDTA$

$AlCl_3 + 3NH_4 \qquad [Al\,(NH_3)_4)]^{3+}\ 3Cl^-$

$[Al\,(NH_3)_4)]^{3+} \qquad Al^{3+} + 3NH_4$

$NiCl_2.6H_2O + 3NH_4 \qquad [Ni(NH_3)_4]^{2+} + 2Cl^-$

$[Ni(NH_3)_4]^{2+} \qquad Ni^{2+} + 3NH_4$

$CS(NH_2)_2 + OH^-$ $H_2O + S^{2-}$
$Al^{3+} + Ni^{2+} + S^{2-}$ $Al_{4.5}Ni_7S_3$

After the deposition, 0.l, 0.3 and 0.5Mol of the ternary thin films grown were characterized using a UV-VIS-N12 spectrophotometer. Spectrophotometer was used to measure transmittance of the films. Other optical properties like absorbance and reflectance were calculated.

4. Result

The optical transmittance versus wavelength measurement of the thin films were taken directly the UV-VIS-NIR spectrophotometer. The wavelength measurements range from 190nm-998nm. The optical absorbance and reflectance measurements were calculated using the following equations:

Absorbance, A obtained from the common logarithm of the reciprocal transmittance.

Transmittance,

Where I is the transmitted flux and is the incident flux (Lothion, 1959).

Therefore Absorbance

Reflectance, R = I A T

Figures 1-6 shows the optical transmittance of 0.1, 0.3 and 0.5 Mole versus wavelength measurement of ternary thin films grown at 300k and 333k.

Figure 1 shows the plot optical transmittance of 0.1, 0.3 and 0.5Mol $Al_{4.5}Ni_7S_3$ grow at 333k increased to about 90%, decreased to about 80% at 190nm, decrease to maximum value of 50% at 313nm, increased sharply to about 80% at 400nm.

Figure 2 gives the plot of optical transmittance of 0.1, 0.3 and 0.5Mol grown at 300k for $Al_{4.5}Ni_7S_3$. the film 0.1m increased to about 70% at 190nm, decreased to about 25% at 313nm, increased to about 70% at 400nm, the film grown 0.3m increase to about 75%, decreased to about 50% at 313nm, increased to about 90%, decreased to about 50% at 313nm, increased to about 80% at 400nm.

Figure 3: shows the optical reflectance of the same concentration versus wavelength measurement of the films grown at 333k while figure 4 gives the optical reflectance of the same concentration versus wavelength of the ternary thin films grown at 300k. Figure 5 shows the graph of the optical absorbance of the same concentration versus wavelength of the same films grown at 333k whereas figure 6 shows the graph of optical absorbance versus wavelength measurement growth at 300k. The result of the optical characteristics considered in figures 1-6 indicates that there is no transmittance in UV region but moderate

in visible and infrared regions while the optical reflectance. The films can suitably be applied in solar cells, photo-thermal solar energy devices and also could be used to transmit solar radiation into building, theses films can be used to anti-reflecting solar radiation. Since these films could be applied in photothermal solar energy devices, they could reduce the reflection off solar energy at the air-glass interface thereby causing enough transmission of solar radiation into the device.

The variation observed from the six graphs may be due to the variation in concentrations and infinities from the surrounding in which the experiment is done.

Fig. 1: Transmittance(%) vs. wavelength(nm) for $Al_{4.5}Ni_7S_3$ thin films at 60°C (333K)

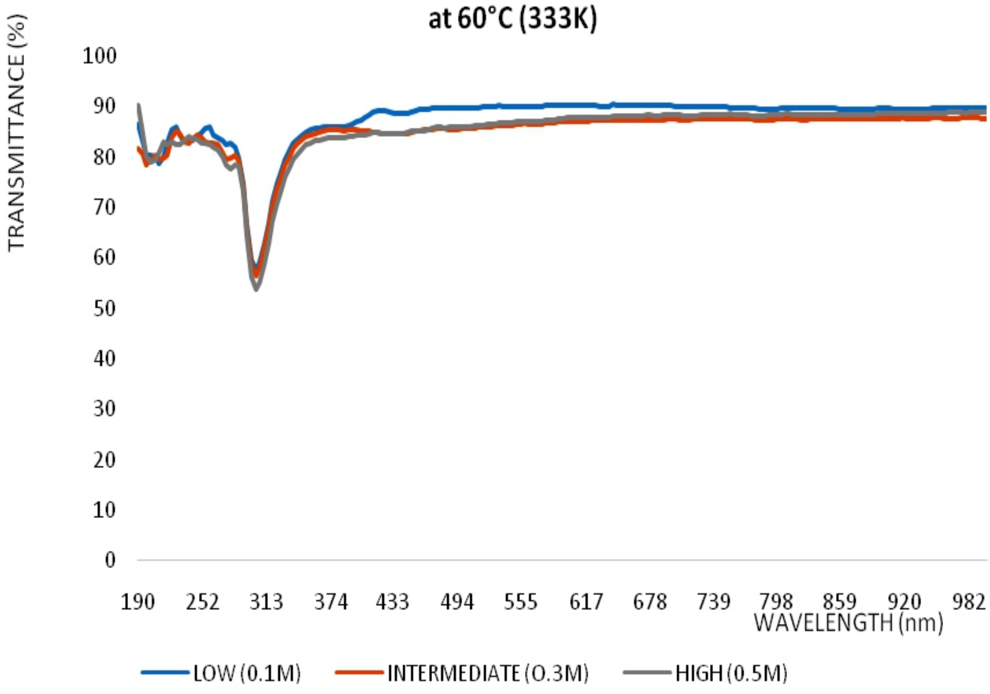


Fig. 2: Transmittance(%) vs. wavelength(nm) for $Al_{4.5}Ni_7S_3$ thin films at room temperature (27°C/300K)

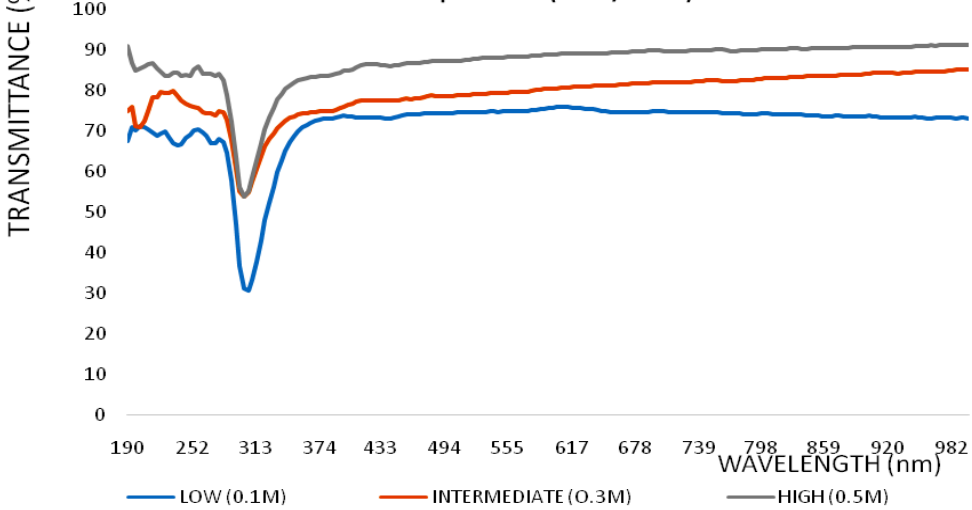
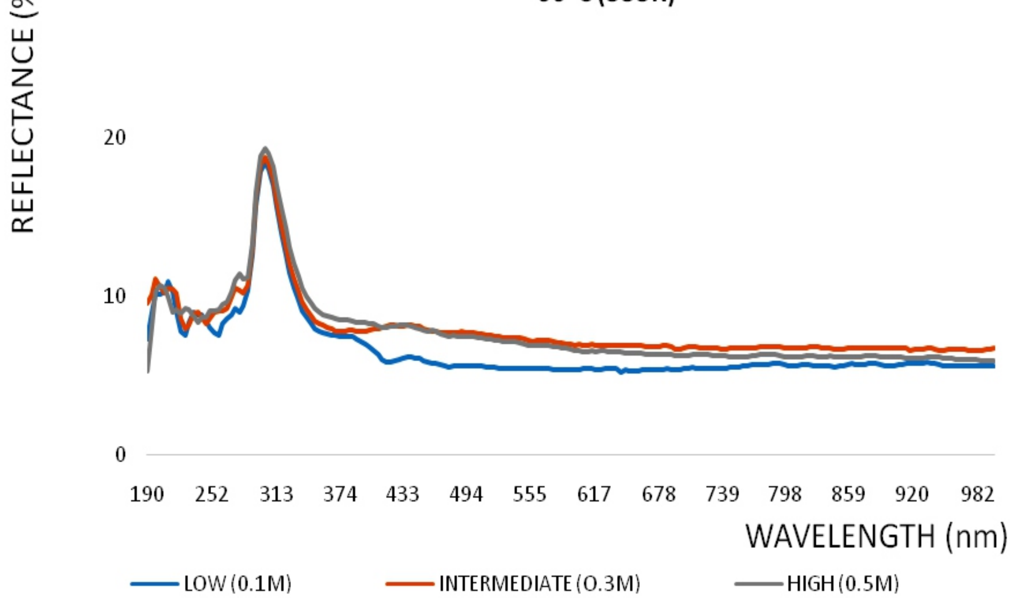


Fig. 5: Reflectance(%) vs. wavelength(nm) for $Al_{4.5}Ni_7S_3$ thin films at 60°C (333K)



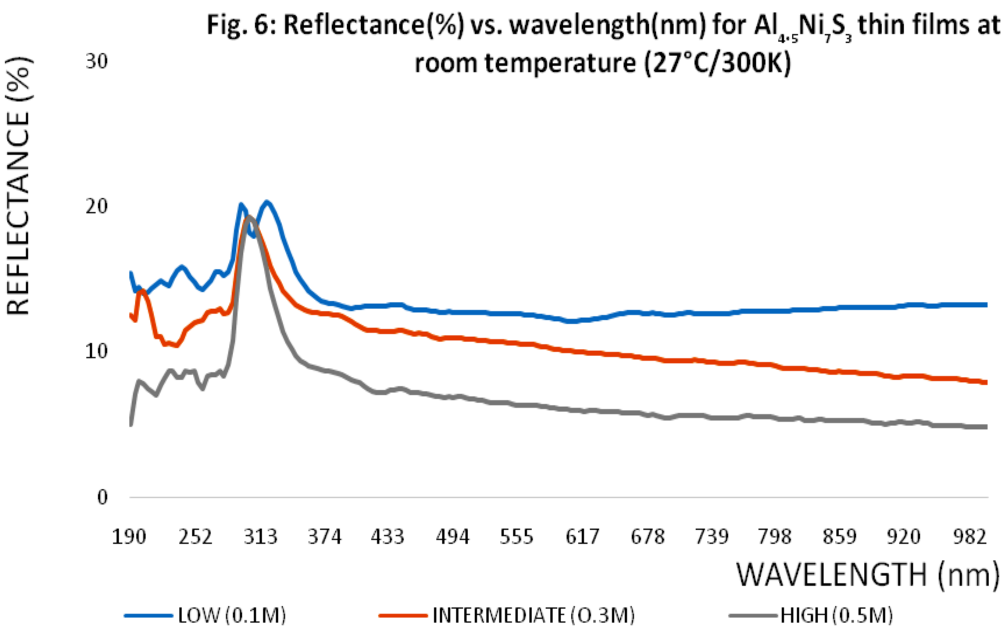


Fig. 6: Reflectance(%) vs. wavelength(nm) for Al4.5Ni7S3 thin films at room temperature (27°C/300K)
REFLECTANCE (%)
30
20
10
0
190
252
313
374
433
494
555
617
678
739
798
859
920
982
WAVELENGTH (nm)
LOW (0.1M)
INTERMEDIATE (0.3M)
HIGH (0.5M)

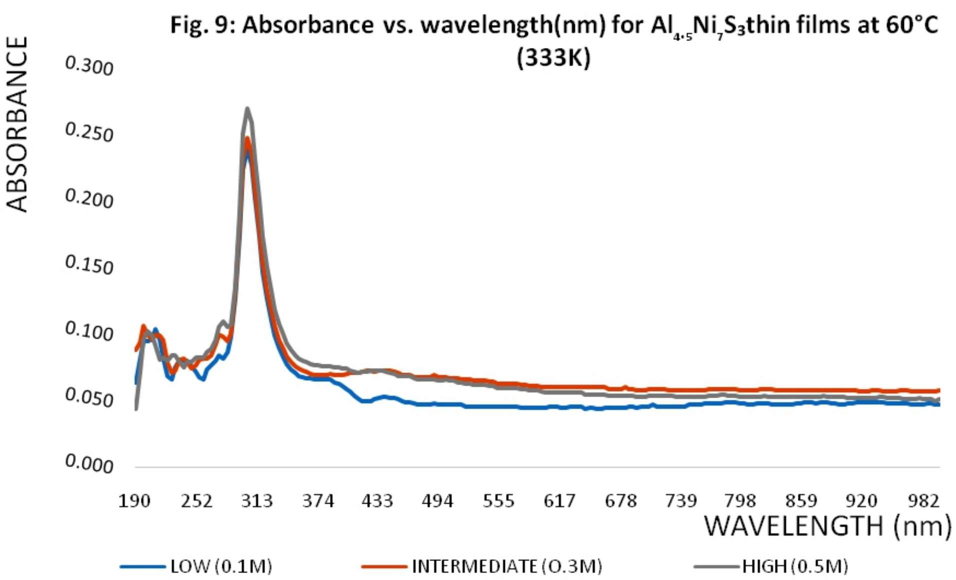
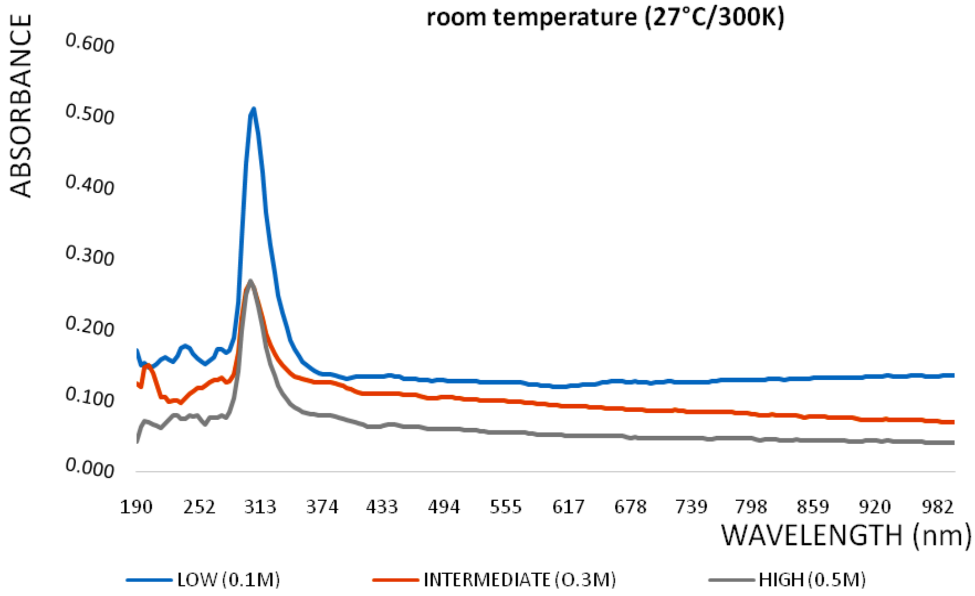


Fig. 9: Absorbance vs. wavelength(nm) for Al4.5Ni7S3thin films at 60°C (333K)
ABSORBANCE
0.300
0.250
0.200
0.150
0.100
0.050
0.000
190
252
313
374
433
494
555
617
678
739
798
859
920
982
WAVELENGTH (nm)
LOW (0.1M)
INTERMEDIATE (0.3M)
HIGH (0.5M)

Fig. 10: Absorbance vs. wavelength(nm) for $Al_{4.5}Ni_7S_3$ thin films at room temperature (27°C/300K)



5. DISCUSSION

The graphs of optical transmittance reflectance and absorbance versus wavelength presented in figures 1-6 above are discussed below.

The plot figure 1 shows optical transmittance of 0.1, 0.3 and 0.5mol $Al_{4.5}Ni_7S_3$ grow at 333k increased to about 90%, decreased to about 80% at 190nm, decrease to maximum value of 50% at 313nm, increased sharply to about 80% at 400nm.

Figure 2: Shows the plot of optical transmittance of 0.1, 0.3 and 0.5mol grown at 300k for $Al_{4.5}Ni_7S_3$. the film 0.1m increased to about 70% at 190nm, decreased to about 25% at 313nm, increased to about 70% at 400nm, the film grown 0.3m increase to about 75%, decreased to about 50% at 313nm, increased to about 90%, decreased to about 50% at 313nm, increased to about 80% at 400nm.

Figures 3 and 4 give the plots of optical reflectance of 0.1, 0.3, and 0.5Mol grown at 333K and 300K. The optical reflectance increased to about 12% at 200nm, decreased to about 8% at 230nm and then increased to the maximum values of about 19% at 313nm for $Al_{4.5}Ni_7S_3$ grow at 333k while the optical reflectance grown 0.5m increase to about 8% at 200nm, decreased to about 7% at 220nm and the to the maximum value of about 18% at 313nm. The film grown 0.3 increased to about 14% at 210nm, decreased to about 11% at 225nm, increased again to the maximum value of about ---- at 313nm for $Al_{4.5}Ni_7S_3$ grown at 300k.

Figures 5 and 6 show the plots of optical absorbance of 0.1, 0.3, 0.5Mol ternary thin films grown at 333K and 300K. The optical absorbance of $Al_{4.5}Ni_7S_3$ thin film grown 0.1, 0.3, 0.5mol increased to about 0.1 at 215nm, decreased about 0.06 at 252nm. The film grown 0.5m increased to about 0.28 at 313nm, 0.3m increased to about 0.25 and 0.1 increased to about 0.23 at the same wavelengths for the films grown at 333k while for the films grown300k, 0.1m increased to about 0.52 at 313nm, 0.3m and 0.5m increased to about 0.28 at the same wavelength value.

6. Implications and Conclusion

6.1 Implications

The implications considered on this paper are as follows:

The deposition parameters like temperature concentrations, pH value and time for which the films are considered very well. There is non-availability of the proposed equipments for carrying out the characterization of the thin films grown in the entire south eastern region of Nigeria. This enabled the researchers to look for universities and nano-material centres at the northern regions, where the films grown were characterized.

6.2 Conclusion

New ternary thin films of aluminum nickel. Sulphide was grown using solution growth technique and characterized with a UV-VIS-VIR spectrophotometer at the wavelength range of 190nm-998nm. It can be agreed from the results that the ternary thin films have the properties of screening off UV portion of the electromagnetic radiation by absorbing and reflecting and admittance of the visible and infrared radiation by transmission.

These properties confirm that the films are suitable materials for solar cells fabrication, solar thermal conversion, anti-reflecting coating, eye glasses coating and coating poultry houses.

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