Fabrication and Characterization of High Efficiency Solar Cell Thin Films (CdNiS).

I.E. Ottih[1*] and A.J. Ekpunobi[2]

[1]Department of Industrial Physics, Anambra State University, Uli, Nigeria.
[2]Department of Physics and Industrial Physics, Nnamdi Azikiwe University, Awka, Nigeria.

E-mail: ifyottih@yahoo.com

ABSTRACT

Chemical bath deposited cadmium nickel sulfide (CdNiS) thin films on glass slides were studied for optical properties. This analysis was done using a Janway 6405 UV-VIS spectro-photometer. The optical characterizations show that the films have low reflectance values across the UV, VIS-NIR regions of the electromagnetic spectrum. This makes the films suitable for antireflection coatings which are employed in the flat plates of solar cell collector. The loss of incident solar radiation due to reflection is highly reduced with this film; hence the solar cell efficiency is increased.

Other industrial and solar applications were found from the analysis. Such applications are thin films for solar control coating, thin films for warming coatings, and thin films used as solar absorbers for a solar cell. The films deposited were also characterized using x-ray mini diffractometer MD_{10}, version 2.00. From the XRD results, the film structure was found to be hexagonal and a grain size of 0.30µm was obtained. Micrographs of the deposited films were taken using an Olympus Optical Microscope.

(Keywords: chemical bath deposition technique, cadmium nickel sulfide, antireflection coatings, warming, solar control coatings)

INTRODUCTION

Energy is the life-blood of every human activity. Modern civilization cannot exist without high levels of energy. Energy provides for things essential to our well being such as food, shelter, heat, communication, transport, medical care, and so on. As a result of these huge needs, many energy resources have been depleted at an alarming rate.

The global energy crisis was initiated when energy from coal, petroleum and natural gas sources were rapidly depleted and could no longer be counted upon to sustain the world's energy needs [1]. Consequently, attention has been focused on alternative sources of energy which cannot be depleted; namely, solar energy.

The challenge for many energy researchers is to grow the best thin films for the fabrication of high efficiency solar cell semiconductors. The development of these materials will minimize the global problem from the energy crisis by producing an in-exhaustible energy supply at low cost. The developmental effort has resulted to the synthesis and characterization of CdNiS thin films. These films were found from analysis to possess favorable properties for solar and industrial applications. Such applications are films for antireflection coating in the solar collector plates [2, 3], solar control coatings, and warming coatings as well as films for solar absorber layer o f a solar cell. This is possible because of the film high band gap value [4].

Coatings for solar and industrial applications include the spectrally selective coatings, non-selective and moderately selective coatings. The spectrally selective surfaces are those surfaces whose optical properties such as transmittance, absorbance, reflectance etc. are dependent on wavelength (5-7). Spectral selectivity can be achieved by means of depositing or coating on substrates that are usually opaque, metallic or transparent. Non-selective and moderately selective coatings include the painted coatings. In selective solar absorbers, the solar radiation is absorbed while the thermal re-radiation is prevented [8].

The process of thin film deposition involves the deposition of material by the atom–by–atom, molecule–by–molecule, and ion–by-ion or cluster of species-by-cluster of species condensation [9]. Thin films deposited by chemical bath deposition techniques have the advantages of being low cost and applicable to the production of large area of devices [10, 11]. The effect of varying parameter such as deposition time on the optical properties of CdS has been reported [12].

EXPERIMENTAL DETAILS

In preparation of the cadmium nickel sulfide thin films, the reaction baths were composed of 10mls of 1.0M of cadmium chloride solution, 10mls of 1.0M of nickel chloride solution, 10mls of 1.0m of thiourea solution (which was the source of sulfide) and 10mls of 14.0M of ammonia solution which acts as the complexing agent as well as the pH regulator.

The parameter varied was the length of deposition time. Five depositions were made by five different deposition times; 8 hours, 9 hours, 10 hours, 12 hours, and 24 hours. For each growth, the mixture was stirred thoroughly using glass rod at each stage to obtain homogenous solution into a 100 ml beaker. Each reaction bath was made up to 90 ml with distilled water.

Glass slides used as substrates for film growth were previously degreased in hydrochloric acid for 24 hours, washed with distilled water and dried in air. They were then inserted and suspended vertically from synthetic foam which covers the beakers containing the solution. After each length of deposition, listed, the slides were withdrawn, rinsed and dried in air.

The thin films grown were characterized for absorbance, transmittance and reflectance using a Janway 6405 UV-VIS spectrophotometer. From the values obtained other properties such as film thickness, band gap, absorption coefficient squared, refractive index and optical conductivity of the films were determined. An x-ray diffraction of the film was done with x-ray mini diffractometer MD_{10} version 2.00.

Theoretical Calculations

The following formulae were employed in our calculations:

Transmittance $T = 10^{-A}$ **(1)**

Where T is the transmittance and A is the absorbance which is determined directly from absorption spectra measurement,

Reflectance $R = 1- (A+T)$ **(2)**

Where R is the reflectance, A and T are absorbance and transmittance, respectively.

Thickness $t = \frac{\ln T}{\alpha}$ **(3)**

Where t is the film thickness and T is the transmittance, α is the absorption coefficient.

Absorption coefficient $\alpha = \frac{K \times 4\Pi}{\lambda}$ **(4)**

Where K is the extinction coefficient and λ is the wavelength of incident radiation [13]. From Equation 4 above, K can be determined.

Optical Conductivity $\sigma o \rho = \frac{\alpha n c}{4\Pi}$ **(5)**

Where n is the refractive index and c is the velocity of light.

Refractive index $n = \frac{1+ R^{1/2}}{1 - R^{1/2}}$ **(6)**

Where R is the reflectance [14].

RESULTS AND DISCUSSION

Figure 1 is the spectral transmittance of CdNiS thin film grown in this work at a room temperature of 300K. A close observation of the plots reveals that the transmittance value of CdNiS thin films increases as the deposition time increases. It is also noted that the transmittance values of the film is very low at the UV region. Films of moderate transmittance values at VIS and NIR region such as film on slide G_5 is used to coat window for warmth. This is because such films allow moderate percentage of the VIS and IR radiations to pass through and heat the inside surface. This is useful for those living in the cold regions of the world and in materials for construction of poultry houses.

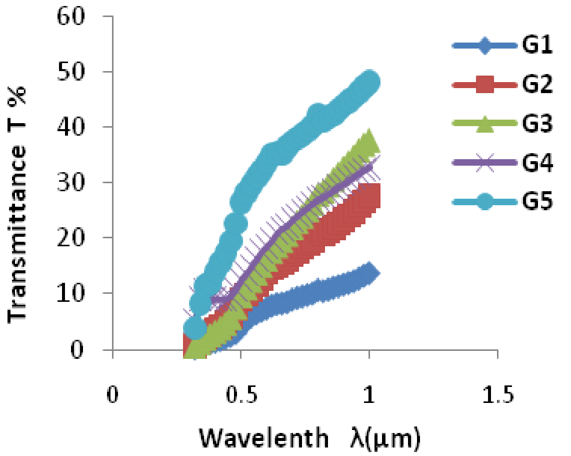


Figure 1: A Plot of Spectral Transmittance of CdNiS Thin Film (Slide G_1-G_5).

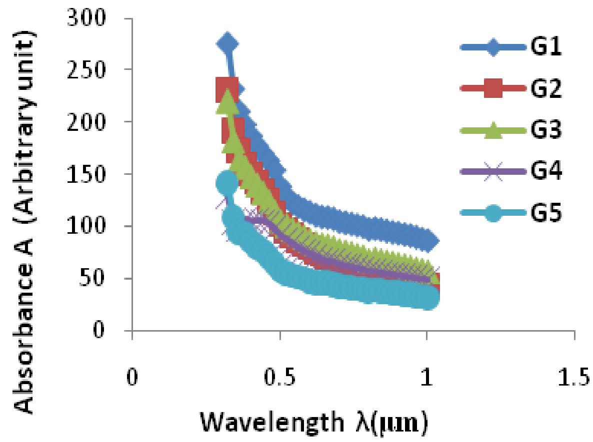


Figure 2: A Plot of Absorbance (A) versus Wavelength for CdNiS Thin Film (Slide G_1-G_5).

The spectral absorbance of CdNiS is shown in Figure 2. The figures indicate that the film has high absorbance in the UV region. It further reveals that thin film grown for the shortest deposition time of 9 hours has the highest absorbance value in the UV region. This is shown by the film on slide G_1. Film on slide G_5 which was grown with the highest deposition time of 24 hours has the least absorbance value. This implies that the shorter the deposition time, the higher the absorbance value. Thin films of high absorbance values at the UV region such as films on slide G_1 are suitable for coating in windows for those living in the temperate regions of the world like Nigeria. This is because much of the harmful ultraviolet radiation will be absorbed by the films and inside will be cool. This film acts like the convectional air-conditioner used by people.

Figure 3 is the spectral reflectance of the CdNiS thin film grown in this work. A close observation indicates that the reflectance values of the films are generally low at the UV, VIS-NIR regions irrespective of the length of deposition of the films. However, it is also noted that the film grown with longest period of time such as film on slide G_5 has the least value of reflectance. This implies that the longer the deposition time the smaller the reflectance value. Films of low reflectance values such as films on slide G5 is used to coat the solar collector flat plates of a solar cell. This reduces the loss of incident solar radiation due to reflection process. As a result, the efficiency of a solar cell made with this film is high.

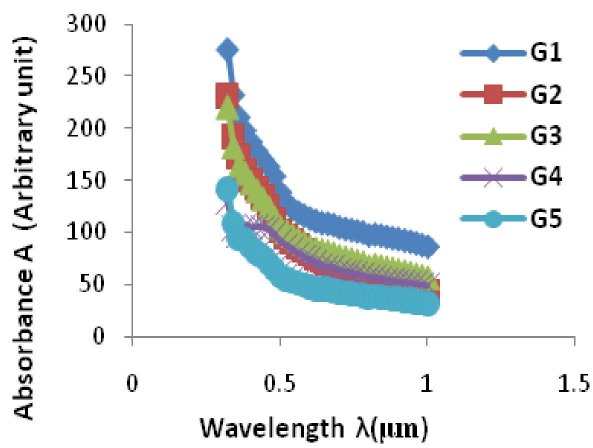


Figure 3: A Plot of Reflectance (R) as a function of Wavelength for CdNiS Thin Film (Slide G_1-G_5).

Figure 4 shows the plots of thickness as a function of deposition time. The figure indicates that thickness increases linearly with the deposition time. From the graph, a peak value of 0.97µm was obtained when deposition was made for 24 hours.

The plot of average values of absorption coefficient squared (α^2) versus the photon energy (hv) is displayed in Figure 5. From the plot, the band gap energy of 3.2eV was obtained. This is determined by extrapolating the straight part of the graph to a point where α^2=0. This implies that the film has a high band gap energy greater than the band gap of CdS thin 2.49eV [12].

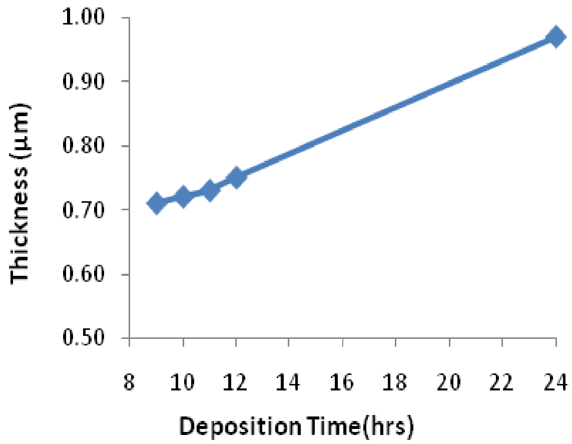


Figure 4: A Plot of Thickness as a function of Deposition Time in Hours for CdNiS Thin Film (Slide G_1-G_5).

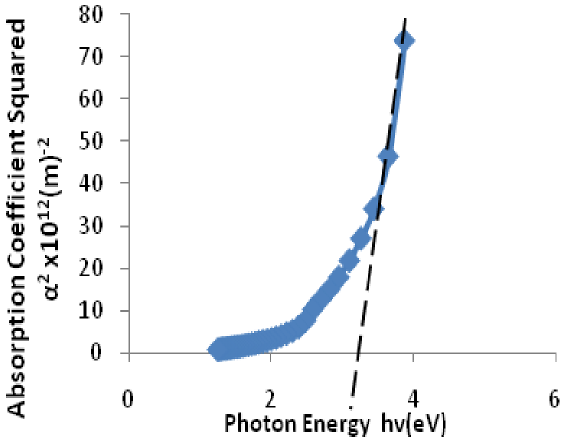


Figure 5: A Plot of Average Values of Adsorption Coefficient Squared versus Photon Energy for CdNiS Thin Film (Slide G_1-G_5).

The increase in the band gap is attributed to the introduction of transition element Ni to the CdS semiconductor. Thin films of large band gap such as CdNiS thin film is used in absorber layer of a solar cell.

The plot of refractive index as a function of photon energy is shown in Figure 6. A close observation of the plot reveals that thin film grown for the highest deposition time such as film on slide G5 has the least value of refractive index. The implication of this is that the longer the deposition time, the lower the refractive index. Films of low refractive index are used together with other suitable thin films to coat the solar cell collector plates.

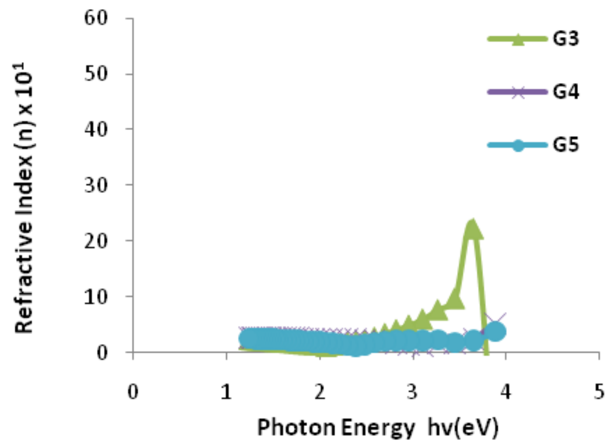
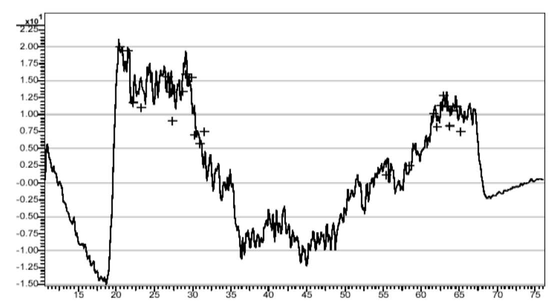


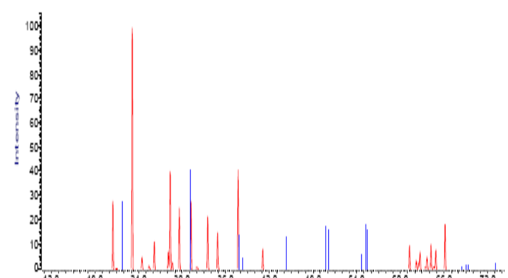
Figure 6: A Plot of Refractive Index as a Function of Photon energy for CdNiS Thin Film (Slide G_3-G_5).

Figures 7 and 8 are the x-ray diffraction spectra and the optical micrograph of CdNiS thin film.



7a

MD-10.4/19/10
ExposureTime:1200/1200sec.
Radiation:CuKa,avgSample:G_4Operator:EMDI
AkureFile:Ottih_G_4.smd



Card # 44-1418 - Cadmium Nickel Sulfide; Heazlewoodite. Formula: Cd Ni3 S2

7b

Figure 7: X-ray Diffraction Spectra for CdNiS Thin Film (Slide G_4).

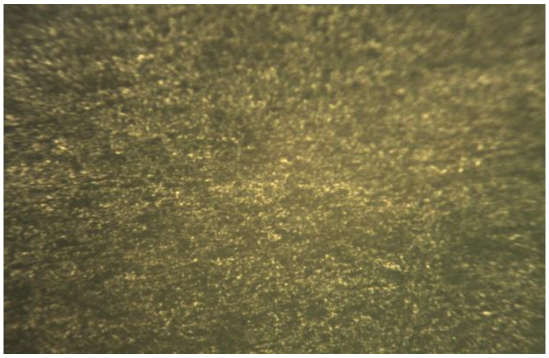


Figure 8: Micrograph of CdNiS thin film ($Slide\ G_3$).

From the XRD results, the grown CdNiS thin film has a hexagonal structure. The lattice constant (a) of 5.8321Å was obtained for the film in the {101} plane at a maximum intensity of 2θ = 28.183 using Bragg's Law given by n = 2dsinθ. This value of lattice constant for CdNiS thin film is slightly higher than the value of (a) for CdS semiconductor thin film of 5.6954Å which was reported [10]. From the optical micrograph, the grain size of CdNiS was found to be 0.30μm.

CONCLUSIONS

CdNiS thin films have been successfully deposited unto glass slides using solution growth technique; the optical studies showed that the film has low reflectance value across the electromagnetic spectra of UV, VIS-NIR regions. This makes the film suitable for coating as an anti-reflection thin film. Again, CdNiS thin film has a low transmittance at UV region and moderate at VIS-NIR regions. This property makes the film suitable for warming coating since much ir heat is allowed to transmit inside the surface. This is important for those living in the cold parts of the world. The film thickness was found to be of range 0.3μm - 1.0μm. The band gap energy was determined to be 3.30eV. This high band gap property of the film makes it suitable for absorber film.

REFERENCES

1. Hayes, D. 1978. "The Solar Energy Time Table". *World Watch Paper*. 4, 2-5.
2. Theye, M. 1983. *Optical Properties of Thin Film*. Butterworth's and Co.: London, UK. 255.
3. Chopra, K.L. and Malhotra, L.K. 1985. *Thin Film Technology and Applications*. Tata McGraw Hill: New Delhi, India. 3, 237-249.
4. Ezema, F.I. 2009. "Effect of Deposition Time on the Band Gap and Optical Properties of Chemical Bath Deposited CdNiS Thin Films". *Optoelectronics and Advanced Material Rapid Communications*. 3 (2):141-144.
5. Agnihotri, O.P. and Gupta, B.K. 1981. *Solar Selective Surface*. John Wiley and Sons: New York, NY. 6:80-110.
6. Chandra, S., Pandey, R.K., and Agarwal. 1980. *Journal of. Appl. Physics*. 13:370-375.
7. Chopra, K.L. and Kaur, I. 1993. *Thin Film Device Applications*. Plenum Press: New York, NY. 385.
8. Hollas, J.M. 1992. *Modern Spectroscopy, 2nd Edition*. John Willey and Sons: New York, NY. 4, 61-62.
9. Nair, P.K. and Nasir, M.T.S. 1992. *Semi-conductor Science Technology.* 7, 239-261.
10. Sze, S.M. 1979. *Physics of Semiconductor Devices*. John Wiley and Sons: New York, NY. 512.
11. Ezenwa, I.A. 2009. "Growth and Characterization of Sulphide Semiconductor Compounds and Supperlattices". Ph.D. Thesis. Nnamdi Azikiwe University, Awka.
12. Pankove, J.J. 1971. *Optical Procession in Semiconductor*. Prentice-Hall: New York, NY. 47-119.
13. Robinson, T.S. 1982. *Thin Films Processes*. Soc. Pub.: London, UK. 65, 910.

SUGGESTED CITATION

Ottih, I.E. and A.J. Ekpunobi. 2011. "Fabrication and Characterization of High Efficiency Solar Cell Thin Films (CdNiS)". *Pacific Journal of Science and Technology*. 12(1): 351-355.

Pacific Journal of Science and Technology