Journal of the Nigerian Association of Mathematical Physics
Volume **17 (November, 2010), pp 393 - 398**

Study of Optical, Solid State and Structural Properties of Nickel Sulphide (NiS) Thin Films Deposited using Solution Growth Technique.

D.U. Onah[1], E.I. Ugwu[1] and [2]S.M. Idenyi.
[1]Department of Industrial Physics,
Ebonyi State University, Abakaliki.
[2]Department of Geology and Exploration Geophysics,
Ebonyi State University Abakaliki, Nigeria.

Abstract

Thin films of Nickel sulphide (NiS) were successfully grown by using the solution growth technique which is cost effective and efficient. Nickel chloride ($NiCl_2$), Sodium sulphate ($Na_2S_2O_3$) and Ammonia NH_3 were used. The optical and solid state properties were obtained from the characterisation done at University of Nigeria Nsukka using PYEUNICAM (SPG-450) spectrophotometer. Photomicrographs of the films showed that they are amorphous in structure. The films have 80% (high) transmittance in the visible/NIR regions of em-spectrum. The band gaps of the films determined when absorption coefficient is zero, ranges from $2.4eV$ to $2.8eV$. These films can be used as window materials for solar cells

Keywords: Thin films, Nickel sulphide and solution growth.

Introduction

Solution growth technique has become an established technique for producing thin films of a wide range of materials with many applications. A liquid or solid such that one of its linear dimensions is very small in comparison with the other two dimensions is known as a thin film [1]. A thin film is also defined as a layer of material which is less than 1000nm. [2]. Formation processes of thin films are always of great interest because they reveal the mechanisms involved in any special structural properties of the films. There are several methods of depositing thin films such as physical techniques, thermal evaporation, epitaxial growth, sputtering and chemical vapour deposition etc. The basic themes considered in choosing a particular method may include flux of atoms or molecules to the surface of the substrate, the energies of the incoming species on the substrate and organizational influences present at the substrates.

Solution technique which is also known as the chemical bath deposition (CBD) technique was developed in 1946 [3]. It can be used to deposit both conducting and non-conducting layers from a solution by electrochemical processes, without the presence of an externally applied field. The metallic ions and non-metallic ions in the deposition solution always react with each other and produce neutral atoms, which condense on suitable substrates. The technique is simple, cost effective and it produces highly uniform films of the same composition and thickness [4]. Films produced by this method have comparable structural and photoelectric properties to those produced using other techniques [5].

In this work we get out to study the optical and solid state properties of NiS thin films deposited using solution growth technique, in order to identify the possible area of applications of these films.

Experimental and Theoretical Procedure:

[1]Corresponding author: E-mail; d_onah@yahoo.co.uk. Tel. +2348051060257

Nickel sulphide (NiS) thin films were deposited on $76.2mm \times 25.mm \times 1mm$ glass slides using the solution growth technique. The glass substrates were thoroughly cleaned by soaking them in concentrated HCl for three days for proper degreasing. After this, they were washed with detergent, rinsed in distilled water and dried in oven. The reaction bath was composed of $5ml\ of\ 1M\ of\ Nickel$ chloride, which was the cation source, $1ml\ of\ NH_3$ which provided the alkaline medium for the reactions, and 5ml of $1M$of $Na_2S_2O_3$ (sodium thiosulphate) which was the complexing agent. The bath solution was well stirred with magnetic stirrer, for 10 minutes and the prepared glass substances were immersed vertically in the bath for various dip times. It was observed that $Na_2S_2O_3$ enhanced the rate of reduction reaction of the Nickel ion and provided a buffering effect.

The composition of the films and their characterisation were obtained by using the PYEUNICAM (SP6-450) spectrophotometer at Medicinal Plant Research Unit, Department of Pharmacology and Toxicology, University of Nigeria, Nsukka. The absorbance, transmittance and reflectance at normal incidence of the radiation from 200nm to 1000nm were considered. The range included ultraviolet, visible and near infrared regions.

The electronic band structure of the thin film has influence on the dielectric function, refractive index, n and extension co-efficient k, these are mathematically related as

$$\varepsilon = n^2 - k - 2ni\,k \qquad (1)$$

This equation which comprises both complex ε_i and real ε_r parts respectively

$$\varepsilon_r = n^2 - k^2 \qquad (2)$$

$$\varepsilon_i = 2nk \quad [10] \qquad (3)$$

These solid state properties have role to play in radiation behavior as it propagates through the thin film material.

The band gap of the film related to the absorption coefficient and the radiation wavelength which is given as

$$\propto^2 = \left[\frac{hc}{\lambda} - E_g\right] \qquad (4)$$

(Hass et al 1982 Chopra 1983) on the other hands, the photon transmission and absorbance can be obtained by

$$I = I_O\ exp^{\propto z} \quad [9] \qquad (5)$$

$I =$ intensity of the radiation at any instant while I_O is the maximum intensity, $\propto$ is the absorption co-efficient, and z is the film thickness.

Results and Discussion:

Fig. 1 Depicts zero absorbance at $200nm$ with irregular behavior absorbance between 200 to 290nm at about 350nm the absorbance experiences peak value of 0.75 and decreased sharply to 0.2 at 380nm. Within 400nm to 1000nm, the absorbance decreases from 0.18 to 0.04.

As in fig. 2, the transmittance 100% within 200nm and 300nm after which it rose again from 60% to about 90% within 400nm to 1000nm.

The % reflectance shows the same behavior as observed in that of fig. 1.

Fig 4 depicts the absorption co-efficient as a function of photon energy which is extrapolated to meet the photon energy at $2.95eV$ when α is zero to render $(\alpha h\nu)^2$ zero to give the energy band gap of the film. The maximum extension co-efficient is obtained when the photon energy is $4.0eV$ as in fig. 6. While the refractive index ranges between 1.2 and 2.25. The real and complex dielectric constants are 5.2 and 125×10^{-3} as shown in figures 7 and 8 respectively, while the optical conductivity has a peak at 0.6.

The films were found to be good for antireflection coatings as it has a low value of refractive index (Born and Wolf, 1980) while the Value of energy hand gaps revealed that the films could be good as window materials for photovoltaic applications, since the range of band gaps for films that can be used for solar cells is $1.5eV\ to\ 3.0eV$ $[Cox, 1978\ and\ Blatt, 1983]$

The trend of Fig. 3 and fig. 4 show that the films have low absorbance within the optical and near infrared regions and a high transmittance within the same range. Fig. 7 indicates that refractive indices of the films increased linearly with increasing wavelengths and showed anomalous behaviour at higher wavelengths. A typical

[1]Corresponding author: E-mail; d_onah@yahoo.co.uk. Tel. +2348051060257

photomicrograph and XDR in Fig.10 and fig.11 showed that the firms deposited were uniform and amorphous not polycrystalline.

Conclusion

Solution growth technique was used in the growth of Nickel sulphide (NiS) thin films using Nickel chloride ($NiCl_2$), sodium sulphate ($Na_2S_2O_3$) and ammonia (NH_3). It was observed that NiS films have high transmittance at higher wavelengths. The relationships between absorbance, Transmittance reflectance and wavelengths respectively were shown in Figs 1,2 and 3 while the variations of absorption coefficient, refractive index, extinction coefficient, real dielectric constant, imaginary dielectric constant optical conductivity with photon energy were shown in Figs 4 to 9. The band gap ranges of the films from 2.4 eV to 2.8 eV suggest that these films could be good for photovoltaic applications, and anti-reflective materials for ultraviolet radiation.

[1]Corresponding author: E-mail; d_onah@yahoo.co.uk. Tel. +2348051060257

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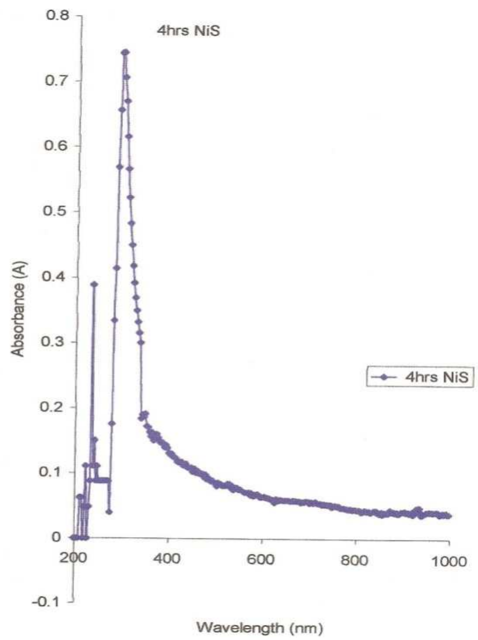

Fig. 1 Absorbance as a function of Wavelength

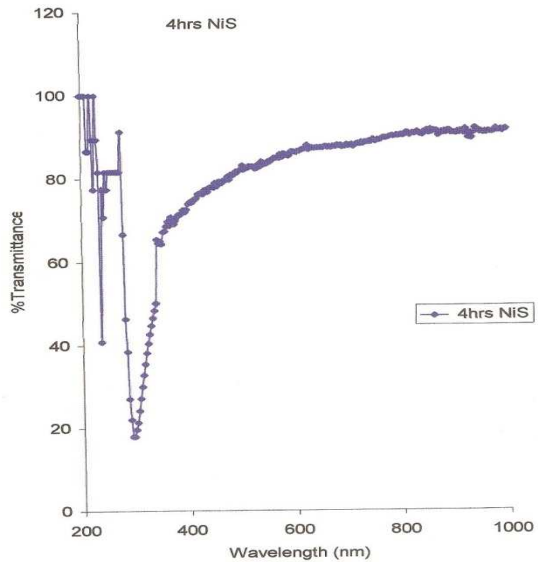

Fig. 2 Percentage Transmittance as a function of Wavelength

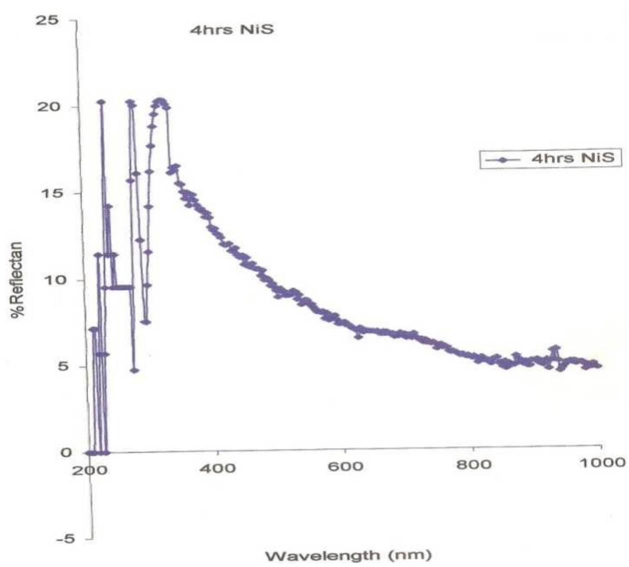

Fig. 3 Percentage Reflectance as a Function Wavelength.

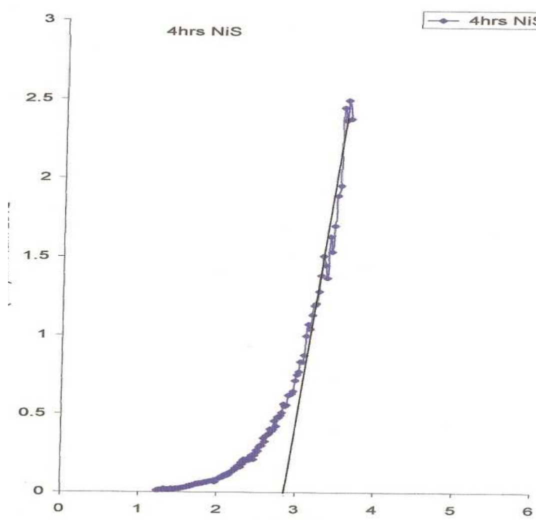

Fig. 4 Absorption Coefficient as a function of Photon Energy

$h\nu(eV)$

[1]Corresponding author: E-mail; d_onah@yahoo.co.uk. Tel. +2348051060257

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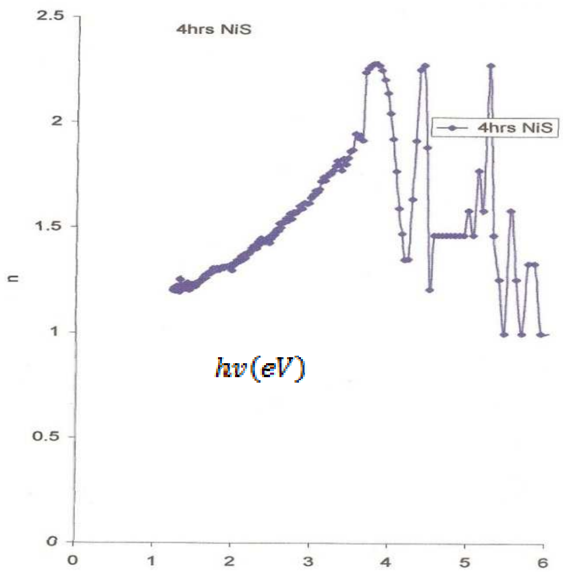


Fig. 5 Refractive Index as a function of Photon Energy

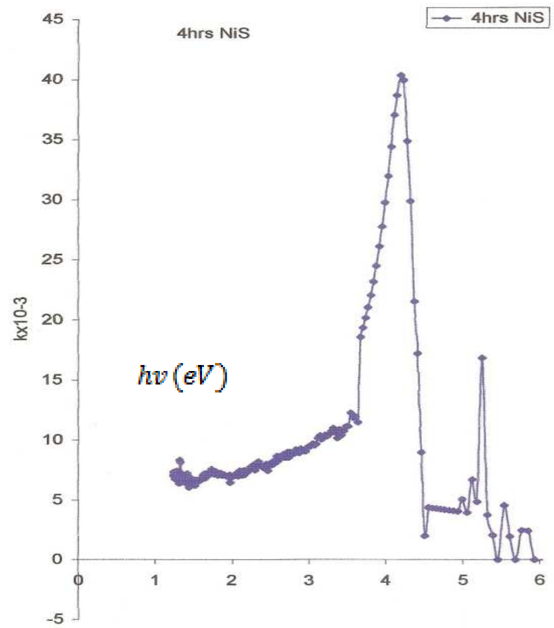
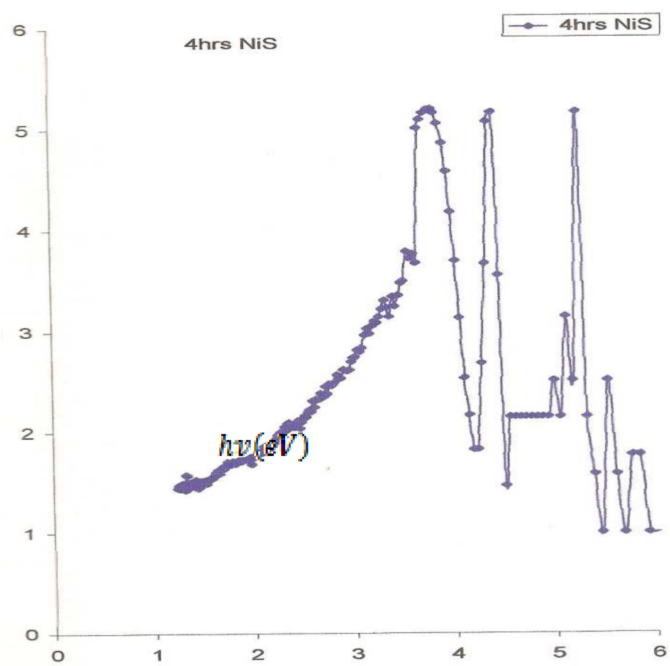


Fig. 6 Extinction Coefficient as a function of Photon



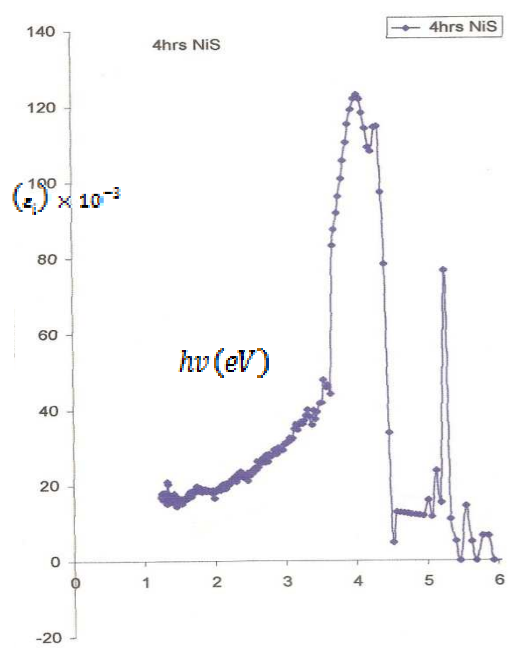


Fig.8 Imaginary Dielectric function of Photon Energy

Fig. 7 Real Dielectric Constant (ε_r) as a Constant (ε_i)as a function of Photon Energy

[1]C Tel. +2348051060…

$\alpha \times 10^{14} S^{-1}$

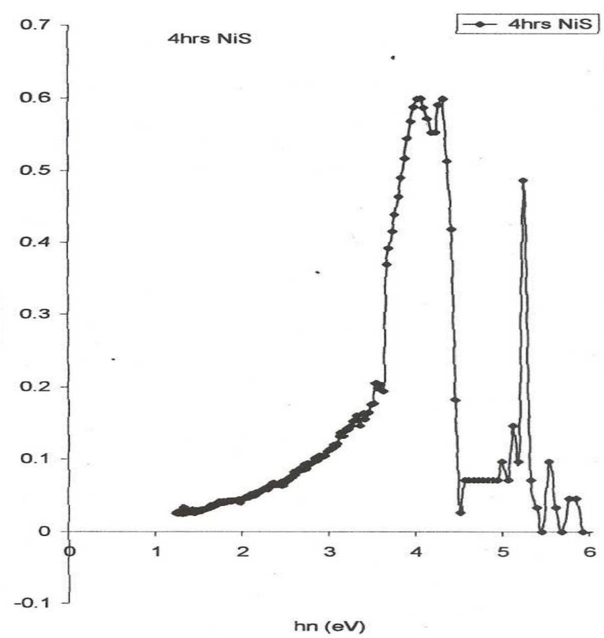


Fig. 9 Optical Conductivity as a function of Photon Energy

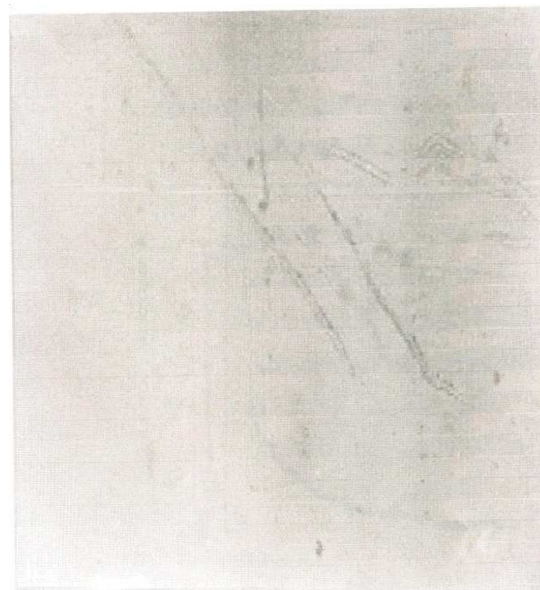


Fig. 10 Photomicrograph of NiS Thin Film.

(ε_{-})

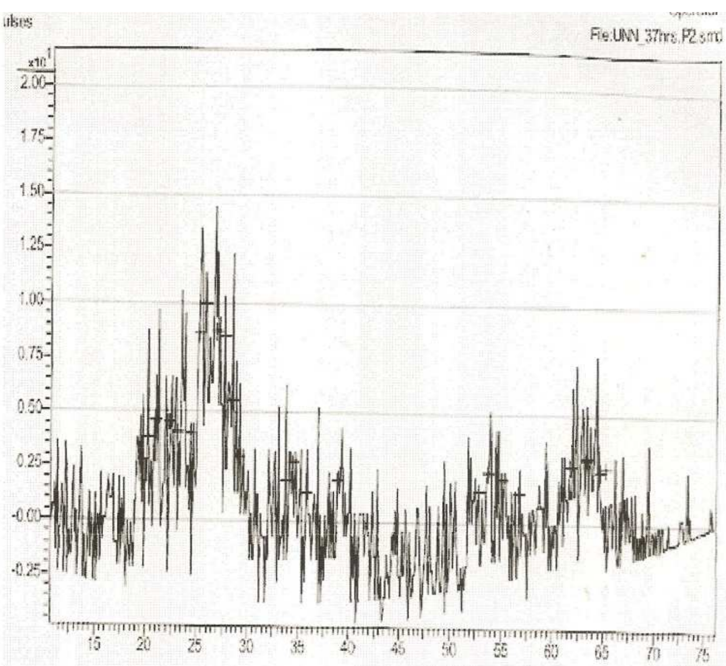


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Fig. 11.XRD for NiS Thin Film

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[1]Corresponding author: E-mail; d_onah@yahoo.co.uk. Tel. +2348051060257

[1]Corresponding author: E-mail; d_onah@yahoo.co.uk. Tel. +2348051060257