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Optical Characterization of Nickel Sulphide Thin Films Prepared by Chemical Bath Deposition Method

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Nickel sulfide thin films were prepared using chemical bath deposition method on a glass substrate. Nickel sulphate and sodium thiosulphate were used as starting chemicals. Ethylenediaminetetra-acetic acid (EDTA), was used as the complexing agent. In this study time was the only parameter optimized to get good quality thin film. Films were characterized using an UV M501 single beam scanning spectrophotometer from a wavelength of 220- 560nm. The nickel sulfide thin films exhibited direct band gap transition with band gap energy 2.3eV. A poor reflectance, moderate absorbance and high transmittance was recorded.

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Keywords: Nickel sulfide [NiS] thin film; chemical bath deposition; Band gap; complexing agent.

1. INTRODUCTION

The cost of photovoltaic (PV) solar cells is being significantly reduced by the development of thin film technology [1]. The optical and electrical uses of the binary compounds have led to a rise in interest in them [2]. Solar selective coatings, solar cells, sensors, photoconductors, infrared detectors, as well as an electrode in a photochemical storage device, are just a few of the devices that use nickel sulfide thin films as semiconductor materials. A variety of methods, including electro deposition, SILAR [3], pulsed laser ablation [4], metal-organic chemical vapor deposition [5], thermal and photochemical chemical vapor deposition can be used for the preparation of nickel sulfide thin film [6], asserted that in chemical bath deposition method, deposition of metal chalcogenide semiconducting thin films occurs due to substrate maintained in contact with dilute chemical bath containing metal and chalcogenions. Due to its simplicity, low cost, low temperature, and possibility for mass manufacturing, the chemical bath deposition process is a desirable option; [7]. Many distinct semiconductor thin films have been successfully deposited using modern chemical bath deposition techniques. By changing the solution pH**,** temperature and bath concentration, growth factors such as film thickness, deposition rate, and crystal quality can be easily controlled. The basic principle involved in the chemical bath deposition method is the controlled precipitation of the desired compound from a solution of its constituents [7]. In this study, nickel sulfide thin film were prepared from aqueous solution of nickel sulphate ($NiSO_4$) and sodium thiosulphate as a source of Ni^{2+} and S^{2-} ions respectively using chemical bath method. EDTA was used as complexing agent. The influence of time, as a major deposition parameter in preparing the thin film was studied. Optical characterization was carried out to determine the bandgap, transmittance, reflectance, absorbance, refractive index and optical conductivity.

2. EXPERIMENTAL METHODS

All solvents and reagents used for the thin films growth includes; Ethylenediaminetetra-acetic acid (EDTA), Ammonium solution (NH_3), Sodium thiosulphate ($Na_2S_2O_3.5H_2O$), Nickelsulphate, and distilled water. Apparatus used include digital meter balance, beakers, stirrer, glass substrate, microscope rack, syringes, masking tape, pen, detergents and hydrochloric acid. 0.1M of each of the reagents were prepared at room temperature. NH_3 is already in a solution form. Other masses of the reagents were obtained using a meter balance. The method used in this research work is the chemical bath deposition technique. In order to avoid spontaneous precipitation of the reaction bath, a suitable complexing agent is added to the reaction bath to control the release of the metallic ion in the solution. Although thin films can be deposited on different kinds, shape and size of substrate [8], a microscope slide was used as the substrate in this work. The procedure on how to clean the substrate is very important in deposition of thin film [9]. The substrate on which the desired compound is to be deposited is immersed in the beaker containing the solution. The glass substrates were suspended into the chemical bath using rack holder to hold the substrate firmly with the tip not touching the bottom of the chemical bath. Dip time was maintained at different hours for each chemical bath. The deposited nickel sulfide thin film was uniform and adhesive. Optical properties were measured using a M 501 UV –VIS spectrophotometer at normal incidence of light in the wavelength ranging from 200 - 560nm.

Table 1. Total volume of all the solution in the chemical bath = 50ml as seen in the table

Solution	Chemical bath 1	Chemical bath 2	Chemical bath 3	Chemical bath 4
$NiS0_4$	5	5	5	5
NH_3	5	5	5	5
EDTA	5	5	5	5
$Na_2S_2O_3.5H_2O$	5	5	5	5
Distilled water	30	30	30	30
Deposition time	24hrs	36hrs	48hrs	60hrs

3. RESULTS AND DISCUSSION

3.1 Wavelength and Absorbance for Four Slides of Time Variation

From the above graph Fig. 1 for variation of time, it can be observed that the thin films have a very low absorbance. This observation of the thin films having a very low absorbance is likely due to their thinness, as the thickness of a material can affect its absorbance properties. Moreover, optical behavior of thin film is determined by the resulting microstructure that depends on deposition parameters such as concentration of substances, deposition time and temperature. Additionally, the materials used in the thin films may have inherently low absorbance in the UV region.

Slide number four; series 4(60hrs) has the highest absorbance 59% in the ultra violet region at 349nm than others. This shows that the thickness of the film on that slide is greater than the thickness of the films on the other slides, resulting in higher absorbance.

3.2 Wavelength and Reflectance for Four Slides of Time Variation

From the above graph Fig. 2 for variation of time it can be observed that the thin film has a very low reflectance. This suggests that the thin film is likely to absorb more light which could have important implications in various applications such as solar cells, optical coatings, and sensors.

But slide number three and four series 3 and 4 has the highest reflectance of 21% than others. This could be due to the difference in the thickness of the thin films on the slides. The high reflectance of series 3 and 4 slides could make them suitable for applications where high reflectance is desirable, such as mirrors, optical filters, and laser cavities.

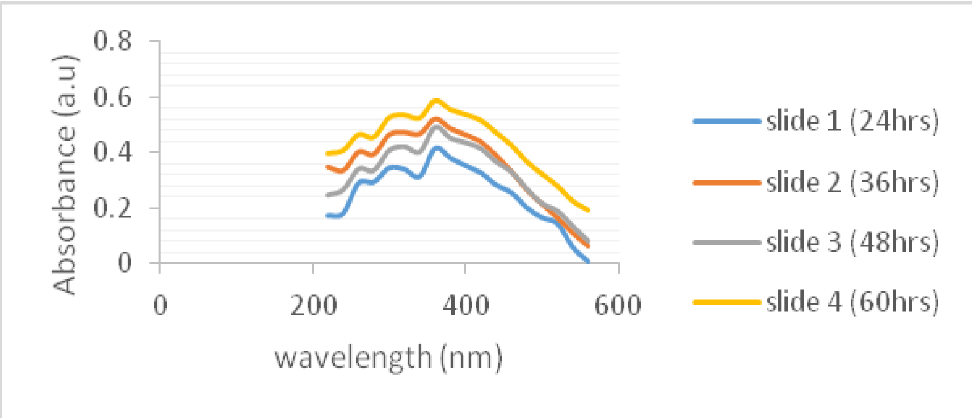

Fig. 1. Plots of absorbance against wavelength for time variation

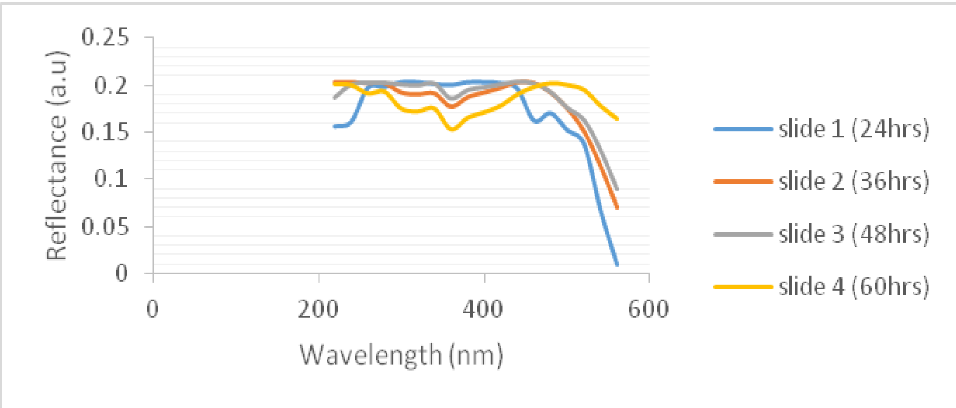

Fig. 2. Plots of reflectance against wavelength for time variation

3.3 Wavelength and Transmittance for Four Slides of Time Variation

From the graph Fig. 3 for variation of time. It was observed that the thin films generally have a higher transmittance. This suggests that the thin film is likely to allow more light to pass through it.

Slide number one; series 1 has the highest transmittance of 99%. Hence it can be used as a good transmitting material that could be serve in various optical applications, such as lenses, windows, and prisms.

3.4 Wavelength and Refractive Index (N) for Four Slides of Time Variation

From the graph Fig. 4, it is observed that the thin film showed high refractive index ranging between 2.4 to 2.7 within the wave length of 250nm to 550nm. Refractive index of a material is inversely proportional to the velocity of light in that material. It is a measure of how light propagates through a material. The higher the refractive index, the slower the light travels which causes an equivalently increased change in the direction of the light within the material. This high refractive index values can be attributed to increase in crystal quality and grain size. High refractive index can restrain the working efficiency and productivity of solar cell [10].

3.5 Photon Energy and Optical Conductivity for Four Slides of Time Variation

From Fig. 5, it is observed that thin films showed a high optical conductivity. Optical conductivity is a measure of the ability of a material to conduct light and is an important property in various optical applications such as solar cells, optoelectronics, and displays.

Furthermore, it can be observed that the thin film deposited at 48 hours has the highest optical conductivity among the samples, which indicates that it is the most effective in conducting light.

This could be due to the fact that the longer deposition time allowed for a more uniform and dense film to be formed, which could enhance the optical properties. It is important to note that the optical conductivity can also be affected by other factors such as the composition, thickness, and doping of the thin films. Therefore, it is crucial to consider these factors when selecting the appropriate material and deposition conditions for a specific application.

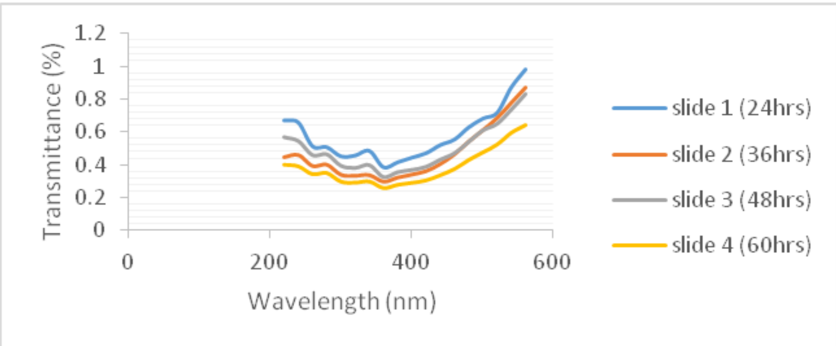

Fig. 3. Plots of transmittance against wavelength for time variation

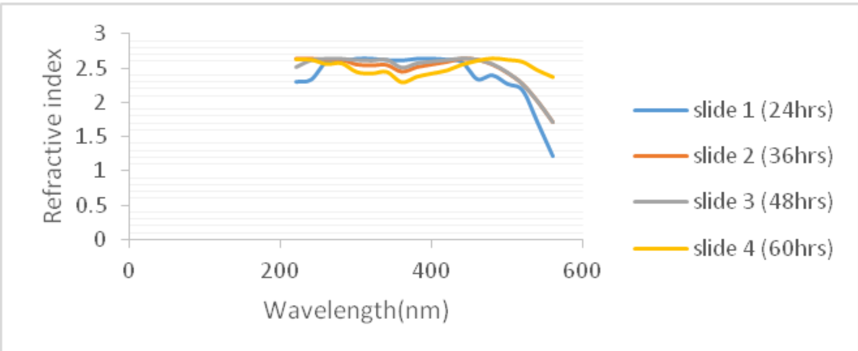

Fig. 4. Plots of refractive index against wavelength for time variation

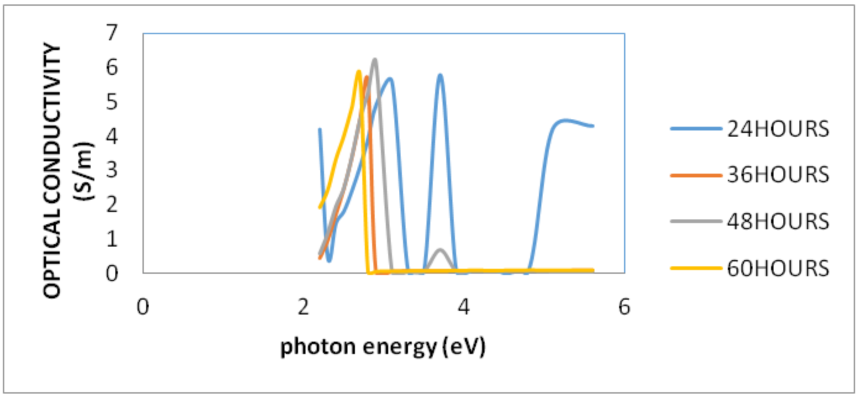

Fig. 5. Plots of optical conductivity against photon energy

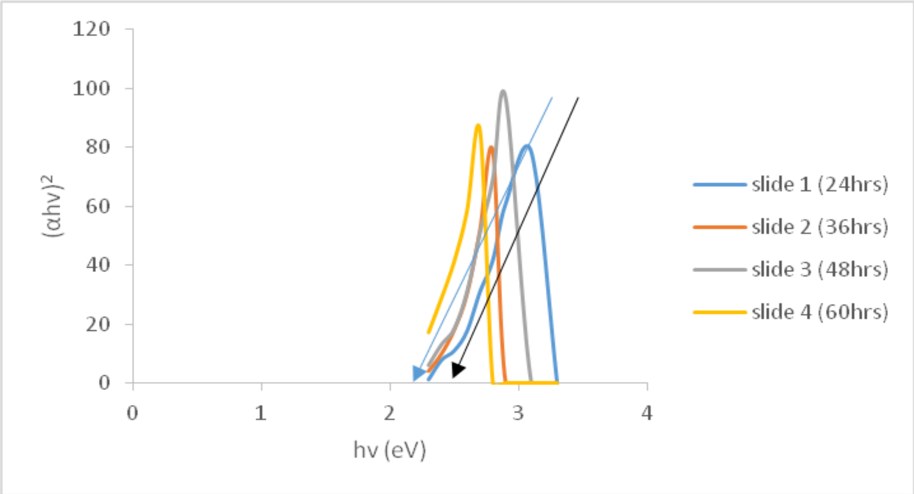

Fig. 6. Plots square of absorption coefficient against photon energy

3.6 Photon Energy and Square of Absorption Coefficient for Four Slides of Time Variation

From the Fig. 6, it can be observed that the value of the band gap energy (energy required to promote a valence electron bound to an atom to become a conduction electron) for nickel sulfide thin films was found to be in the range of 2.3eV. This result is similar to what has been reported in literature review [11] suggesting that the band gap of NiS thin films is consistent and reproducible. Band gap energy is an important parameter that determines the electrical and optical properties of a material. The optical band gap with direct transition can be calculated from the following relation $\alpha hv = A(hv\text{-}Eg)^{n}$ [12]. The value of the energy gap Eg was determined by plotting $(\alpha hv)^2$ versus hv and then extrapolating the straight line portion to the energy axis at $\alpha = 0$. This value falls within the typical range of band gap energies for semiconductor materials, which suggests that NiS thin films could be useful in making solar cells and other optoelectronic devices that require materials with a specific band gap energy. It is important to note that the band gap energy determines the range of wavelengths of light that a material can absorb. In this case, the observed band gap energy of 2.3 eV indicates that the NiS thin films will not absorb photons of energy less than 2.3 eV. This suggests that the NiS thin films are only efficient at absorbing light with wavelengths corresponding to energies higher than 2.3 eV. Therefore, the use of NiS thin films in solar cell applications would require careful consideration of the solar spectrum and the efficiency of the conversion process. This information is useful in designing and optimizing the performance of optoelectronic devices that require materials with specific optical and electrical properties.

4. CONCLUSION

Nickel sulfide thin films has been developed from chemical bath deposition technique. Optical characterization was carried to measure absorbance, transmittance, refractive index, band gap energy and reflectance spectra of nickel sulfide thin film. The effect of deposition parameters such as deposition time and temperature are seen to affect the optical properties of the thin films, in that nickel sulfide thin film showed a moderate absorbance, poor reflectance and high transmittance. The optical band gap was determined to be 2.3eV. Results also showed a high optical conductivity and a refractive index ranging between 2.4 to 2.7. These interesting optical properties suggest their potential for various applications, including in solar cells and other electronic devices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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