

SYNTHESIS AND OPTICAL PROPERTIES OF ALUMINIUM NICKEL SULPHIDE($Al_{4.5}Ni_7S_3$) TERNARY THIN FILMS FOR OPTOELECTRONIC DEVICES

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ABSTRACT

$Al_{4.5}Ni_7S_3$ ternary thin films were deposited on the substrates by using Solution Growth Technique (SGT). The films were grown at temperature of 333K. The sources of Aluminium, Nickel and Sulphur ions are Aluminium Chloride, Nickel Chloride, ethylenediamine tetraacetic acide (EDTA), concentrated ammonia solution and thiourea. The films were annealed at 300°C for 2 hours. Optical characterization of the films was carried out using UV-VIS-NIR Spectrophotometer in the wavelength range of 300nm-1000nm. The optical transmittance was obtained directly by the Spectrophotometer and the other optical properties were determined by theoretical calculations. The average energy band gaps of the films grown at different concentrations and at a temperature are 3.70, 3.60eV and 3.55eV for different dip times. From the results, it was observed that the direct band gap exhibited by these films decreases with increase in concentrations. The wide direct band gap exhibited by these films make them good materials for solar cell fabrication and optoelectronic device. The high transmittance exhibited by the films reveal that the films are good candidates for the construction of roofs and wall of the poultry houses. This can provide the needed heat required for warming of young chicks.

Keywords: Synthesis, optical, transmittance, nickel, ternary thin films,

INTRODUCTION

Ternary thin films which composed of three elements are increasingly favored over binary systems for advanced optoelectronics and solar energy conversion. These include using solution growth technique and SILAR methods to create flexible, cost-efficient, large-area semiconductor films for next-generation devices. Ternary materials are heavily researched for solar absorbers and optoelectronic devices. The bandgap of ternary thin films is essential for improving solar cell

efficiency. It also improves uniformity and optimizing the grain size. Ternary thin films require temperature controls to improve conductivity and optoelectronic.

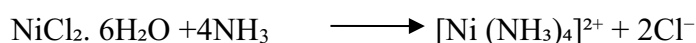
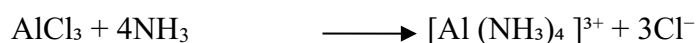
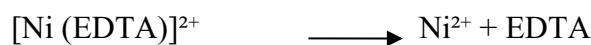
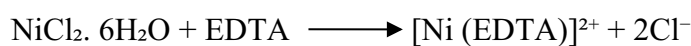
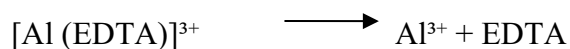
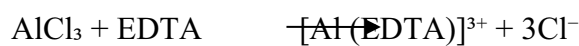
Ternary compound semiconductors have caused much attention for the researchers because they useful in solar cells and are also known as suitable materials for photovoltaic device applications (Morkoc, et al., 1991 & Gil, 1998) as they have high optical absorption co-efficients. The preparation and study of physical properties of ternary chalcogenide compounds have increased in recent year (Cruz-Vazquez, Rocha-Alonzo, BurrueI-Ibarra and Inoue, 2001; Uhuegbu, 2010). Ternary compounds are found to be suitable material for optoelectronic device applications and good material for window layer solar cells (Woon-Jo and Cye-Choon, 2003). Some of the films are investigated for use as super-ionic conducting materials (Paramanik, Bhattacharya and Basu, 1987; Ndukwe, 1996; Ezema and Asogwa, 2004). The ternary compounds had been studied for efficient solar energy conversion materials (Padam and Rao, 1986; Pawar, Tamhankar and Lokhande, 1986). The survey of literature shows that many ternary thin films have been deposited using highly technological, sophisticated and very expensive techniques. However, in third world countries, the high technological and sophisticated techniques are not easily achieved because of their complexity and the poverty of the third world countries. Hence, considerable efforts are put into developing simple and cheap techniques of depositing thin films. The chemical bath deposition technique solution growth technique offers the simplest, cheapest, most economical and affordable method of depositing thin films of various kinds. It does not require sophisticated instrumentation like vacuum systems and other expensive equipment.

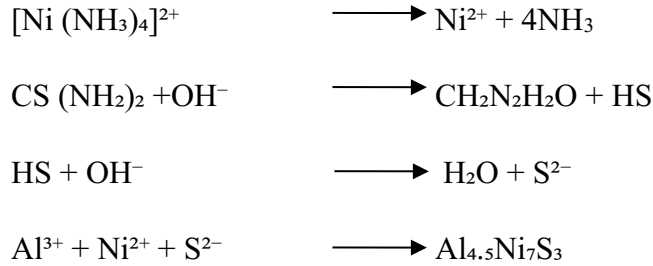
Presently a distinction between thin films and bulk materials has been made. Materials science of coatings and thin films has become a well-established line of research. In fact, people encounter coatings and thin films daily in life sometimes without knowing their importance. The use of thin films has the purpose of adding properties to an item often consisting of another material that has useful properties for a specific application (Greene, 2014). Thin films and coatings are furthermore used in a variety of applications and the properties that are modified could for instance decorative, optical, resistive, mechanical or thermal (Greene, 2017). The science of thin films and coatings is interdisciplinary (Mozetic, et al., 2018) and involves solid state physics, physical metallurgy, quantum mechanics and thermodynamics. Both theoretical and experimental considerations are needed to understand their electronic structure together with their microstructural evolution and how this in turn relates to the properties of the thin film.

MATERIALS AND METHODS

The ternary thin films of Aluminium Nickel Sulphide ($Al_{4.5}Ni_7 S_3$) were deposited using solution growth technique. Before the deposition, glass substrates were degreased in trioxonitrate (V) acid for 24 hours, washed with detergent, rinsed in de-ionized water and dried in air. The purpose of degreasing the surfaces is to provide nucleation centers for the growth of the films, thereby yielding adhesive uniformity grown films. The films were grown in different concentrations 0.1M, 0.3M and 0.5M respectively and at temperature of 333K for a dip time of 2 hours. The chemical bath for the deposition of $Al_{4.5}Ni_7 S_3$ contains 16mls of 0.1M of $AlCl_3$, 16mls of 0.1M of $NiCl_2 \cdot 6H_2O$, 10mls of 0.1M of EDTA, 16mls of 0.1M of $CS(NH_2)_2$ and 10mls of concentrated aqueous ammonia (NH_3) in a 100ml beaker. The same volume of mls of solution was used for the deposition of films at the concentrations of 0.3M and 0.5M respectively. The mixture was stirred with magnetic stirrer for the uniformity of the solution. EDTA and ammonia solutions were used as a complexing agents which slow down the reactions in order to eliminate spontaneous precipitation. The substrates were dipped into the reaction baths vertically with help of the perforated synthetic foam. The substrates were allowed to remain in the bath for a dip time of 2 hours. The films were washed in de-ionized water and dried in air after each deposition. After the deposition, the films were annealed at temperature of 300oC for 2 hours and characterized for optical transmittance using UV-VIS-NIR Spectrophotometer.

The reactions involved in the complex ion formation and film deposition processes of the ternary thin films grown are as follows:-





RESULTS AND DISCUSSION

Figures 1 to 4 show the plots of absorbance against wavelength, the plots of transmittance against wavelength, the plots of reflectance against wavelength and the plots of $(\alpha h\nu)^2$ as a function of photon energy of $\text{Al}_{4.5}\text{Ni}_7\text{S}_3$ thin films grown at different concentrations

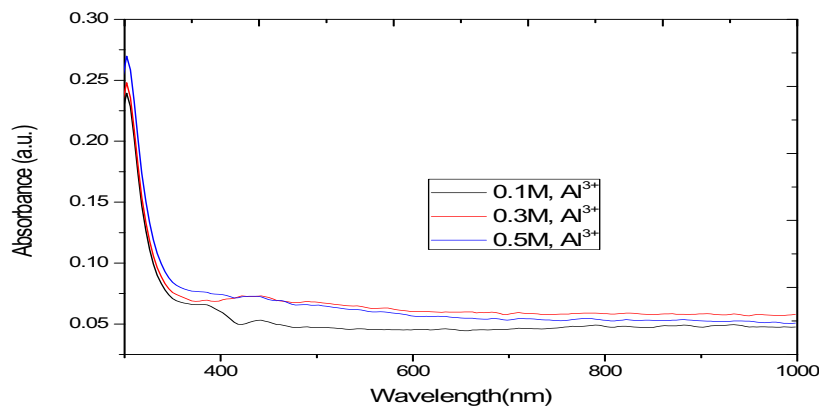


Figure 1: Plots of Absorbance Against Wavelength at 333K

From the graph, the absorbance increases with increase in the concentration of the precursor solutions. In all, the absorbance values are within the range stipulated by Lambert-Beer's law (<http://www.wikilectures.eu/index-php>). The range of absorbance values reported is lower

compared to the report of Augustine and Nnabuchi (2018) for CuO/PbS quaternary thin films, and Nnabuchi and Augustine (2018) for Mn₃O₄/PbS quaternary thin films.

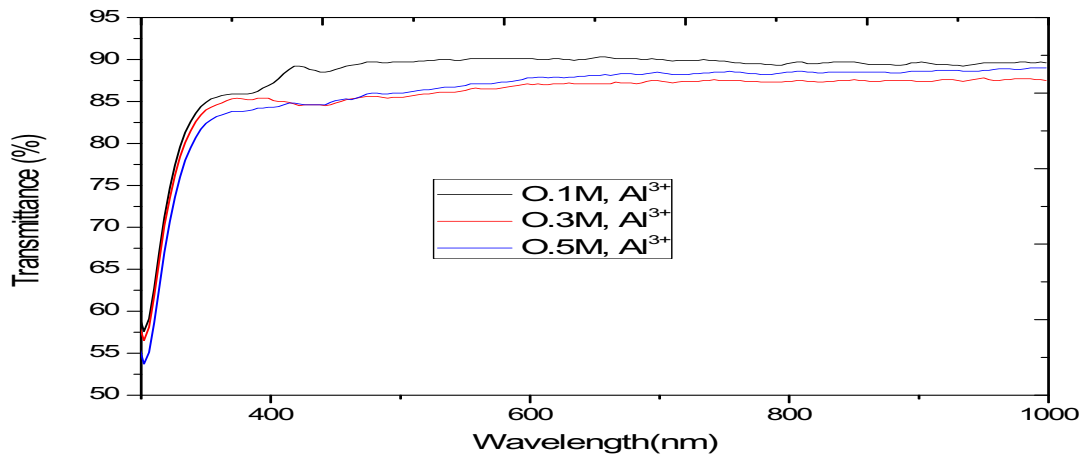


Figure 2: Plots of Transmittance Against Wavelength at 333K

From the graph, the transmittance increases with decrease in concentration in the wavelength range of 300-400nm. Here, 0.1M sample transmit better compared to other samples. The transmittance

of thin films can be greatly modified by different deposition parameters. Generally, the transmittance of the films deposited in this work is very high with a maximum of 95%. The high transmittance of the thin films in the infrared region placed them as suitable materials for construction of roofs and walls of poultry houses. This will provide the needed heat required for warming of young chicks and has the potential to reduce the cost of energy consumption associated with the use of electric bulbs, stoves and lamps to produce the needed heat to warm young birds. These findings are in agreement with those of Augustine and Nnabuchi (2018) for CuO/PbS thin films, Uhuegbu (2007) for FeCuS thin films and Chikwenze and Ekpunobi (2007) for ZnSe thin films.

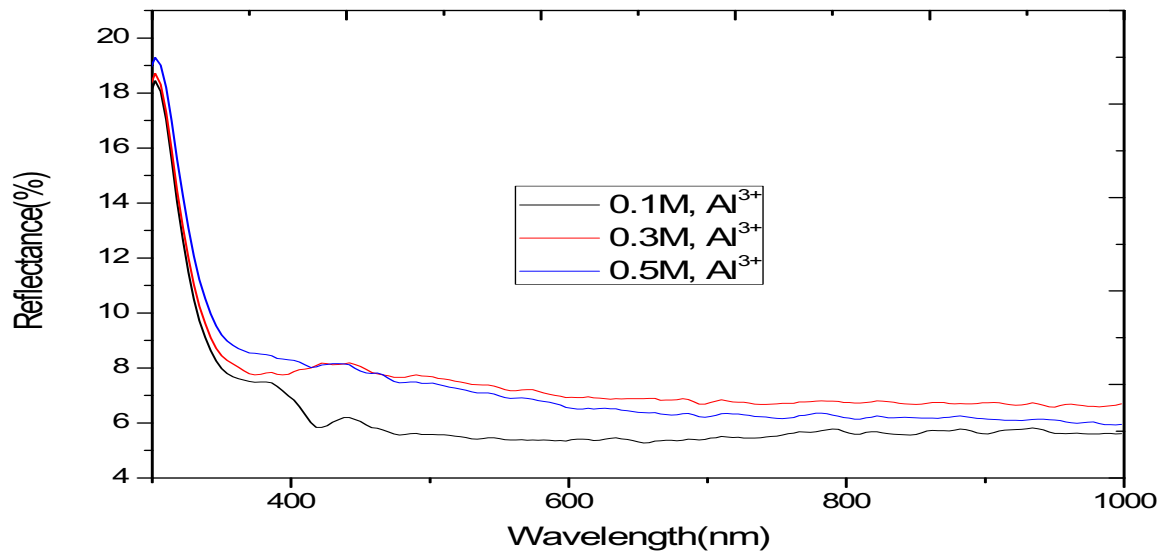


Figure 3: Plots of Reflectance Against Wavelength at 333K

From the graph, the reflectance decreased with increase in wavelength exhibiting a minimum in the infrared region was observed for 0.1M layer. A similar trend was observed for $Al_{4.5}Ni_7S_3$ samples deposit at 333K. These findings are in agreement with those of Ottih, Ekpunobi and Ekwo (2011) for CuNiS thin films and Uhuegbu (2010) for FeCuS ternary thin films.

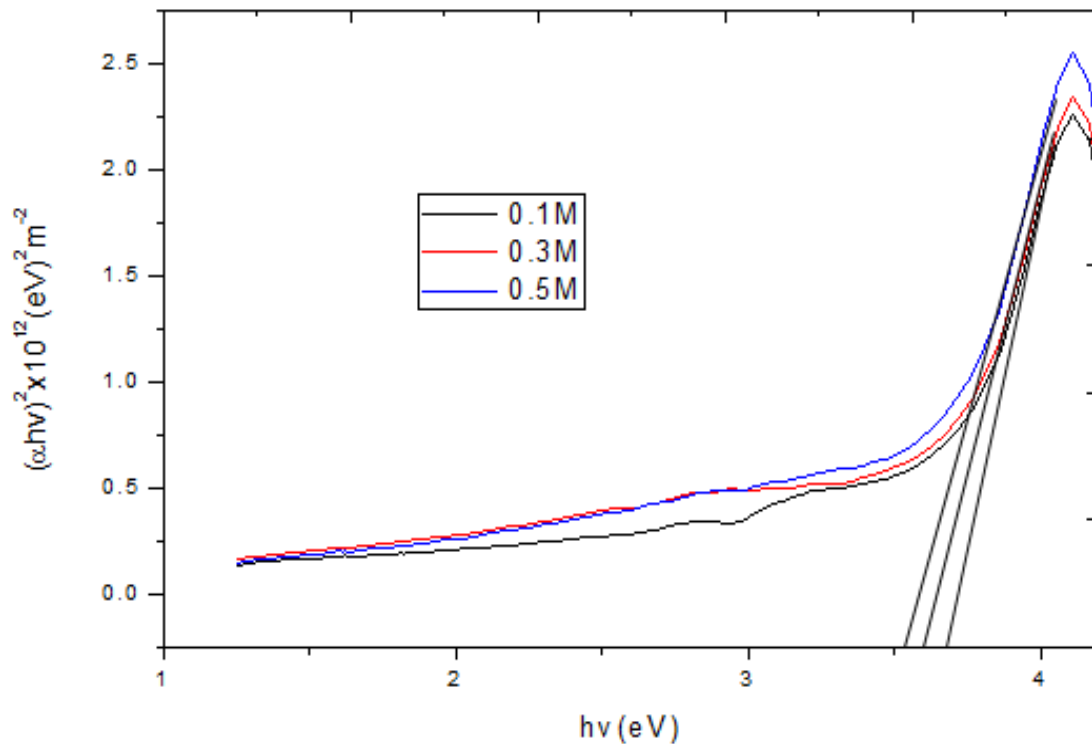


Figure: Plots of $(\alpha h\nu)^2$ as a Function of Photon Energy at Different Concentrations at 333K

From the graph, the band gap values are 3.70eV, 3.60eV and 3.55eV for 0.1M, 0.3M and 0.5M respectively. It can be seen that the band gap values for $\text{Al}_{4.5}\text{Ni}_7\text{S}_3$ thin films are far above that of binary NiS thin films. Clearly, the incorporation of aluminium ions (Al^{3+}) into NiS matrix leading to alloying of the type $\text{Al}_{4.5}\text{Ni}_7\text{S}_3$ may have shifted the band gap away from the fundamental absorption edge. The wide direct band gap exhibited by these films make them good candidates for solar cell fabrication; window layer solar cells which is in agreement with (Petkov, Todorov, Kozhuharova, Tcky, Cernoskova and Ewen, 2006; Agbo, 2011). Therefore, $\text{Al}_{4.5}\text{Ni}_7\text{S}_3$ thin films deposited in this work may be used as alternative for possible incorporation in CIGS solar cells.

CONCLUSION

New ternary thin of Aluminium Nickel Sulphide ($\text{Al}_{4.5}\text{Ni}_7\text{S}_3$) grown at different concentrations have been successfully deposited on glass substrates using solution growth technique. The optical characterization was examined using UV-VIS-NIR Spectrophotometer. The result reveals that the wide energy band gap exhibited by the films make them suitable solar cell fabrication and optoelectronic devices

RECOMMENDATION

I recommend that Future researchers should use FTO substrates to deposite these films and compare the result with those obtained using glass substrate

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