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Spectral Selective Properties and Possible Applications of Iron Zinc Sulphide Ternary Thin Film

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ABSTRACT

Iron zinc sulphide ternary thin film has been grown on glass substrate and characterized using a spectrophotometer. The optical properties considered revealed high absorbance and reflectance but low transmittance in the UV; low values of absorbance and reflectance accompanied by high transmittance in the VIS. The direct band gap and indirect band gap obtained are 2.3eV and 1.9eV. The possible applications were discussed.

KEY WORDS: Solution growth technique (SGT), absorbance, transmittance, reflectance and iron zinc sulphide thin film.

INTRODUCTION

Thin films are crystalline or non-crystalline material developed two dimensionally on a substrate surface by physical or chemical method. Thin films are popular and effective transducers for the harnessing of solar energy. In all cases, the total energy captured by these transducers is directly proportional to the surface area; hence all solar energy devices must have a large surface area in order to produce significant energy.

The preparation and study of physical properties of ternary chalcogenide compounds has increased in recent years [1 – 4]. Ternary compounds are found to be suitable material for opto-electronic device applications and good material for window layer solar cells [5]. Some of the films have been investigated for use as superionic conducting materials and solar energy conversion materials [6 – 15].

The spectral properties considered in this work are; absorbance (A), transmittance (T) and reflectance (R). The consequence of exposing such a surface to solar radiation is that only certain wavelengths of the incident radiation are transmitted, absorbed or reflected [16 – 24]. In other words, the values of these spectral properties become wavelength dependent, varying over the spectral regions, especially (0.3 – 3.0 μm) of solar radiation spectrum. The transmittance, absorbance and reflectance are calculated using equations found in literatures [25 – 28].

Experiment and Materials

The chemical deposition of the iron zinc sulphide ternary thin film onto the glass substrate was carried out by using a mixture of 1 M ferrous nitrate, 0.1 M zinc chloride, 0.1 M ethylenediaminetetracetate (EDTA) 14 M ammonia, 1 M thiourea distilled water, microscopic glass slides inside a beaker.

The chemical bath deposition technique was used to prepare the $FeZnS_{2.5}$ ternary thin film on glass substrate (slide) which has been previously degreased in concentrated nitric acid (HNO3) for 48 hours, cleaned in cold water with detergent, rinsed with distilled water and dried in air. The degreased cleaned surface provide nucleation centre for growth of the film, hence yielding highly adhesive and uniformly deposited film.

The mixture was thoroughly stirred with a glass rod before the glass slide was vertically introduced into the beaker. The dip time of about 20 – 48 hours at pH between 9 and 11 was observed for the deposition process which took place at room temperature. The grown samples were removed from the reaction bath rinsed with

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distilled water and allowed to dry. They were then annealed at 423 K for 1 hour to obtain adherent transparent thin films.

During deposition, cations and anions in the deposition solution reacted to become neutral atoms which either precipitated spontaneously or very slowly. Fast precipitation implied that thin films could not be formed on the substrate immersed in the solution. However, with the addition of NH_3 and EDTA, the reaction slowed down for thin film of neutral atom to be formed on the substrate. Sulphide ions were released by hydrolysis of thiourea. By the process of ion- by ion exchange, $FeZnS_{2.5}$ was deposited on the glass substrate in the form of transparent, uniform and adherent ternary thin film.

The stepwise reactions involved in the complex ion formation and film deposition processes for $FeZnS_{2.5}$ are:

$Fe (NO_3)_3.9H_2O$ + EDTA--------------$[Fe(EDTA)]^+ + NO_3^-$

$[Fe (EDTA)]^+$ ----------------------Fe^{3+} + $EDTA^{2-}$

$Zn (NO_3)_2$ + TEA--------------------$[Zn(TEA)]^{2+}$ NO_3^-

$[Zn (TEA)]^{2+}$ ---------------------Zn^{2+} + TEA

$(NH_2)_2CS + OH^-$ ----------------- $(NH_2)_2CO + HS^-$

$HS^- + OH^-$ ---------------- $H_2O + S^{2-}$

$Fe^{3+} + Zn^{2+} + 2.5S^{2-}$ -----------$FeZnS_{2.5}$

The thin film was characterized using UNICO UV-2102 PC Spectrophotometer to determine the spectral absorbance, transmittance and reflectance of the thin film on the glass substrate with blank substrate as a reference glass slide.

RESULTS

The graphs of spectral absorbance, transmittance and reflectance versus wavelengths are presented in figures 1, 2 and 3, respectively. The absorbance (A) varied from a value of about 0.20 at 200 nm to a maximum value of about 0.92 at 300 nm, before decreasing gently with wavelength. This result showed that the film has high absorbance at ultraviolet (UV) wavelength (0.2 < λ < 0.4 µm) and low absorbance at visible (VIS) and infrared (IR) wavelengths (0.4 < λ < 1 µm).

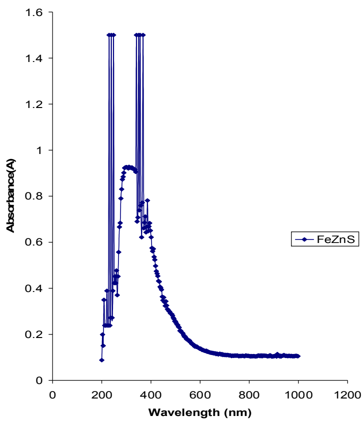

Figure 1 : Absorbance (A) as function of wavelength (λ) for FeZnS Thin Film

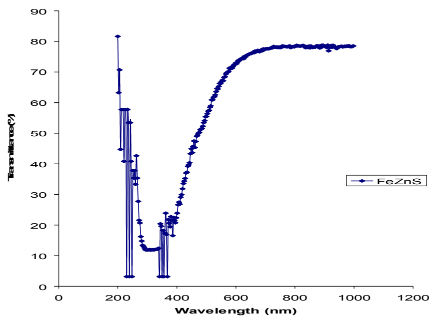

Figure 2 : Transmittance (T) as function of wavelength (λ) for FeZnS Thin Film

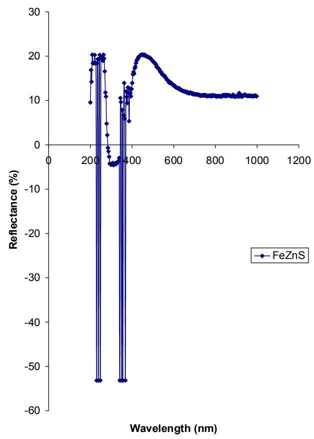

Figure 3 : Refectance (R) as function of wavelength (λ) for FeZnS Thin Film

The transmittance (T) decreased from a value of about 70 % to minimum value of about 12 % at 300 nm before it increased to 79 % at 806 nm. This means high transmittance at visible and infrared wavelengths and low transmittance at UV wavelength.

The reflectance decreased from about 20 % at about 280 nm sharply to a minimum value of -4 % at 300 nm thereafter, increased to 20 % at 500 nm before decreasing gently with wavelength.

DISCUSSION

The film has high absorbance values in the UV region of electromagnetic radiation (0.2 < λ < 0.4 µm) and low absorbance values in the visible region (VIS) ((0.4 < λ< 0.7 µm) and infrared (IR) region (0.7 < λ < 1 µm). It has high transmittance in the visible and infrared (IR) regions and low values in the UV region. The spectral selectivity characteristics of the $FeZnS_{2.5}$ ternary film make the film suitable material in solar energy application, especially in eye glasses industry and poultry houses.

The relative high absorbance and reflectance of the film in the UV region and relative high transmittance and low reflectance of the films in the visible and infrared regions make the film suitable material for eye glasses industry since it is capable of absorbing and or reflecting off the dangerous UV radiation which is harmful to the skin of human beings and animals and at the same time capable of transmitting the infrared radiation needed for vision and infrared radiation for the warmth needed by human beings and animals. The characteristics of high transmission in VIS and IR are also applicable in Photovoltaic industry, producing highly efficient solar cells and in photo-thermal application.

The optical selectivity characteristics of the films are also applicable in building of poultry house where it is necessary to protect the chicks from the UV radiation and admitting the VIS and IR radiation into the house for the warmth of the birds.

The variations observed from the three graphs may be due to variation in concentrations and impurities from the environment where the experiment is carried out.

Conclusion

New ternary thin film of iron zinc sulphide using solution growth technique (SGT) have been grown on glass substrate and characterized using a spectrophotometer. The optical properties considered revealed high absorbance and reflectance but low transmittance in the UV; low values of absorbance and reflectance accompanied but high transmittance in the VIS. From these results, it is observed that the film has the property of screening off UV portion of the electromagnetic radiation by absorbing and reflecting and admittance of visible and infrared radiation by transmission. These properties confirm the film good materials for coating poultry buildings, eye glasses coating, antireflection coating and solar cells fabrication which is in agreement with the findings of several other researchers on similar ternary thin films [29, 30].

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