

Effects of Dye on Selected Optical and Solid State Properties of ZNSE Thin Films for Applications in Solar Energy Harvesting Device

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Abstract

The effect of dye extract on the Transmittance and Absorbance behavior of dye sensitized ZnSe thin film was investigated. The films were deposited using chemical bath technique by an aqueous mixture appropriate precursor to provide the needed Information Zinc ion and selenide ion. The dye extracted from the leaf of *Chromolaena Odorata* (Siam Weed) plant was used to sensitize the film. Uv spectrophotometer was used in the optical analysis. The results obtained indicate that the transmittance values for the ZnSe and dye sensitized ZnSe thin films showed a high value (20%-90%) in the spectral region as wavelength increases corresponding to maximum sensitivity for photonic vision. It was also observed that addition of dye and increase in deposition temperature increased the absorbance of the films. The absorbance of dye sensitized ZnSe thin film deposited at 333K was almost constant between 400nm to 900nm. The highest absorbance value recorded was 0.61 for dye sensitized ZnSe deposited at 353K while the lowest was 0.13 for dye sensitized ZnSe thin film deposited at 333K. The plots indicated that the films have a direct band gap ranging from 3.88-3.95eV.

Keywords: Transmittance, Absorbance, Band gap, chemical bath, dye, UV- Spectrophotometer, Temperature and annealing.

Date of Submission: 20-12-2021

Date of Acceptance: 04-01-2022

I. Introduction

In this 21st century, the use of solar energy powered devices ranging from hand held to more bulky and installed ones are very common occurrence. There have been immense improvements in solar Technology such that its development and refining is capable of powering thousands of installations worldwide. Solar electricity was once considered an exotic technology but was only given attention in terms of powering space satellites and an occasional classroom experiment [2, 5]. Solar electricity can power anything from calculator to an entire community. Today, solar electricity has become practicalised and hence applied as a means of generating electricity outside power lines. They have no moving and maintenance parts with long life span exceeding for decades. Photovoltaic are these days standardized such that its application is extended to many commercial, industrial, military as well as other consumer applications for modest power requirements [3, 2]. Dye-sensitized solar cells (DSSC) are promising alternatives to conventional solar cells because of their cheap, environmentally friendly, and easy to fabricate [11, 3]. Dye-sensitized ZnSe thin film because of its panchromatic nature has been found useful in solar energy harvesting. They work even in low-light conditions such as non-direct sunlight and cloudy skies. Thin film technology has provided an opportunity for investigators to delve into solar energy research. Zinc Selenide (ZnSe), a group II-IV semiconductor compound has gained a remarkable attention in solar energy device fabrication due to its good optical and solid state properties [4]. It is a leading material in the fabrication of solar cells. It has direct band gap transition type [6, 8]. ZnSe is a preferred material for lenses [2, 3, 4], window layers and output couplers for its low absorptive at infra-red wavelengths and its visible transmission [3, 4]. Nano based zinc selenide thin films with a wide direct band gap (3.87) has a high transmittance in the visible region having great interest in practical applications in optoelectronics and photonic [7, 9]. Dye-sensitized ZnSe thin films can be deposited using a variety of methods, including thermal evaporation, self assembly technique, spray pyrolysis, electron beam evaporation, and solution growth technique.etc [2, 1].

In this present work, dye-sensitized ZnSe thin films were deposited using chemical deposition technique and annealed. The samples were characterized using Spectrophotometer and Fourier infra red transform.

II. Theory

2.1 Absorbance (A)

Absorbance is the quantity directly determined from absorption spectra measurement and the instrument scales are often calibrated in this unit (au). By definition,

$$A = \log \left(\frac{I_0}{I} \right) = \log_{10} \left(\frac{I}{T} \right) \quad 1a$$

$$A = 2 - \log_{10} (\%T) \quad 1b$$

Where I_0 and I are the incident and transmitted intensities respectively. According to [10, 5], absorbance and absorption coefficient (a) are related thus;

$$a = \frac{Ac}{V} \quad 2$$

Where c , and v are the velocity of light and frequency of the electromagnetic wave respectively. Absorbance can be calculated from transmittance or % transmittance using equation 6a and 6b.

2.2 Transmittance (T)

Whenever an electromagnetic wave such as light crosses the interface between two different materials such as thin film and glass, a fraction of light is reflected by the inner surface while some amount of electromagnetic wave is refracted through the inner surface and finally transmitted. The reflectance is the amount of reflection in terms of energy while transmittance is the amount of transmission in terms of energy. Mathematically, Transmittance of the specimens is defined as the ratio of the transmitted intensity (flux) (I) to the incident (flux) intensity (I_0).

$$T = I/I_0 \quad 3$$

The absorbance A is the logarithm of the reciprocal of the transmittance. Hence, from equation (6) we can deduce transmittance from absorbance in the form,

$$T = 10^{-A} \quad 4$$

Thus, when one is known, the other can be found. It is the absorbance/transmittance of thin films that are usually obtained directly using spectrophotometer during optical characterization while other properties are gotten from calculations based on these.

2.3 Band gap (E_g)

Band gap is a solid state property and is one of the important parameters in the characterization of a material. The knowledge of optical absorption is necessary in the study of band gap. Photon-induced electronic transitions can occur between different bands which led to the determination of the energy band-gap or within a single band such as free-carrier absorption. The band gap is a difference in energy between the lowest point of conduction band and the highest point of valence band. In other words it is the energy required for an electron to move from the valence band to the conduction band.

The shape of absorption spectrum and dispersion near the fundamental absorption edge are caused by the electron transition from upper part of the valence band to the lower part of the conduction band [2, 3]. This electron transition can be direct or indirect. It is direct when there is no photon participation and without change in crystal momentum of an electron. In other words it is indirect when the interaction with a photon produces a considerable change in the crystal momentum. The various types of transition give rise to different frequency dependencies of the absorption coefficient near the absorption edge.

According to [1, 8], the absorption coefficient for direct transition is given by,

$$ahv \propto (hv - E_g)^\gamma \quad 5$$

Where $\gamma = 1/2$ if the transition between the upper part of the valence band to the lower part of conduction band are allowed by the selection rules and $\gamma = 3/2$, the transitions are forbidden. Hence,

$$ahv = A(hv - E_g)^{1/2} \quad 6$$

For allowed transitions, that is

$$(ahv)^2 = B(hv - E_g) \quad 7$$

In most cases, indirect transitions [4] are weaker than direct ones by 3 or 2 orders of magnitude. This is because they result only by second order – perturbation and can only be observed in energy regions which are free of direct transition. The dependence of the absorption coefficient on the energy of light quanta near the fundamental edge is given by equations 6 and 7.

A graph of α^2 versus $h\nu$ gives a straight-line graph with negative band gap as the intercept. However, in the region of absorption edge, the absorption falls to such low values that it becomes difficult to measure the part which is due to band-to-band transition. This is due to the fact that it is now liable to be masked by other incidental absorption or losses in specimens or experimental equipment. Due to this, a plot of α^2 versus $h\nu$ is not

usually straight at the absorption edge region. Hence, the intercept that gives the band gap is extrapolated from the straight portion of the graph to the point.

$$a^2 = 0 \tag{8}$$

[8] Discovered that in some compounds, the density of impurities affected the position of the absorption edge in such a way as to shift it to a shorter wavelength and this causes a large increase in the band gap of such material. In joules, the photo energy for a given wavelength in meters is given by,

$$E = hv = hc/\lambda \tag{9}$$

Where, h = plank's constant, c = velocity of light,

λ = wavelength in meter (m), and v = frequency of the radiation .

If λ is in nm,

$$hv (ev) = \frac{1241}{\lambda} \tag{10}$$

Equation (10) is used in this study in calculating the photon energies in eV for various wavelengths, λ in nm.

III. Experimental Detail

All chemicals used in this work were analytical grade (AR) and the solutions were prepared in deionized water. The chemical bath used to prepare dye-sensitized ZnSe thin films in this work were prepared in the following order. 20ml of 0.7M ZNSO4, 20ml of 0.3M CH4N2S, 2drops of NH3 and 4ml of Dye was added in 100ml cleaned and dried beaker labeled (1). 20ml of 0.7M ZNSO4, 20ml of 0.3M CH4N2S, 2drops of NH3 without dye was also added in 100ml cleaned and dried beaker labeled (2). The pH level of beaker (1) content was 9.0 and reduced to 8.9 on addition of 4ml of dye. The content of beaker 1 and 2 was stirred for about five minutes to ensure proper mixture, thereafter; substrates separated and suspended with synthetic foam were immersed vertically at the center of each reaction bath (i.e. 100ml beaker 1 and 2). These reaction baths was inserted in water bath (1000ml beaker containing about 400ml of water) and was heated with constant temperature magnetic stirrer. The substrates used for the deposition of dye sensitized ZnSe thin films were microscopic glass slide (25.4mm x 76.2mm) already prepared. The films were deposited at constant temperature of 80⁰C for 60minutes.

The process was repeated with 20ml of 0.5M ZNSO4 and the films deposited at constant temperature of 60⁰C for 60minutes.

IV. Results And Discussion

4.1 Optical Characterization

The Absorbance and transmission spectra of the dye sensitized ZnSe thin film samples are taken in the ultra violet (UV), visible and infra red (IR) regions (200-900nm) by using UV-VIS-NIR Perker Elmer spectrophotometer lambda 950 with UV Win lab software. The machine measures directly the transmission of the sample. By using the %T data, all other optical parameters were calculated.

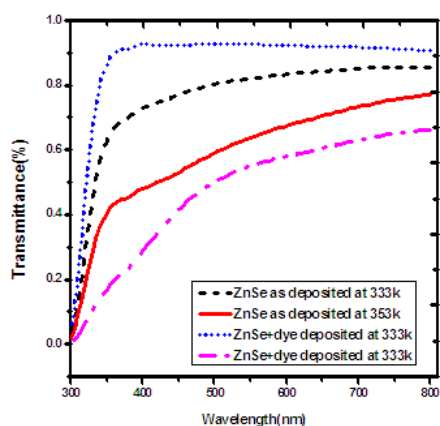


Fig: 1 plot of Transmittance verses wavelength for dye-sensitized ZnSe

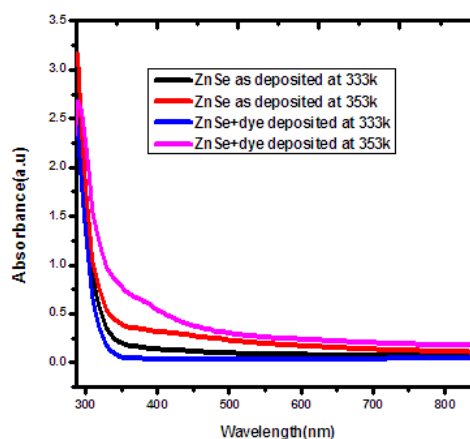


Fig: 2 plot of Absorbance verses wavelength for dye-sensitized ZnSe

The transmittance value for all the deposited dye-sensitized ZnSe thin films increases with increasing wavelength from 300nm to 900nm as shown in Fig: 1. the transmittance varied between 20 to 90% in the visible and IR region, this implies that dye-sensitized ZnSe thin films can be used as window layer material in solar cells. The plot of Fig: 2 indicate that deposited dye-sensitized ZnSe thin films have its absorbance value decreased with increased wavelength. Its highest value recorded was 0.59 for film deposited at 353k and the lowest 0.13 for film deposited at 333k. The band gap energy for the dye-sensitized ZnSe thin films in Fig: 3 ranges between 3.75eV to 3.87eV. This wide band gap makes dye-sensitized ZnSe thin film a key material for solar cell fabrication.

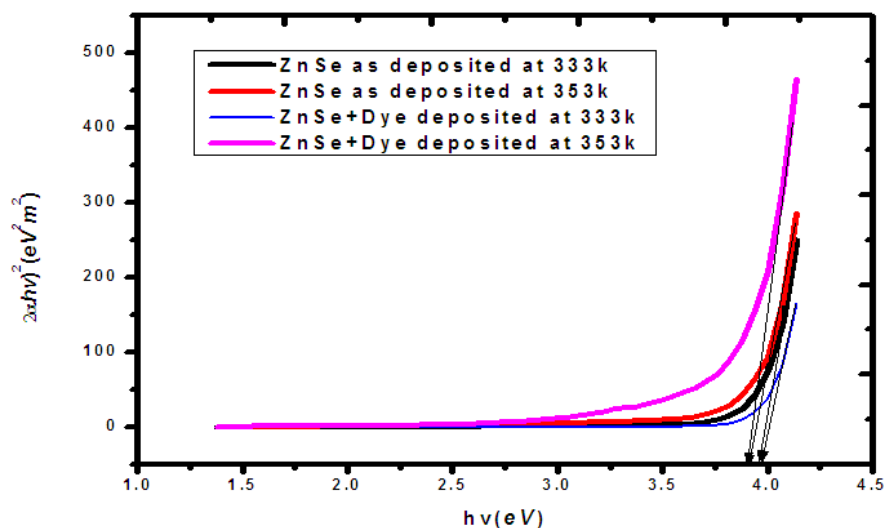


Fig: 3 plot of $(\alpha h\nu)^2$ versus $h\nu$ for dye-sensitized ZnSe

V. Conclusions

In this study, dye-sensitized ZnSe thin films deposited on glass substrate using solution growth technique have been analysed. The analysis showed that the deposition temperatures and presence of dye has profound influence on the optical properties of the deposited films. Evident from the results is also that the dye shifted the absorption edge of the thin films. The films has high transmittance and low absorbance with direct band gap ranges between 3.75eV to 3.87eV making dye sensitized ZnSe thin film a good material for window layer in solar cell fabrication for solar energy harvesting.

REFERENCES

- [1]. Abeles, F. (1972). Optical properties of Metals and Solids. Amsterdam, North Holland Publishing Company, 97.
- [2]. Agbo, P. E. and Nwofe, P. A. (2015). Structural and Optical properties of Sulphurised Ag₂S thin films. *International journal of thin Films Science and Technology*, 4, 9-12.
- [3]. Agbo, P. E. and Nwofe, P. A. (2015). Comprehensive studies on the Optical properties of ZnO-core. *Journal of Nanotechnology Advance Material*, 3, 63-97.
- [4]. Chopra, K. L. and S. R. Das, 1983. Why Thin Films Solar Cells? Springer.
- [5]. Dexter, D. L. (1956). Absorption of light by Atoms in Solids. *Physical Review letters*, 101, 48-55.
- [6]. P. E. Agbo, P. A. Nwofe, C. A. Elekwachi, M. N. Nnabuchi. *J. Ovonic Res.* 12 (3), 163-1169 (2016)
- [7]. Ismail, B. and R. Gould, 1989. Structural and electronic properties of evaporated thin films cadmium telluride. *Physica Status Solidi (A)*, 115 (1): 237-245.
- [8]. Moss, T. S. (1961). Optical Properties of Semiconductors. London, Bullenworth and Co. publishing Ltd, 2.
- [9]. Nazar, A.S. (2014). Physical Properties of Silver Doped ZnSe Thin Films for Photovoltaic Applications. *Iranian Journal of Energy and Environment* 5 (1): 87-93, 2014
- [10]. Okoli (2007). Growth and Characterization of Ternary Compounds and Possible Applications. Ph.D Thesis, Department of Physics and Industrial Physics NAU Awka.
- [11]. Thewlis, J. (1962). Encyclopaedic Dictionary of physics. Oxford Pergamann Press, 5, 1179.
- [12]. Tiwari, G. N. (2012). Solar Energy Fundamentals, Design, Modeling and Applications. New Delhi, India: Nasora Publishing House Pvt. Ltd.

Ben Joshua Robert, et. al. "Effects of Dye on Selected Optical and Solid State Properties of ZNSE Thin Films for Applications in Solar Energy Harvesting Device." *IOSR Journal of Applied Physics (IOSR-JAP)*, 14(01), 2022, pp. 01-04.