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# On the Refractive Index and Dielectric Constant of Dye-Sensitized ZnSe Thin Films for Applications in Solar Energy Harvesting Device

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## ABSTRACT

The effect of dye extract on the refractive index index and dielectric behavior of dye sensitized ZnSe thin film was investigated. The films were deposited using chemical bath technique by an aqueous mixture appropriate percusors to provide the needed Information Znic ion and selenide ion. The dye extracted from the leaf of *zea maze* (maize) plant was used to sensitize the film. Uv spectrophotometer was used in the optical analysis. The results obtained show thatthe index of refraction tends to decrease as wavelength increases for all the films depositedand varied marginally between 1.20- 2.70. It was also observed that the addition of dye increased the refractive index as the deposition temperature increased. . The dielectric constant (real) increased as wavelength increased for all films deposited at 333K. Dielectric constant (imaginary) decreased as wavelength increases at increase in deposition temperature and was highest around the visible region.

Keywords: Refractive Index, Dielectric constant, chemical bath, dye, UV-Spectrophotometer, Temperature and annealing.

## INTRODUCTION

All over the world, relying on renewable energy, particularly solar energy is becoming increasingly popular. One of the first factors that holds any one back from jumping on the solar Bandwagon is the price and the presumed cost of installing this renewable technology.Currently more researches are aimed at the development of thin film materials to withstand the advancement in technology. 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. Photovoltaics 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 they are 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, and 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 [2, 1].
In this present work, dye-sensitized ZnSe thin films were deposited using chemical deposition technique.

## THEORY

### Refractive index (n)

Refractive index, a measure of how light behaves as it passes through a sample is significant for optical communication and in designing devices and spectra dispersion. Materials with the highest refractive index slow down light wave the most, and hence have the highest bending. When reflectance is normal to a surface, it can be expressed in terms of refractive index and extinction coefficient, thus,

$$R = \frac{(n-1)^2 + k^2}{(n+1)^2 + k^2} \qquad (1)$$

Where n = refractive index and k = extinction coefficient. For semiconductors and insulators, k is very small i.e. $k^2 << n^2$ and equation (1) reduces to,

$$R = \frac{(n-1)^2}{(n+1)^2} \qquad (2)$$

$$and n = \frac{1 + R^{1/2}}{1 - R^{1/2}} \qquad (3)$$

Complex index of refraction is actually used to describe the interaction of electromagnetic – radiation with matter. n has both real and imaginary part as in equation

;

n = n – ik (4)

Both n and k depend on the wavelength.

The index of refraction is properly defined to be the ratio of the speed of light (c) in a vacuum to the speed (v) of the electromagnetic wave in the medium of propagation;

$$n = \frac{c}{v} \quad (5)$$

## Dielectric constant ($\varepsilon$)

A dielectric is a substance that is a poor conductor of electricity, but a good means of electrical storage. When a dielectric material is placed in an electric field, electric current (charges) do not flow through it as in electrical conductor, instead electric polarization occurs because they do not have free electrons that may drift through them. When dielectric polarization occurs, positive charges are displaced in the direction of the field and negative charges shift in the opposite direction. This creates an internal electric field that reduces the electric field within the dielectric itself and makes it a poor conductor, but a good storage medium. The dielectric constant is a property of a material that determines the movement of electromagnetic radiation through it. As dielectric constant increases, the total amount of electric charge per area increases. This in turn enables the object to hold large electric charge for long periods of time. The real part of the dielectric constant explains how much amount the material will slow down the speed of light while the imaginary part explains how much a dielectric material absorbs energy from electric field due to dipole orientation. The complex dielectric constant ($\varepsilon$)

$$\varepsilon = \varepsilon_r + \varepsilon_i = (n + ik)^2 \quad (6)$$

Where $\varepsilon_r and \varepsilon_i$ are the real and imaginary parts of $\varepsilon$ and (n + ik) is the complex refractive index. If we expand (n + ik) and equating with real and imaginary parts gives

$$\varepsilon_r = n^2 - k^2 \quad (7)$$

$$\varepsilon_i = 2nk \quad (8)$$

Equation (3) was used to calculate the refractive index, while the real and imaginary dielectric constants were estimated using the equations (7) and (8).

## 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 $ZNSO_{4,}$ 20ml of 0.3M $CH_4N_2S$, 2drops of $NH_3$ and 4ml of Dye was added in 100mlcleaned and dried beaker labeled (1). 20ml of 0.7M $ZNSO_{4,}$ 20ml of 0.3M $CH_4N_2S$, 2drops of $NH_3$ without dye was also added in 100mlcleaned 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 80°c for 60minutes.
The process was repeated with 20ml of 0.5M $ZNSO_4$ and the films deposited at constant temperature of 60°c for 60minutes.

## RESULTS AND DISCUSSION
### Optical Characterization
### UV-Vis Spectroscopy:

The 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.

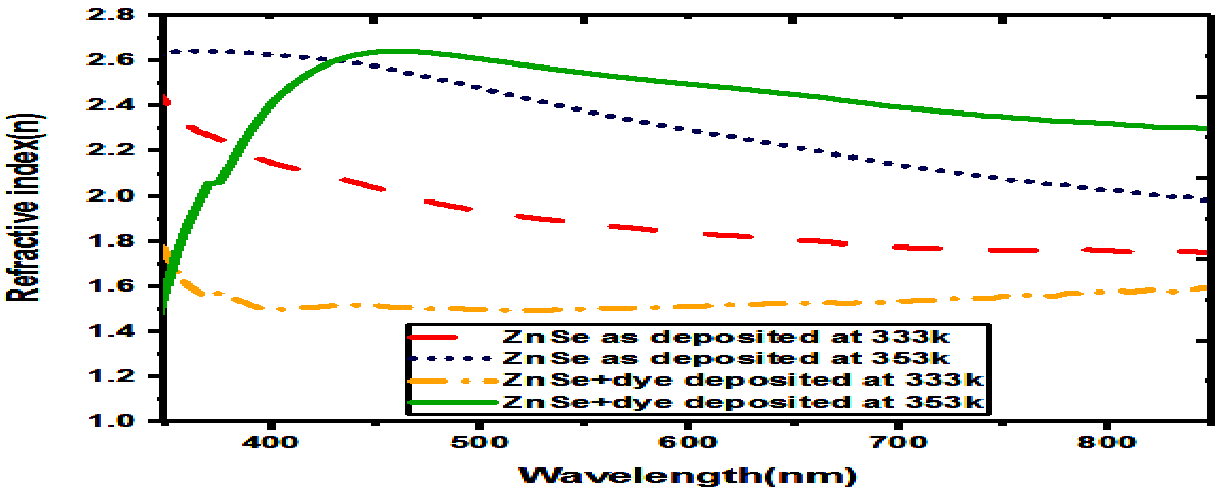


**Fig: 1. plot of Refractive index verses wavelength for dye-sensitized ZnSe**

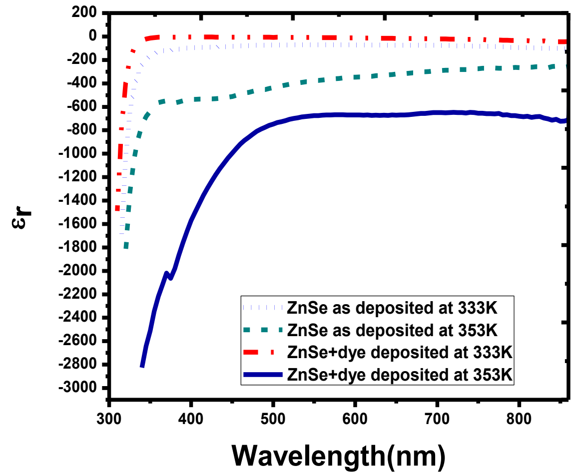


**Fig: 2. plot of dielectric constant (real) verses wavelength for dye-sensitized ZnSe**

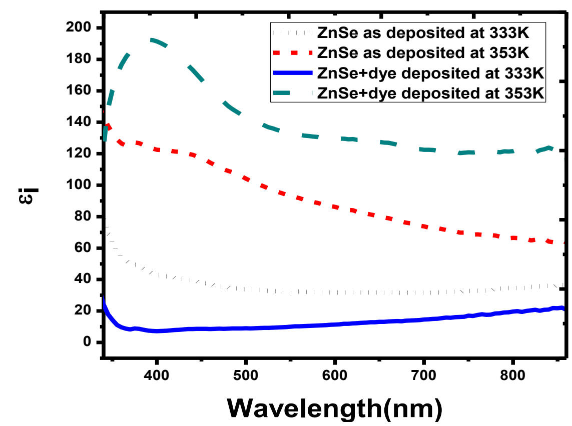


**Fig: 3. plot of dielectric constant (imaginary) verses wavelength for dye-sensitized ZnSe**

The plot of refractive index against wavelength for the deposited dye sensitized ZnSe thin films at different Temperatures is displayed in Fig: 1. it was observed that the index of refraction value tends to decrease as wavelength increases for all the films deposited and varied marginally between 1.20-2.70. It was also observed that the addition of dye increased the refractive index as the deposition temperature increased.

The plot of real and imaginary dielectric constant against wavelength for ZnSe thin films with and without dye is displayed in Figs: 2 and Figs:3 respectively. The plots indicates that the real dielectric constant ($\varepsilon_r$) for all deposited ZnSe thin films ranges from 0.00 to -3000 while the imaginary dielectric constant ($\varepsilon_i$) for all deposited ZnSe thin films ranges from 140 to 180. For films deposited at 333K with and without dye, real dielectric constant was constant between 350 to 850nm. The dielectric constant (real) increased as wavelength increased for all films deposited at 333K. Dielectric constant (imaginary) decreased as wavelength increases at increase in deposition temperature and was highest around the visible region. Materials having high value of dielectric constant will allow light to pass through it slowly and absorbs energy from electric field due to dipole orientation vice versa.

## CONCLUSION

In this study, dye-sensitized ZnSe thin films deposited on glass substrate using solution growth technique have been analyzed. The analysis showed that the deposition temperatures and presence of dye has profound influence on the refractive index and dielectric constant of the deposited films. This could be attributed to the presence of primary photoreceptors (xanthophylls and carotenes) in the dye. The high dielectric constant (imaginary) of the films around the visible region andincreased refractive index value as the deposition temperature increased makes dye sensitized ZnSe thin film a good material for window layer in solar cell fabrication for solar energy harvesting.

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