IMPACT: International Journal of Research in Humanities, Arts and Literature (IMPACT: IJRHAL)
ISSN (P): 2347–4564; ISSN (E): 2321–8878
Vol. 9, Issue 4, Apr 2021, 11–20

OPTICAL PROPERTIES OF DYE EXTRACTED FROM HIBISCUS SADBARIFFA FLOWER

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Received: 02 Apr 2021 **Accepted: 07 Apr 2021** **Published: 10 Apr 2021**

ABSTRACT

Dyes have various technological applications. In this work, the optical properties of dye extracted from the flower of hibiscus sadbariffa were deposited on glass substrate using screen printing technique. The optical properties of the dye were studied using UV –VIS spectrophotometer. The results obtained revealed that the dye has low reflectance and transmittance in the wavelength range of 200 - 900 nm with high absorbance in the wavelength range of 200 - 800 nm. The dye has highest extinction constant in the ultraviolet and visible light regions of the electromagnetic spectrum. Its absorption coefficient is highest in the ultra violet region and reduces towards the infra-red region The reflection coefficient of the dye is high in the ultra violet region and decreases in the infra–red region. The dye has high refractive index that fluctuates with peaks at a wavelength greater than 950nm. The extinction constant of the dye increases with wavelength from 200 - 600 nm its optical conductivity decreases exponentially with wavelength. The dye has an energy band gap greater than 1.5 eV. The results reveal that the dye of hibiscus sadbriffa flower can be used to fabricate solar cells, electronic and solar devices, for selective surfaces and for thermal control.

KEYWORDS: *Dye, Screen Printing, Optical Properties, Selective Surfaces and Solar Devices*

INTRODUCTION

A dye is a colored substance that gets attracted to a substrate once applied to it. For a dye to be applied to a substrate, it must be in aqueous form. Dyes are classified into two groups: natural dyes and synthetic dyes. Synthetic dyes are the type of dyes that are obtained from the mixture of two or more chemicals while natural dyes are obtained from plant source such as roots, leaves, flowers and wood. Most natural dyes present all colors in the visible spectrum [1]. Synthetic dyes are made from synthetic resources such as petroleum by-products and earth minerals. Synthetic dyes have the disadvantages of being expensive, environmental pollutants, toxic and of poor color variation. Natural dyes on the other hand have the advantages of being widely available, inexpensive and environmental friendly. Also, natural dyes do not require sophisticated technology for production. As a result of these advantages, there is a great interest in the use of natural dyes in the fabrication of different electronic devices as the dye is the main factor that affects the performance of a Dye Synthesized Solar Cell (DSSC) [2]. Natural dyes possess excellent light harvesting pigments required for the generation of charge carriers for the production of electricity [3].

Paudel *et al.*,[4]. explored the optical properties of natural dyes extracted from flowers, leaves, back and rhizome of some plant species to know their potentials of being used in dye sensitized solar cells and organic light emitting diodes.

Some of the dyes showed good absorbance in the visible region with blue shift in the absorbance maximum as a result of increase in the polarity of the solvent. Some of the dyes exhibited high fluorescence emission in the visible region with good prospect of being used in the fabrication of organic light emitting diodes. Pratiwi et al., [5] studied the absorption properties of a mixture of dyes extracted from moss chlorophyll and mangosteen peels anthocyanin using UV- VIS spectroscopy. The dye mixture was found to have higher absorbance and improved the conversion efficiency of the dye sensitized solar cell. The effect of optical absorption of natural dyes on the efficiency of dye synthesized solar cells using TiO_2 as working electrode, carbon layer as counter electrode and natural dye from plant species as photosynthesizer was studied by Pratiwi *et al*., [2]. They studied absorption wavelength range, quantum efficiency and the efficiency of the DSSC for the anthocyanin dyes from three different plants. They found that the DSSC had low efficiencies[6].

The use of a material for solar energy applications depends on its possession of some characteristics. High refractive index for example makes a material suitable for anti-reflection coatings. Also, for the use of a material in solar cells, the material must be a direct band semiconductor with small energy band gap and high absorption coefficient [7]. Furthermore, for a surface to be a selective surface, it must have high absorbance over solar spectrum and a low emittance for longer wavelengths to reduce thermal radiative losses [6]. Selective surfaces are capable of absorbing solar energy in the high intensity visible and near infra-red spectral regions and exhibit poor infrared radiating properties. Selective surfaces find applications in solar collectors and solar windows.

Since optical characteristics of dyes are very important factors either for recording media or for dye sensitized solar cell and solar energy applications, in this work, we extracted and deposited dye from *hibiscus sadbariffa* on glass substrate and studied its optical properties to enable us know its potential applications in the fabrication of DSSC and other solar devices.

MATERIALS AND METHOD

Dried flowers of *hibiscus sadbariffa* were purchased from the local market in Agbor, Delta state, Nigeria. The flowers were blended in the laboratory using an electric blender. Ethanol was added to the flowers during blending to extract the pigments. The blended flowers were sieved to extract the pigment which forms the dye. The dye was deposited on glass substrate using screen printing technique.

The substrate used for the deposition was microscopic glass. The glass slides were initially soaked in tetraoxosulphate (vi) acid for twenty-four hours to remove contaminants, washed in detergent solution and rinsed several times in distilled water and dried in an air tight chamber to minimize contamination and stains from dust particles. The optical properties of the dye were studied using AvaSpec –HS204XL ultraviolet visible spectroscope. The reflectance and transmission spectra of the dye were measured in the wavelength range of 200 – 900 nm. The absorption spectra of the dye were obtained using the expression

$$\text{Absorption} + \text{Transmission} + \text{Reflectance} = 1 \quad (1)$$

The extinction constant, k which is a measure of light absorbing capacity of the dye is given as

$$k = \frac{Absorbance}{4\pi} \quad (2)$$

The absorption coefficient, α is a measure of the fraction of incident radiation energy absorbed per unit thickness per unit mass and is given as

$$\alpha = \frac{Absorbance}{wavelenght} \quad (3)$$

The refractive index, $n(\lambda)$ of the dye at different wavelengths were computed using the expression (Ogundare and Olarinoye, 2014)

$$n(\lambda) = \frac{1+\sqrt{R(\lambda)}}{1-\sqrt{R(\lambda)}} \quad (4)$$

Where $R(\lambda)$ is the measured reflectance.

The reflection coefficient was computed using the expression (Osiele. 1992)

$$R_{coeff} = \frac{(1-n)^2 + k^2}{(1+n)^2 + k^2} \quad (5)$$

The refractive index was used to obtain the dielectric constant (note the i = 1) using the equation (Okujagu and Okeke, 1997)

$$\varepsilon_i = 2nk \quad (6)$$

And

$$\varepsilon_2 = (n - ik)^2 \quad (7)$$

Where ε_1 is the real part of the dielectric constant and ε_2 is the imaginary path of the dielectric constant. The optical conductivity of the dye was computed using the expression [8].

$$\sigma_0 = \alpha n c \varepsilon_0 \quad (8)$$

Where c is the speed of light in vacuum and ε_0 is the permittivity of free space.

In order to determine the energy band gap of the dye, direct transition was assumed based on the equation

$$\alpha = A\left(h\nu - E_g\right)^{1/2} \quad (9)$$

Where α is absorption constant, A is a constant, h is Planck's constant, ν is frequency and E_g is energy band gap. A graph of α^2 was plotted against hν and the linear part of the graph was extrapolated to intercept with the hν axis to obtain the energy band gap.

RESULTS AND DISCUSSIONS

The reflectance and transmittance spectra of the dye extracted from *Hibiscus sabdariffa* is shown in Figure.1. It reveals that the dye has low reflectance in the ultra-violet and visible light regions of the electromagnetic spectrum. Also, the reflectance does not vary significantly in the wavelength range of 200 to – 800 nm. For wavelengths between 800 and 1000 nm the reflectance of the dye increased significantly showing a high reflectance at a wavelength of 1000 nm. The reflectance spectrum of the dye reveals that the dye can be used for surface coatings to reflect light in the infra-red regions of the electromagnetic spectrum.

The transmittance spectra of the dye shown in Figure.1 reveals that the dye has low transmittance of about 2% in the wavelength range of 200 – 500 nm with small numerical variations. Above 500 nm, the transmittance increased significantly to a maximum of about 7% at the wavelength of 900nm and fluctuates in the wavelength range of 900 and 1000nm. Generally, the transmittance property of the dye is low although it has maximum transmittance in the infra-red region of the electromagnetic spectrum. The transmittance property of the dye shows that it is a poor transmitter of electromagnetic radiation which makes the dye a potential material for coating of selective surfaces.

The absorption spectra of the dye extracted from *Hibiscus sabdariffa* is shown in Figure 2. The figure which shows a slight increase in absorbance at low wavelength of up to 250nm and continuously decreases very slightly, as wavelength increases. The dye has high absorbance close to unity in the ultraviolet region and about 0.83 in the infra-red region. Above the wavelength of 800 nm, the absorbance fluctuates with maximum absorbance peaks.

The high absorbance of the dye, in the wavelength range of 200 to 800 nm, makes the dye of *Hibiscus sabdariffa* very suitable for solar thermal control in buildings and cars, and as active component in the fabrication of electronic and solar devices. It also makes it suitable for photothermal conversion of solar energy [9]. This property will enable the surfaces on which the dye is deposited to absorb a good portion of the electromagnetic spectrum while allowing the visible part of the electromagnetic spectrum to pass through.

Figure. 3 shows the variation of extinction constant with wavelength for the dye extracted from *Hibiscus sabdariffa.* The figure reveals that the extinction constant is thesame within this wavelength range of 200 to-620 nm. This shows that the dye has a constant light absorbing capacity within this wavelength range. Figure 3 further reveals that in the wavelength range of 200 to – 620 nm, the extinction constant of the dye is 0.08, the extinction constant of the dye is 0.07 in the wavelength range of 630 to – 830 nm but for the wavelength range of 840 to-890 nm, the extinction constant of the dye is 0.06. This indicates that the dye of *hibiscus sabdariffa* has the highest extinction constant in the ultraviolet region of the electromagnetic spectrum and this constant decreases as we move to the infra- red region of the electromagnetic spectrum indicating that the dye of *hibiscus sabdariffa* absorb more light in the ultra-violet and visible light sections of the electromagnetic spectrum.

The absorption coefficient of the dye reduces exponentially with wavelength as shown in Figure. 4. This indicates that the dye of *hibiscus sabdariffa* has high absorption coefficient in the ultraviolet region of the electromagnetic spectrum and very small absorption coefficient in the infra – red region of the electromagnetic spectrum showing that the dye of *hibiscus sabdariffa* is a good absorber of the ultra –violet part of the electromagnetic spectrum.

The reflection coefficient of the dye obtained from *hibiscus sabdariffa* is shown in Figure. 5, which reveals that in the wavelength range of 200 to– 900 nm, the reflection coefficient of the dye reduces gradually. But for the wave range of

950to – 1000 nm, the reflection coefficient reduces with fluctuations. The reflection coefficient of the dye is quite high showing that it is a good reflector of electromagnetic radiations from the ultra violet region to the infra- red regions.

The variation of the refractive index with wavelength for the dye extracted from *hibiscus sabdariffa* is shown in Figure. 6. The figure reveals that the refractive index of the dye does not vary so much with wavelength in the wavelength range of 200 to – 900 nm. But between 900 to-1000 nm, the refractive index varies very high and fluctuates with peaks. Between the wavelength ranges of 187to – 900 nm, the refractive index varies between 1.33 and 2.03, but between the wavelength ranges of 910 – 1000 nm, it varies between 2.33 and 4.17. Within the ultra violet, visible and infra –red regionof the electromagnetic spectrum, the refractive index of the dye of *hibiscus sabdariffa* is higher than that of water and glass.

The variation of the optical dielectric constant and optical conductivity of the dye extracted from *hibiscus sabdariffa* with wavelength is shown in Figure 7. It reveals that from wavelengths of 200 nm, the dielectric constant increases with wavelength until it gets to a maximum at a wavelength of about 1000 nm. This shows that transverse electromagnetic wave can propagate through the dye without attenuation since the dielectric constant is greater than zero for wavelength range of 200 to-1000 nm.

Figure 7 also shows that the optical conductivity of the dye reduces exponentially with wavelength in the wavelength range of 200 – 1000nm. This shows that the dye has high optical conductivity in the ultra violet region of the electromagnetic spectrum and very low optical conductivity in the infra-red region of the electromagnetic spectrum [11].

In order to obtain the energy band gap of the dye, a direct band transition was assumed for the dye. A graph of α^2 against hν was plotted and the linear part was extrapolated to the hν axis to obtain an energy band gap of about 2.3 eV for the dye as shown in Figure 8. With the energy band gap of 1.5 eV, the dye can be used for the fabrication of solar cells and electronic devices, for solar coating and as a selective surface. For semiconductors, the optical properties have some similar features [11-12]. The achievement of aluminum selenide thin films from aluminum chloride as source of aluminum and selenium dioxide as a source of selenium using electrodeposition technique as shown in [11-12] finds the Absorption spectrum as a function of wavelength, reflection spectrum as a function of wavelength, absorption coefficient as a function of wavelength and Extinction coefficient as a function of wavelength.

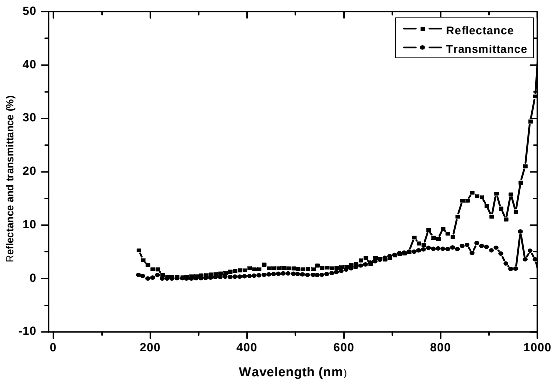

Figure 1: Reflectance and Transmittance Spectra of the Dye Extracted From Hibiscus Sabdariffa.

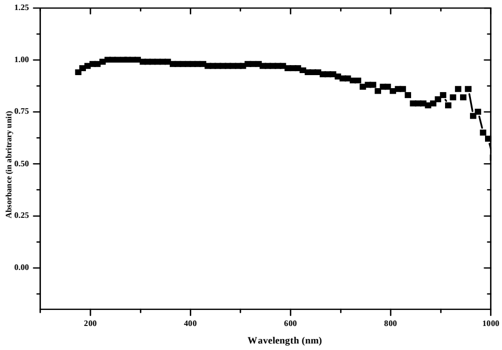

Figure 2: Absorption Spectra of the Dye Extracted From Hibiscus Sabdariffa.

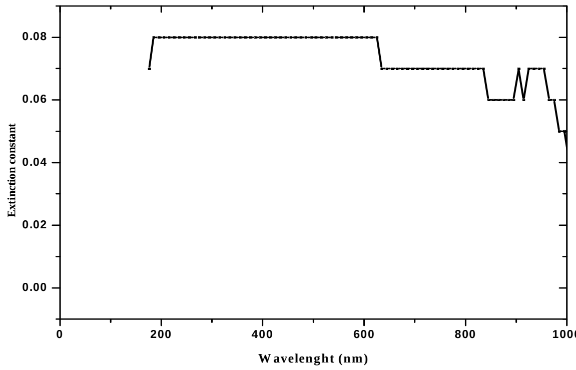

Figure 3: Variation of Extinction Constant with Wavelength for the Dye Extracted From Hibiscus Sabdariffa.

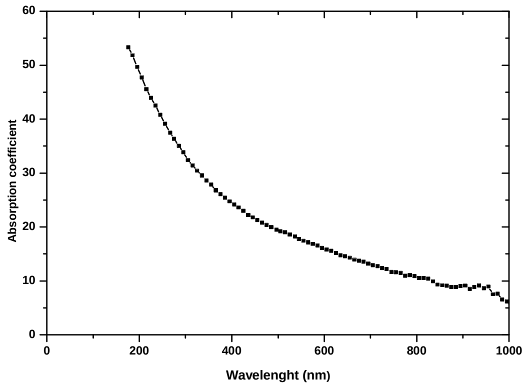

Figure 4: Variation of Absorption Coefficient with Wavelength for the Dye Extracted from Hibiscus Sabdariffa.

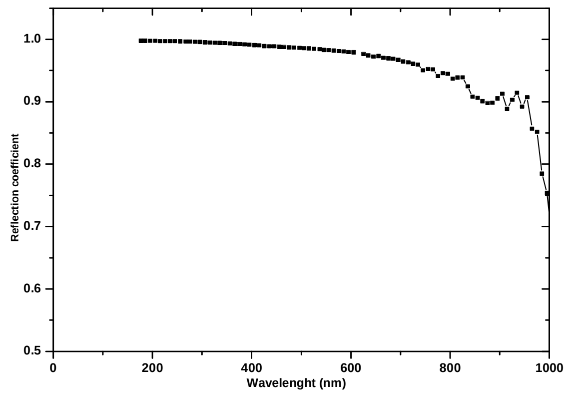

Figure 5: Variation of Reflection Coefficient with Wavelength for Dye Extracted From Hibiscus Sabdariffa.

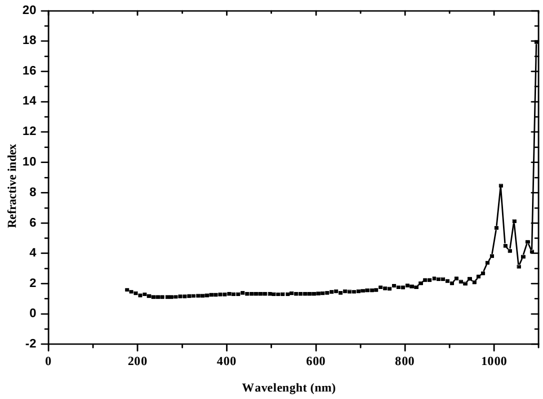

Figure 6: Variation of Refractive Index with Wavelength for Dye Extracted from Hibiscus Sabdariffa.

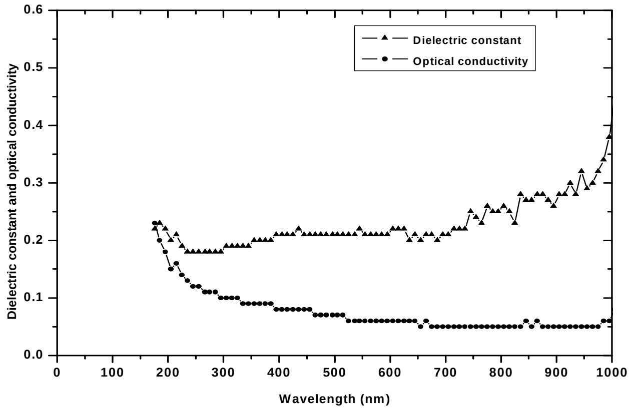

Figure 7: Variation of Optical Dielectric Constant with Optical Conductivity With Wavelength for Dye Extracted From Hibiscus Sabdariffa.

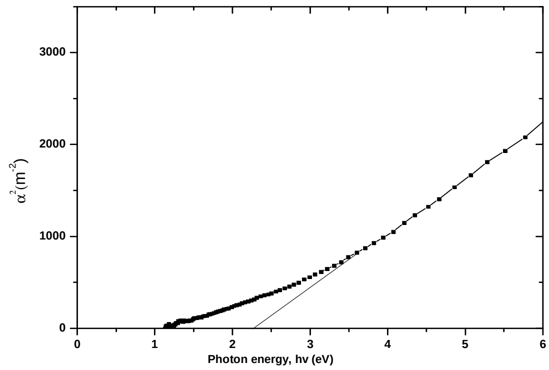

Figure 8: Determination of the Energy Band Gap of the Dye Extracted from Hibiscus Sabdariffa.

CONCLUSIONS

Optical properties of the dye extracted from the flower of *hibiscus sadbariffa* have been successfully studied. The dye has high absorbance, low reflectance and low transmittance. The dye has high reflectance coefficient and high absorption coefficient with a small energy band gap. These properties make the dye a potentially suitable material in the fabrication of electronic devices, solar cells and solar devices. The refractive index of the dye is high, the optical conductivity of the dye decreases exponentially with wavelength while the dielectric constant increases with wavelength. These properties reveals that the dye extracted from the flower of hibiscus *sadbariffa* can be used for surface coatings, selective surface and solar thermal control.

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