

STUDY, FABRICATION AND CHARACTERIZATION OF MANGIFERA INDICA BASED DYE SENSITIZED SOLAR CELL

BY

¹Salawu M. A; ¹Alabi A. B; ²Muhammad .S. and ¹Akomolafe T.

¹Department of Physics, University of Ilorin

²Department of Physics with Electronics, Federal University Birnin Kebbi

Email: abideen2004@gmail.com. GSM: 08030788553.

ABSTRACT

The study, fabrication and characterization of *Mangifera Indica* based dye sensitized solar cell (DSSC) were carried out. *Mangifera Indica* pigment was extracted using 5g of *Mangifera Indica* leaves soaked in 10 mls of methanol for 72 hours. The microscopic glass substrates were dipped into the solution to have the thin film of about 1 μm thickness. The UV-visible spectrophotometry analysis was carried out on the film to measure the percentage transmittance and Beer's Lambert law was employed for the estimation of absorbance of the *Mangifera Indica* film at each wavelength in the visible to near infrared region of the solar spectrum. The Fourier Transform Infrared (FTIR) and Atomic Absorption (AAS) spectroscopy analyses were carried out to determine the functional groups and elemental compositions of the *Mangifera Indica* photo sensitizer respectively. The pH of the pigment was investigated using pH meter. The *Mangifera Indica* based DSSC was fabricated using Indium Tin Oxide (ITO) glass substrate, *Mangifera Indica* pigment as photo-sensitizer, Titanium dioxide (TiO_2) paste, graphite paste and iodide/triiodide electrolyte. The result of UV-Visible spectrophotometry analysis shows the transmittance ranges of 55 % to 78 % and absorbance of 0.1 a.u to 0.35 a.u in the visible to near infrared region of the solar spectrum. The pH meter displayed the pH of 3.6 for the *Mangifera Indica* pigment. The AAS analysis confirmed 0.1 mg/L each for iron (Fe), zinc (Zn) and magnesium (Mg) and 0.2 mg/L of sodium (Na) respectively. The FTIR analysis confirmed the O-H, C=C, ϕ -O-H and C-H stretching at 3270 cm^{-1} , 1636 cm^{-1} , 1261 cm^{-1} , 1084 cm^{-1} and C-H and C-Br bending at 1019 cm^{-1} and 661 cm^{-1} respectively. The maximum open circuit voltage generation of 132 mV was estimated for the *Mangifera Indica* based DSSC using digital multimeter.

Keywords: *Mangifera Indica*, DSSC, Photosensitizer, UV-Visible spectrophotometry, DSSC

Introduction

The photosynthetic green plants are very common in Nigeria and rich in chlorophyll and the use of this natural pigment has been regularly examined in several studies for different applications. Among the researchers that have examined one chlorophyll pigment or the other were Abdulsalam *et al.*, 2016; Alahmed *et al.*, 2015; Danladi *et al.*, 2016; Gong and Sumathy, 2012; Hatem *et al.*, 2015; Kamal *et al.*, 2015; Kroon and Lenzmann, 2007 and Mohammed *et al.*, 2017.

The history of *Mangifera Indica* (Mango) began thousands of years ago on the Indian sub-continent. It is the home fruit of many countries including Nigeria, India, Pakistan and the Philippines (Indu, 2017). *Mangifera Indica* is considered as one of the most important fruits crops in tropical and subtropical areas of the world (Uno *et al.*, 2015). It has several medical health benefits such as anti-aging activities and anti-oxidant in food to mention but few. The advantages of using natural dyes extracted from leaves over synthetic dyes as photosensitizers in the fabrication of Dye Sensitized Solar Cell (DSSC) are because of their availability and affordability. *Mangifera Indica* contained tannin, anthocyanins and carotenoids sensitizers (Uno *et al.*, 2015). Figure 1 shows the *Mangifera Indica* leaves used as photosensitizer in this study.



Figure 1: *Mangifera Indica* leaves

MATERIALS AND METHOD

5g of *Mangifera Indica* leaves was soaked in 10 mls of methanol for 72 hours. The microscopic glass substrate was dipped into the extracted pigment to have the thin film of about $1\ \mu\text{m}$ thickness. The UV-Visible spectrophotometry analysis was carried out on the film to measure the percentage transmittance and Beer's Lambert law was employed for the estimation of absorbance of *Mangifera Indica* film at each wavelength in the visible region to near infrared region of the solar spectrum. The Fourier Transform Infrared (FTIR) and Atomic Absorption (AAS) spectroscopy analyses were carried out to determine the functional groups and elemental compositions of the *Mangifera Indica* photo sensitizer respectively. The pH of the pigment was investigated using pH meter. The *Mangifera Indica* based DSSC was fabricated using Indium Tin Oxide (ITO) glass substrate, *Mangifera Indica* pigment as photo-sensitizer, Titanium dioxide (TiO_2) paste, graphite paste and iodide/triiodide electrolyte. The fabricated *Mangifera Indica* based DSSC was tested with digital multimeter to measure the open circuit voltage.

RESULTS AND DISCUSSION



Figure 1: pH measurement of *Mangifera Indica* pigment
The *Mangifera Indica* pigment has the pH value of 3.6 which shows the acidity of the chlorophyll pigment.

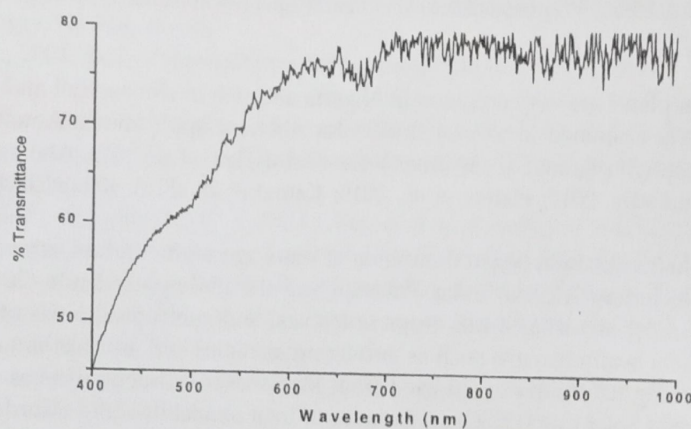


Figure 2: Transmittance spectrum of *Mangifera Indica* thin film

Figure 2 shows the percentage transmittance against wavelength (nm) of *Mangifera Indica* film. The wavelength range of the spectrum lies between 400 nm and 1000 nm in the visible to near infrared region. The observed transmittance increases as the wavelength increases in the visible to near infrared region of the solar spectrum. The transmittance is relatively stable between the wavelength ranges of 600 nm to 1000 nm.

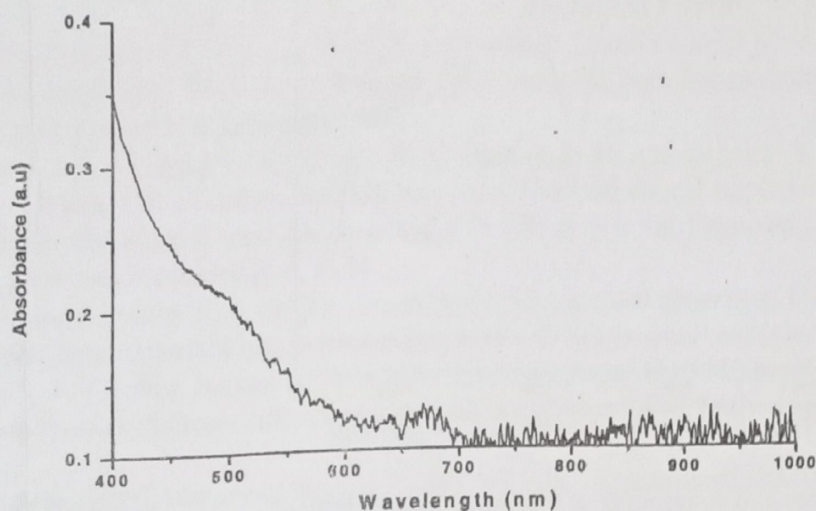


Figure 3: Absorbance spectrum of *Mangifera Indica* film

Figure 3 shows the plot of absorbance against the wavelength (nm) of *Mangifera Indica* film. The absorbance of *Mangifera Indica* film was calculated using Beer's Lambert law. The maximum absorption of the photons by the dye occurred between 400 nm and 550 nm wavelengths with the maximum peak value of 0.35 at 400 nm and decreases as the wavelength increases throughout the visible region to near infrared region. The absorbance of the dye ranges from (0.1-0.35) arbitrary unit. The movement of electrons from the ground state to the excited state and the energy absorbed were shown in the absorbance spectrum. The absorbance at each wavelength was calculated using equation (1).

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

Where A is absorbance, T is Transmittance and $\log_{10}$ is the common logarithm.

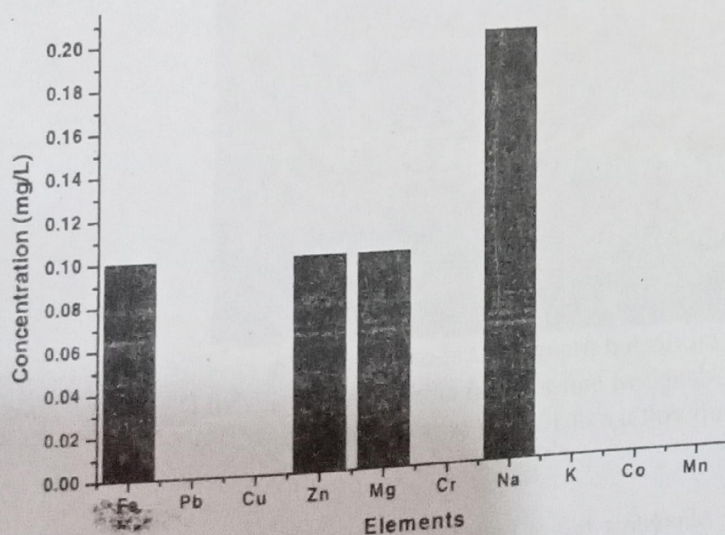


Figure 4: Bar chart showing the elemental composition of *Mangifera Indica* pigment. The results of Atomic Absorption Spectroscopy (AAS) confirmed the presence of iron (Fe), zinc (Zn), magnesium (Mg) and sodium (Na) at different concentrations. The concentration of 0.21 mg/L was confirmed for sodium and 0.1 mg/L each for iron, zinc and magnesium.

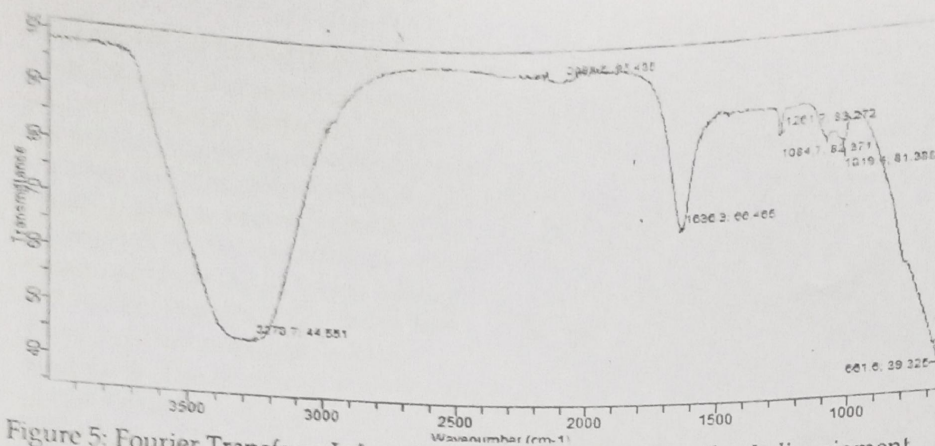


Figure 5: Fourier Transform Infrared (FTIR) spectrum of *Mangifera Indica* pigment

Table 1: Showing the origin, wavenumber and assignment of *Mangifera Indica* pigment

Origin/Group	Wavenumber (cm ⁻¹)	Assignment/Compound Class
O-H	3270	Hydroxyl group, H-bonded, OH stretch
C=C	1636	Alkyl C=C stretch
φ-O-H	1261	Aromatic ethers, Aryl-O-H stretch
C-H	1084	Aromatic C-H in plane bond
C-H	1019	Aromatic C-H in plane bond
C-Br	661	C-Br stretch

Figure 5 shows the FTIR spectrum and Table 1 shows the origin, wavenumber and assignment of *Mangifera Indica* pigment with its vibration and stretching modes. It was observed that the peaks ascribed to *Mangifera Indica* are O-H (stretching) at 3270 cm⁻¹, alkyl C=C (stretching) at 1636 cm⁻¹, aromatic ethers, φ-O-H (stretching) at 1261 cm⁻¹, C-H (stretching) at 1084 cm⁻¹ and 1019 cm⁻¹, C-Br (stretching) at 661 cm⁻¹.



Figure 6: Testing of fabricated *Mangifera Indica* based DSSC

Figure 6 show the testing of fabricated *Mangifera Indica* based DSSC. The fabricated DSSC was tested with digital multimeter and the maximum open circuit voltage of 132 mV was estimated.

CONCLUSION

The study, fabrication and characterization of *Mangifera Indica* based dye sensitized solar cell were carried out. The UV-Visible spectrophotometry results showed that the transmittance of *Mangifera Indica* film increases with wavelength from 45 % to about 80 % and the absorbance decreases abruptly from 0.1-0.35 arbitrary unit as the wavelength increases from 400 nm to 1000 nm in the visible to near infrared region of the solar spectrum. The AAS analysis of *Mangifera Indica* pigment confirmed the presence of zinc, iron, magnesium and sodium at different concentrations. The FTIR analyses shows the O-H, C=C, φ-O-H, C-H and C-Br stretching at respective wavenumbers. The testing of the fabricated *Mangifera Indica* based DSSC displayed the maximum open circuit voltage of 132 mV.

REFERENCES

- Abdulsalam M. S., Abdu S. G., Danladi E., Jonathan E. and Onimisi M. Y. (2016): 'Photovoltaic Performances of Dye Sensitized Solar Cells Using Natural Dyes Extracted from Bougainvillea Flower and Mango Leaves', *Journal of Scientific Research & Reports*, 10, 1-5.
- Alahmed Z.A., Chysky J., Mukhzeer M.S., Reshak A. H. and Suhaimi S. (2015): 'Materials for Enhanced Dye-sensitized Solar Cell Performance', *Int. Journal of Electrochemical Application*, 10, 2859 – 2871.
- Danladi E., Jonathan E. and Muhammad Y.O (2016): Natural Pigments as Sensitizers for Dye Sensitized Solar Cells, *Advances in Materials*, 5, 31-34.
- Gong J. and Sumathy K. A (2012): Theoretical study on third generation Photovoltaic Technology: Dye-sensitized solar cells, *International Conference on Renewable Energies and Power Quality*, 14, 1845-1859.
- Hatem S., El-Ghamri, Sofyan A. Taya S.A., Taher M., Amal M., Al-Kahlout N., Monzir S., and Abdel-Latif (2015): 'Natural Dyes as Photosensitizers for Dye-sensitized Solar Cells', *Journal of Nano and Electronic Physics*, 7, 3-6.
- Indu Mehta (2017): History of Mango – 'King of Fruits', *International Journal of Engineering Science Invention*, www.ijesi.org 6(7), 20-24.
- Kamal S. E., Monzir S. A, Taher M. E. and Taya S. A. (2015): Dye-sensitized solar Cells based on dyes extracted from dried plant leaves, *Turkish Journal of Physics*, 39, 24-30.
- Kroon J. M. and Lenzmann F. O. (2007): Recent Advances in Dye-Sensitized Solar Cells, Hindawi Publishing Corporation *Advances in Opto-Electronics*, 20, 10.
- Mohammed Isah Kimpa, Kasim Uthman Isah, Jibrin Alhaji Yabagi, Sulaiman Taufiq, Mohd Arif Bin Agam (2017): Synthesis and Characterization of Natural Sensitizers for Dye Sensitized Solar Cells, *Traktoriâ Nauki = Path of Science* 3(10), 2001-2006. ISSN: 2413009.
- Uno, U.E., Emetere, M.E., Fadipe, L.A., Oyediji, J. (2015): Progress on *Mangifera indica* As Dye Sensitized Solar Cell, *International Journal of Applied Engineering Research*, Research India Publications 10(7), 17685-17695, ISSN 0973-4562.