Synthesis and characterization of properties of zinc coated Thaumatococcus daniellii extracts for solid state application

Emetere M.E.1,2 & Ahiara Ikechukwu M.1,

1 Department of Physics, Covenant University Canaan land, P.M.B 1023, Ota, Nigeria.
2 Department of Mechanical Engineering Science, University of Johannesburg, South Africa.

Abstract. Recent technological inventions focus on the eco-friendly device that would not constitute hazard to immediate environment i.e. both in the short and long term. This research focus on screening bio-semiconductor using synthesized zinc coated Thaumatococcus daniellii extract. The band gap of sample 1 (extract in methanol solution), sample 2 (extract in ethanol solution) and sample 3 (extract in butanol solution) was calculated as 2 eV, 1.67 eV and 2 eV respectively. Also, the low and high Q-transition energy in the ethanol and butanol solution was able to show that the d-shell (d^{10}) of the zinc atom was modified. This modification is a huge possibility of deriving bio-semiconductor from plant extract.

1. Introduction
Recent research is now focusing on eco-friendly technologies device. The hazards of waste disposal of used electronics device have revealed that the components of electronics are not eco-friendly at the long-term. Hence, there is the need to go on sustainable bio-materials that are eco-friendly both in the short and long term [1-4]. A material that meets this description is the adoption of plant extract. Hence, beyond the use of plant extract for medicinal, pharmaceutical, food additive and dye purposes, it use has extended into electronics such as semiconductor, bio-filters etc.

Cataldi et al.[5] worked on an environmentally friendly, adaptable and applicable electronic component development approach relying on crop components and graphene. A major monomer of sheellac and tomato cuticula with graphene is produced by the combination of a corn-derived protein, aleuritic acid and zein, bio composite conductors with low electrical resistance (almost 10 sq−1) with outstanding mechanical and fatigue strength. Various high-performance electronic applications are observed, such as THz electromagnetic shielding, flexible GHz antenna construction, and flexible solar cell electrode. Comparable to traditional non-degrading equivalents, outstanding performance results are evaluated from each implementation. Azmi et al. [6] did a study on the ability of the extract of aloe vera as an electrolyte for an accumulator; Aloe Vera comprises of acid that can produce electrical current. Results from the experiment identified that aloe vera extract does not have a stable voltage and currency value and demonstrated the potential use of aloe vera extract in reduction the chemicals applied in a conventional electrolyte solution.

In this research, the metallic coated plant extract was synthesized for the purpose of performing initial screening for semiconductor device. The UV-Vis spectrometry was used to characterize the sample. UV-Vis spectrometry is simple and cost-effective characterization method. The UV-Vis light is passed through a sample and the transmission of light by a sample is measured [7-9]. The absorbance is mathematically calculated from the transmittance (T) mathematically by
$A = -\log(T)$

where transmittance is calculated as

$T = -\log\left(\frac{I}{I_0}\right)$

where $I$ is the intensity of the UV light. The quantity of absorption at any wavelength is due to the molecule's chemical structure [10-12]. Ref [13] used the UV-Vis spectrometry to examine the interactions of molecularly imprinted sensors (MIPs) where only the change in absorbance is measured as a function of wavelength. Zinc oxide has been proven to have tremendous optical properties that make them a good candidate as optoelectronic devices [14-15].

2. Methodology

Fresh *Thaumatococcus daniellii* leaves (Figure 1) were collected from Ota, Ogun state, Nigeria. The leaves were obtained in less than an hour after rainfall. The inherent chemical components of *Thaumatococcus daniellii* (i.e. tetracontane (28.76%) and L-ascorbic acid (15.07%); hexadecanoic acid (21.62%) and γ-sitosterol (11.06%) [16])

![Figure 1. Thaumatococcus daniellii](image)

This process is to enable the clean nature of the leaf before grinding. The leaves were divided into three portions. Each portion was grinded in electronic blender using methanol, ethanol and butanol as solution for each portion of the leaf. The homogenous liquid was filtered using a sieve. The filtrates were placed in enclosed petri dishes and heated in an oven at 90 °C for 1 hour and allowed to cool and settle for 24 hours. After cooling, 0.05 mole of zinc carbonate was added and heated for 20 minutes at 80 °C. The filtrates were stored in airtight bottles. The filtrates were allowed to settle for 24 hours. Then the filtrates characterized using the UV-Vis spectroscopy and water has the diluting medium. The dilution factor is 10.

3. Results and Discussion

The absorbance from the UV-Vis spectrometry is presented in Figure 2. Sample 1 is the zinc coated *Thaumatococcus daniellii* extract that has been processed with methanol. Sample 2 is the zinc coated *Thaumatococcus daniellii* extract that has been processed with ethanol. Sample 3 is the zinc coated *Thaumatococcus daniellii* extract that has been processed with butanol. The zinc wavelength is already known i.e. 362-381 nm [16-17]. In this research, we are more interested in the $\pi-\pi$ transitions of the zinc coated plant extract; hence the wavelength that was considered was 400-650 nm. [18-21]. Figure 2a shows sample 1 having one $\pi-\pi$ transition at wavelength of 625 nm. This shows that the components of the *Thaumatococcus daniellii* extract in methanol had no influence on the d-shell of the zinc coating. It was observed that the ethanol solution in sample 2 has enabled complex that has enabled the second $\pi-\pi$ transitions as presented in Figure 2b. The Zn$^{2+}$ atom that has adjacent singlet and triplet states (that lie on same orbital symmetry) is the likely cause of the second transition. Figure 2c showed the intense Q peak transition energy at 625 nm. The same Q peak transition energy is said
to be responsible for the transition at 545 nm. Based on literature [22-24], the Q- band of the \( \pi-\pi \) transitions exists at the point (iii)\&(iv) of Figure 2c. The point (i) and (ii) in Figure 2c are as a result of low Q peak transition energy on the components of the \textit{Thaumatococcus daniellii} extract. The transition patterns in samples 1-3 have made easy to identify the Q-transition in the complexes of transition metal ions (e.g. zinc) with macrocyclic ligands (components of \textit{Thaumatococcus daniellii} extract).

![Figure 2](image-url)

**Figure 2.** UV-Vis absorption spectrum zinc coated \textit{Thaumatococcus daniellii} extracts (a) extract in methanol solution (b) extract in ethanol solution (c) extract in butanol solution

Using the power series (equation 3) curve fitting, it was easy to identify the coefficients in the equation as presented in Table 1. It can be shown by the coefficients that sample 2 and 3 has something in similar i.e. the low and high Q-transition energy. This is because the ethanol and butanol was able to modify the d-shell (d\(^{16}\)) of the zinc atom.

\[
y = ax^b + c
\]

(iii)

| Table 1. Coefficient of the power series curve fitting |
| --- | --- | --- |
| Sample 1 | 6.408E5 | -2.1638 | 0.57759 |
| Sample 2 | 45551 | -1.7814 | 0.99505 |
| Sample 3 | 22611 | -1.7083 | 0.59194 |
The statistical models further validated the results in Table 1 as shown in Table 2. The second evidence that sample 2 and 3 has the high and low q-transition energies are shown by the one-way ANOVA. The one-way ANOVA between sample 1 and 2 shows that the following statistical output: variance in the group (sample 1 and 2) is 0.0215395; omega square is 0.1651; Levene’s test for homogeneity of variance, from means p (same) is 2.081E-13; Levene’s test, from medians p (same) is 2.283E-10; Welch F test in the case of unequal variances are F=100.3, df=429, p=2.364E-21.

Table 2. Statistical models for analyzing the absorbance of the synthesized material

|                | Sample 1 | Sample 2 | Sample 3 |
|----------------|----------|----------|----------|
| Taxa_S         | 251      | 251      | 251      |
| Individuals    | 264      | 268      | 206      |
| Dominance D    | 0.004125 | 0.00403  | 0.004039 |
| Simpson 1-D    | 0.9959   | 0.996    | 0.996    |
| Shannon H      | 5,508    | 5,52     | 5,519    |
| Evenness e^H/S | 0.9831   | 0.9945   | 0.9933   |
| Brillouin      | 3,091    | 2,675    | 3,108    |
| Menhinick      | 13.06    | 12.23    | 14.93    |
| Margalef       | 44.84    | 44.71    | 46.92    |
| Equitability J | 0.9969   | 0.999    | 0.9988   |
| Fisher_alpha   | 345.1    | 261.4    | 0        |
| Berger-Parker  | 0.005419 | 0.004745 | 0.003536 |
| Chao-1         | 251      | 251      | 252      |

Figure 3. Residual plot of absorption spectrum of zinc coated *Thaumatococcus daniellii* extracts (a) extract in methanol solution (b) extract in ethanol solution (c) extract in butanol solution
The one-way ANOVA between sample 2 and 3 shows that the following statistical output: variance in the group (sample 2 and 3) is 0.152449; omega square is 0.7538; Levene’s test for homogeneity of variance, from means p (same) is 1.877E-06; Levene’s test, from medians p (same) is 0.006585; Welch F test in the case of unequal variances are F=1538, df=459.4, p=1.104E-148. The one-way ANOVA between sample 1 and 3 shows that the following statistical output: variance in the group (sample 1 and 3) is 0.058897; omega square is 0.385; Levene’s test for homogeneity of variance, from means p (same) is 1.123E-28; Levene’s test, from medians p (same) is 1.241E-20; Welch F test in the case of unequal variances are F=315.2, df=358.5, p=4.728E-51. It is clearly shown that sample 2 & 3 had more in common compared to other group. Also, the residual plot presented in Figure 3 affirmed earlier postulation (via the magnitude and pattern of the residuals) that sample 2 and 3 (Figure 3b) is more related. The band gap of the synthesized is given as is given as 2 eV, 1.67 eV and 2 eV for sample 1, 2 & 3 respectively.

4. Conclusion
The zinc coated Thaumatococcus daniellii extract has proven to have tremendous properties that makes it a good candidate for the green solution semiconductor device. The band gap of the synthesized is given as is given as 2 eV, 1.67 eV and 2 eV for sample 1, 2 & 3 respectively. Also, the low and high Q-transition energy in the ethanol and butanol solution was able to show that the d-shell (d10) of the zinc atom was modified. It was discover that the butanol extraction solution (sample 3) was the most viable sample with four π-π transitions that connote that there was formation of oxide layer via the modified adjacent singlet and triplet states that lie on same orbital symmetry.

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