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# Bulk Heterojunction Solar Cell Fabricated using Plant Extracts

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## ABSTRACT

This research study is an in-depth material investigation including the behavior of the wild olive extraction and Jamson dye mixture to be used in bulk heterojunctionphotovoltaic cells. Characteristics of the bulk heterojunction solar cell and how the performance of cell changes with the introduction of different amount of Potassium Iodide (KI) was also investigated. Based on experiments subjected to various compositions in additions of above low-cost natural materials, it was able to optimize the photovoltaic parameters through the change of KI concentration as well as mixturing ratio of the wild olive extracts and the dye of Jamson fruit. Accordingly, the best amount of KI to achieve the maximum current density was 0.075 g while the maximum values of both current density and photovoltage were simultaneously acquired when the olive extraction and dye of Jamson fruit were mixed with 1: 2 ratios. Under above optimized circumstances, it delivered 75$\mu$A$cm^{-2}$ short circuit photocurrent density, 160 mV open circuit voltage, with 28.13% fill factor and 0.0034 % energy conversion efficiency.

## 1. INTRODUCTION

Due to the rising concerns over the exhaust of fossil fuel and the associated environmental consequence of the carbon emission problem, search for renewable energy has become a hot research topic worldwide. Organic semiconducting materials based photovoltaic (PV) technology developments have attracted tremendous attention from both the academic community and the industry. In principle, the organic solar cells employ organic material-based light-absorbing functional layers to convert sunlight to electricity. Typically, the light absorbing layer is made of a blend of donor material and a fullerene based acceptor materials. The observation of the photovoltaic effect on organic materials began in 1986 with the two-layer device with a structure of ITO/copper phthalocyanine/perylenediamide/gold [1]. Later in the early 1990s, the discovery of ultrafast charge transfer from polymer to fullerene initiated the research field of bulk hetero-junction (BHJ) solar cells [2]. Over the past two decades, substantial research progress in the development of more robust light harvesting materialswere themost popular research area among researches.The further modification of the modeling theory of the OPV physics, better understanding and elucidation of the light-to-electricity process and the continuous optimization of the device fabrication process with new strategies employed improved the performance in terms of efficiency. [3]

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## 2. EXPERIMENTAL

### 2.1. Preparation of Wild Olive extraction

Initially, 20g of Wild Olive leaves were taken and added with 25ml of ethanol and 20ml of water. The mixture was ground for 30min using ablender.The blended mixture was strained using a cloth strainer and squeezed. Extra concentrated HClwas added to the liquid until a precipitate was obtained.The precipitate was separated from the solution using centrifugation.The precipitate was washed three times using distilled water.Then 5 ml of ethanol was added to it and mixed well.

### 2.2. Preparation of Jamson dye solution

10g of Jamson fruit was taken and 6ml of ethanol was added to it. Then it was ground well using a blender. The mixture was strained as mentioned earlier.

### 2.3. Preparation of the coating mixture

According to volume ratios of WildOlive and Jamson dyes were stirred thoroughly for 1 hour.The volume ratios of Olive and Jamson were 1:1 and 1:2. Then the required composite solution was prepared by adding different amounts of Potassium Iodide to both ratios of mixture of two dyes. The Potassium Iodide masses added to the mixture were 0.025 g, 0.050 g, 0.075 g, 0.100 g, 0.125 g.

### 2.4. Preparation of Platinum counter electrodes

Fluorine-doped Tin Oxides (FTO) glass plates were cut into the size of 1cm × 2 cm, which were cleaned in an ultrasonic bath using tap water, distilled water and ethanol respectively. The washed glass plates were boiled in an isopropyl alcohol solution in a beaker over a hot plate at 60 ˚C for 15 minutes. Then two drops of cloroplatinic acid in ethanol (.01 M) were coatedon the conducting side of the FTO glass and heated at200˚C using a hot plate.

### 2.5. Photovoltaic cell Assembling and characterization

Mixture coated FTO glass and Pt sputtered conducting glass plate were assembled together using two clips. After assembling, the Photovoltaic cell was energized under a 1000 $Wm^{-2}$ light source. The photovoltaic parameterswere characterized by galvanostat/potentiostatwithScience workshop 750 interface coupled with a computer.TheMott-Schottky measurements were analyzed using a computer coupled with MetrohmAutolab PGSTAT204.

## 3. RESULTS AND DISCUSSION

Table 1 showsthe open circuit voltage ($V_{oc}$) and short circuit current ($I_{sc}$) of photovoltaiccells with an area of 1 $cm^2$ under the illumination of 1000 $Wm^{-2}$ which were prepared by using two ratios of mixture of dyes with potassium iodied (KI).

**Table 1**: Open circuit voltage ($V_{oc}$) and short circuit current ($I_{sc}$) of photovoltaic cells

| Mass of KI | 1:1 ratio of Olive and Jamonextract | | 1:2 ratio of Olive and Jamonextract | |
|---|---|---|---|---|
| | $V_{oc}$(mV) | $I_{sc}$(μA) | $V_{oc}$(mV) | $I_{sc}$(μA) |
| 0.025g | 71 | 0.3 | 140 | 4.1 |
| 0.05g | 284 | 1.8 | 297 | 27.0 |
| 0.075g | 236 | 7.3 | 161 | 75.0 |
| 0.1g | 356 | 22.6 | 181 | 6.5 |

Figure 1 shows the plot of current density (J) Vs voltage (V) characteristics of the photovoltaic cell with an area of 1 $cm^2$ under the illumination of 1000 $Wm^{-2}$whilethe amount of Potassium Iodide was changed.Figure 1 clearly shows the change of the photocurrent for a different amount of Potassium Iodide in the mixture of Olive and Jamson. By changing the Potassium Iodide amount added to the mixture, the photovoltaic current has changed and the maximum current was given by 0.075g, which is 75μ$Acm^{-2}$.

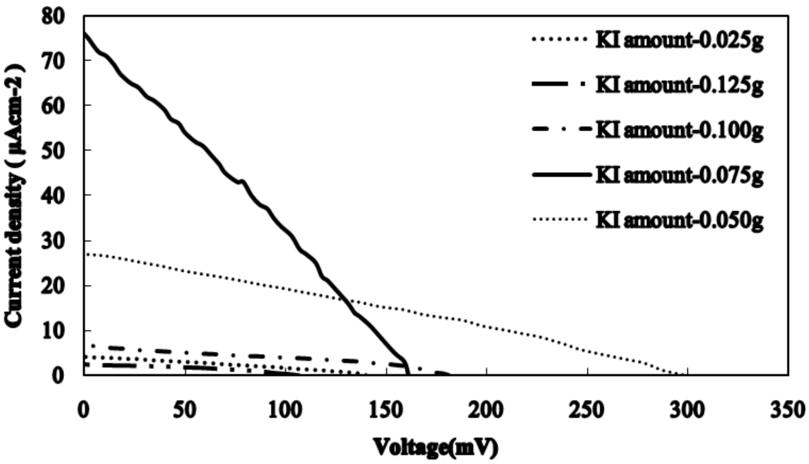


**Figure 1:** Behavior of the current density (J) vs voltage (V) curves for different amounts ofKI

Table 2 shows the short circuit current density (Jsc), open circuit voltage (Voc) and calculated results using equations 1 and 2 for fill factor (FF) and the energy conversion efficiency (η) of photovoltaic cell.

$$FF = (\text{maximum current x maximum voltage}) / (I_{sc} \text{ x } V_{oc}) \;\ldots\ldots\ldots\; (1)$$

$$\eta = [(FF \text{ x } I_{sc} \text{ x } V_{oc}) / 1000Wm^{-2}] \text{ x } 100\% \;\ldots\ldots\ldots\; (2)$$

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Table 2 shows that the current density and the voltage of photovoltaic cells. The highest efficiency and the highest current density are 3.39× $10^{-3}$ %and 75.0 μA $cm^{-2}$ and it was given by the 0.075g mass amount of Potassium Iodide.

**Table 2:** Photovoltaic parameters of the cells with an area of 1 $cm^2$ under the illumination of 1000 $Wm^{-2.}$

| Amount of KI (g) | $V_{oc}$ (mV) | $J_{sc}$ (μA $cm^{-2}$) | FF(%) | η (%) |
|---|---|---|---|---|
| 0.025 | 140 | 4.1 | 30.3 | 1.74 × $10^{-3}$ |
| 0.050 | 297 | 27.0 | 28.8 | 2.31× $10^{-3}$ |
| 0.075 | 161 | 75.0 | 28.1 | 3.39× $10^{-3}$ |
| 0.100 | 181 | 6.5 | 3.5 | 4.15 × $10^{-4}$ |
| 0.125 | 106 | 2.5 | 37.4 | 9.9 × $10^{-5}$ |

**Figure 2** shows how the efficiency of photovoltaic cells change with the amount of Potassium Iodide. It shows clearly thatthe peak point is given at 0.075 g.

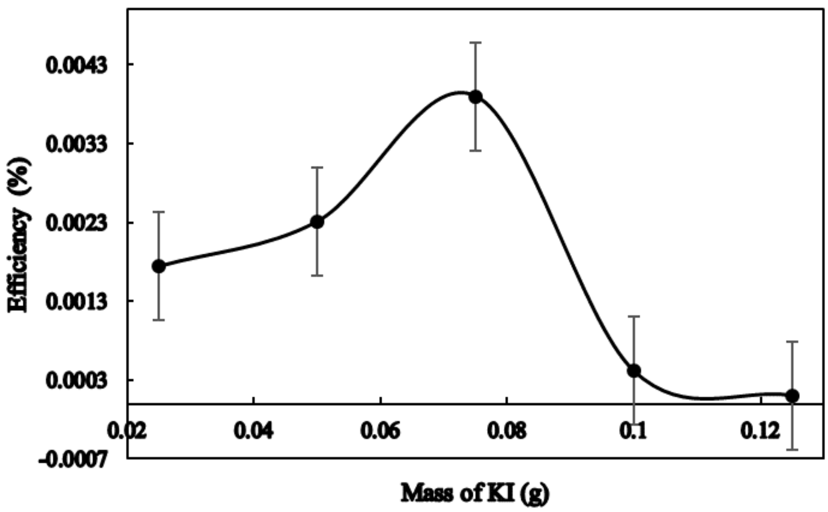


**Figure 2:** Variation of the efficiency with the added amount of KI

The Mott-Schottky measurementswere carried out on the Olive extract and Jamson dye thin films deposited on FTO glass. It is shownin figure 3(a) and 3(b) respectively.The flat band potentials for these thin films were determined from the intercepts of the potential vsreciprocal of square capacitance in y axis.The negative slope of figure 3(a) confirmed that the Olive thin filmisp-type and the positive slope of figure 3(b)

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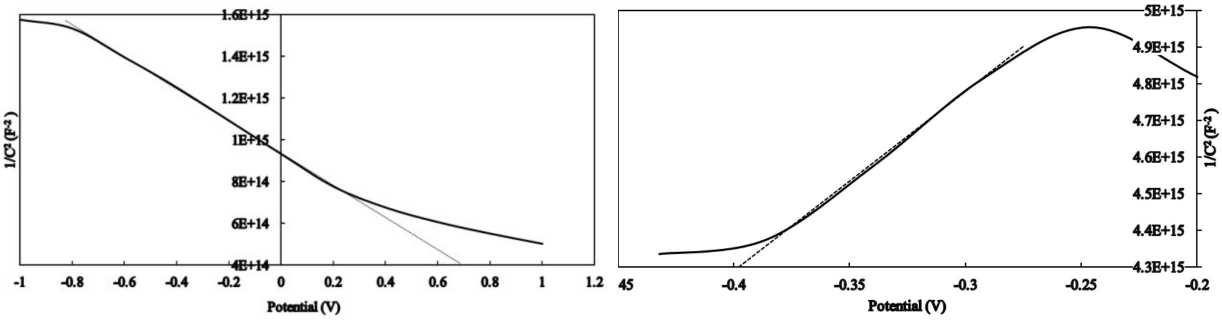
confirmed that the Jamson thin filmisn-type.The values of the flat band potential of the Olive extract and Jamson dyewere0.7V and -0.39 V respectively.




(a) (b)

**Figure 3:** Mott-Schottkyplots of the Olive extract (a) and Jamson dye (b)

Oleuropein, Hydroxytyrosol,polyphenols and flavonoids, including luteolin, rutin, caffeic acid, catechin and apigenin are the chemical compounds reported to be in wild Olives [4]. Acids and variety of proteins are alsopresent in it. The extract from Olives in ethanol contains all the above-mentioned compounds. Therefore, it will affectpositivelyonphotovoltaic cells.Caffeic acid is mainly giving a push for this phenomenon.

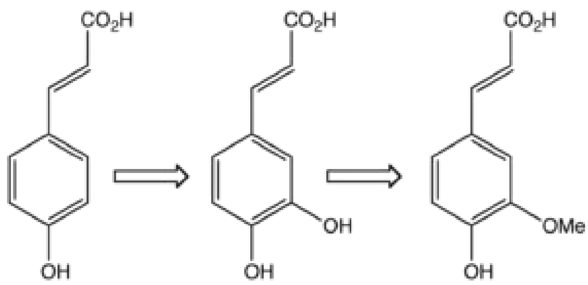
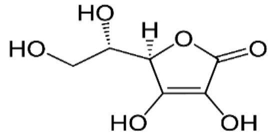
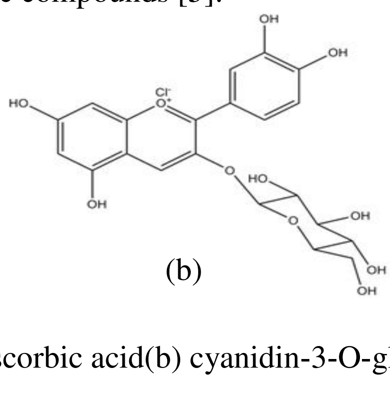



**Figure4:** Caffeic acid [4]

Major chemicalcompounds in Jamson fruit also has an effect.Fullyripened*Carissacarandas* (Jamson) fruit, consist of ascorbic acid (Figure 5 a),an antioxidant, anthocyanin and phenolic compounds [5].




(a)



(b)

**Figure 5:** Chemical structures of (a) ascorbic acid(b) cyanidin-3-O-glucoside [6]

Usually, anthocyanin is a sensitizer that can inject electrons to electron acceptors. Therefore, these kinds of plant materials function satisfactorily in bulk heterojunction solar cells.

## 4. CONCLUSION

The best amount of KI to achieve the maximum current density was 0.075 gwhile the both the maximumcurrent density and photovoltage were simultaneously acquired when the olive extraction and dye of Jamson fruit mixedwith 1:2 ratios. Under above optimized circumstances, it delivered 75 μA $cm^{-2}$ short circuit current density, 160 mV open circuit voltage with 28.13% fill factor and 0.0034 % energy conversion efficiency. Introducing the potassium iodied into the mixture of dyesinfluenced toincreased the electirical conductivity of this organic photovoltaic cells. Further studies need to be carried out to identify the charge transfer mechanism in mixturesof natural extractions from Wild Olive and Jamson fruits for the enhancement of photovoltaic efficiency of this type of bulk heterojuction solar cells.

## REFERENCES

[1] Tang, C. W,*Two-layer organic photovoltaic cell.*,Applied Physics Letters, 48(1986) , 183–185.
[2] Yu G, Gao J, Hummelen J.C, Wudl F, Heeger A.J, Polymer Photovoltaic Cells: *Enhanced Efficiencies via a Network of Internal Donor-Acceptor Heterojunctions*.Amerassoc advancement science 270 (5243)(1995), 1789-1791.
[3] Qun Ye and Jian Wei Xu, Bulk Heterojunction Solar Cells – Opportunities and Challengers,Solar cells ,New Approaches and Reviews, 2015.
[4] https://en.wikipedia.org/wiki/Caffeic_acid
[5] https://en.wikipedia.org/wiki/Olive_leaf
[6] WickramasingheG.C,Balasundaram D.,RajasekaraU.G.M.D, AponsuG.M.P.L,Perera V.P.S., *Optimization of Adsorption of Carissa carandas Dye on $TiO_2$Photoanodes for Sensitization of DSSCs*,Institute of Physics Sri Lanka, 35th Technical Session(2019).17-23.