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A Method to Harvest Electrical Energy from Living Plants

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Abstract

In this paper, some fundamental investigations are established to demonstrate the potential of harvesting electrical energy from living plants. The energy is harvested by embedding electrodes into the plant to allow flow of ions and hence generate electricity. Multiple random tests have been conducted using different type of electrodes and plants as an attempt to determine the characteristics of the harvesting system. It is found that voltages are produced to greater or lesser extents by all tests where combination of copper-zinc and aloe vera produces the highest voltage. In addition, it is shown in this paper its ability to light up Light Emitting Diode (LED), digital clock and calculator which grants it a potential to be used for low power electrical consumption appliances in the future.

Keywords: renewable energy; organic energy; weak energy source; energy harvesting system; living plants

1. INTRODUCTION

Over the past centuries, world economic growth is inseparable to the ever-expanding use of hydrocarbon energy sources such as petroleum, coal and natural gas. The trend of global economic currently hinges on increasing rates of production of these fuels. However, petroleum oil and gas, and coal are non-renewable energy resources that will cease in the future. The ever rising cost of fossil fuels not only causes inflation but also hinders the economic growth [1] as the production of goods and cost of shippment are dependent on the cost of fuels [2,3,4]. If price continues to rise with increasing demands, this will consequently negatively affect the trade and poverty [5].

Not only that, our world is severely defected due to the extensive use of burning fossil fuels that raises the level of carbon dioxide in the atmosphere thus resulting the serious greenhouse effects. Greenhouse gases gradually increase the temperature of the Earth's surface and therefore bring us a warmer atmosphere and collapsing global environment [6]. There is no doubt that climate change is upon us, do the next to minimize those long-term effects. Therefore, increasing use of renewable energy have been encouraged by government of many countries, as it provides an excellent opportunity for mitigation of greenhouse gas emission and reducing global warming through substituting conventional energy sources [7,8,9]. Accordingly, we must aggressively utilize renewable energy in an effort to safeguard our future and the Earth [10]. Switching to renewable energy sources for electricity generation provides beneficiary management strategies from the economic, as well as environment point of view [11].

In view of these consequences, researchers are extensively developing green energy as substitutions to fossil fuel [12,13,14,15]. Among the options are the weak energy sources. Previous studies has found a method that generate bioelectricity by direct extraction of photosynthetic electrons with inserting a nanoelectrode from living algal cell [16]. Similarly, it was shown the possibility of harvesting electricity from a living-plant using Glucose Oxidase (GOx) and bilirubin oxidase (BOD) modified electrodes during photosynthesis process [17]. In another development, Magcap claims they successfully developed a new method to harvest electricity from trees that due to the difference in pH between tree tissues and soil [18]. Consequently, a team of electrical engineers from University of Washington devised a voltage boost converter for energy harvesting from trees [19]. According to Wadle, although this development is in its infancy, it has the potential to provide an unlimited supply of constant, clean energy without relying on fossil fuels [18].

This paper presents some fundamental procedures to harvest weak electricity from living plants. It was done by embedding pairs of electrodes into the plants where electrical energy is harvested by completing the connection with conditioning circuit. As an attempt to determine the optimum pair of electrode and energy source, multiple random tests had been conducted on different type of electrodes and plants. Details of the experimental works are further explained in Section II. Towards the end, the best combination that produces the highest voltage was tested on Light Emitting Diode (LED), digital clock and also a digital calculator to investigate its potentiality on low electrical power appliances.

2. EXPERIMENTAL DETAILS

In this section, detail procedures of several experimental steps are described. The experimental work is divided into three parts:- selection of electrodes and energy sources, optimization of the harvesting system and investigation on potential applications.

2.1 Investigation of Type of Electrodes and Energy Sources.

Since there are many types of electrodes available, the best pair that produces the highest power output has to be determined prior to any further optimization attempts. In the present work, four different material of electrodes have been selected because they are locally abundant and easily available. They consist of copper, ferum, zinc and aluminum. The positive and negative terminal of the electrode was determined according to its electrochemical potential, E. Therefore, the electrode with higher and lower electrode potential, E° was selected as anode and cathode, respectively. Simultaneous oxidation and reduction process occur at anode and cathode allow the flow of negative ions to the anode and positive ions move towards cathode [20].

Due to the vast variety of plants available locally, only plants with good potential were considered. Aspects of consideration include of easy-embedding and stem moisture content. The current work selects three different kinds of plants which were pulai tree (*Alstonia Sp)*, banana tree (*Musa acuminate*) and also aloe vera (*Aloe Barbadensis*). They were selected because they are abundant in local as well as their trunk or leaf structure allowed for easy embedding by electrode.

Figure 1 shows the illustration of the experimental set-up where four distinct pairs of electrodes (Cu-Fe, Cu-Zn, Al-Zn, Cu-Al) were embedded into the pulai tree and connected with a multi-meter to measure its corresponding open circuit output voltage. Similar procedure was repeated for the other two potential plants, banana tree and aloe vera.

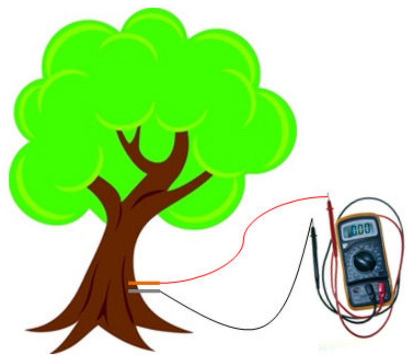

Figure 1: Connection between the electrode pairs to the trees and the multi-meter.

2.2 Optimization of the Harvesting System

The best combination of electrodes and energy source found form the previous sections were selected for further optimization. In the optimization attempts, two aspects were considered in the current work, the first being the number of electrodes used and the second is the use of an appropriate conditioning circuit.

It is hypothesized that the number of electrodes is analogous to the number of ordinary dry cell batteries such as AA. By increasing the number of electrodes embedded into the plants, the harvested electrical energy should increase proportionately. In the attempt to test this hypothesis, additional pair of electrodes was increased up to three pairs.

The second optimization attempt in this paper was the use of an electronic circuit to provide conditioning to the harvested power from plant. This conditioning circuit is aimed to allow electricity to boost until sufficient electricity is used as a "boost converter". To visualize the performance of the energy harvesting system, LED was used as an indicator in terms of its brightness because it consumes a very small amount of power [14].

2.3 Investigation on the Potential Application

As a preliminary evaluation on this organic energy, potential application on low electrical consumption appliances was investigated. They include of some daily-use electrical devices such as LEDs, digital clock and scientific calculator.

To further investigate these applications, longer testing periods was carried out by allowing the operation mode connected for an hours. Observations were made from time to time to inspect condition of the harvesting system.

3. RESULTS AND DISCUSSION

3.1 Selection of Electrode Pair and Energy Source.

Figure 2 shows the open circuit voltage from the pulai trees. It suggests that copper-zinc electrodes produces the highest voltage approximately 0.8V. This is followed by Cu-Fe (0.5V), Cu-Al (0.4V) and Al-Zn is the lowest (0.38V). It was also found that for all combination, the harvested voltage was stable up to 60minutes.

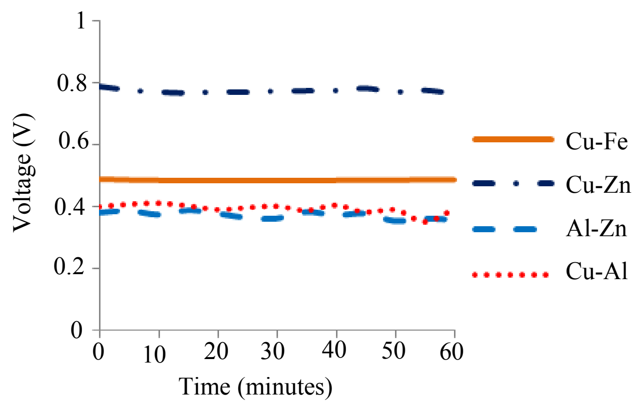

Figure 2: Voltage profile over time obtained from pulai tree, scientific name as *Alstonia Sp* by using different pairs of electrodes.

Similar trend of voltage output was obtained when banana and aloe vera were used as the energy source. However, it was found that aloe vera produces the highest open circuit voltage with Cu-Zn as electrodes followed by banana tree and pulai. It can be seen that the output voltage obtained from banana and aloe vera is 0.913V and 0.945V as shown in Fig. 3 and Fig. 4 respectively. These results show that combination of electrodes and the type of plants play important role in determining the harvested voltage output.

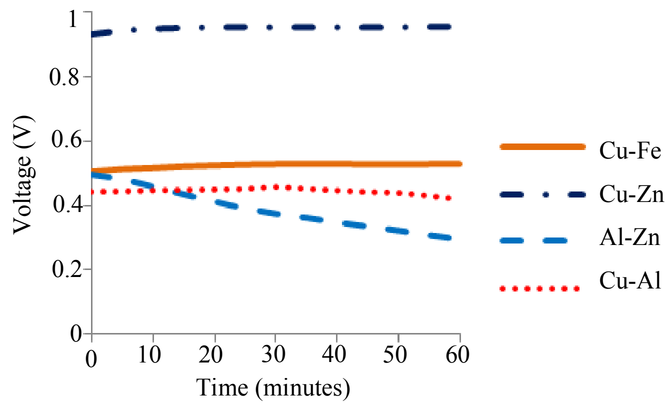

Figure 3: Voltage profile over time obtained from banana tree using different pairs of electrodes

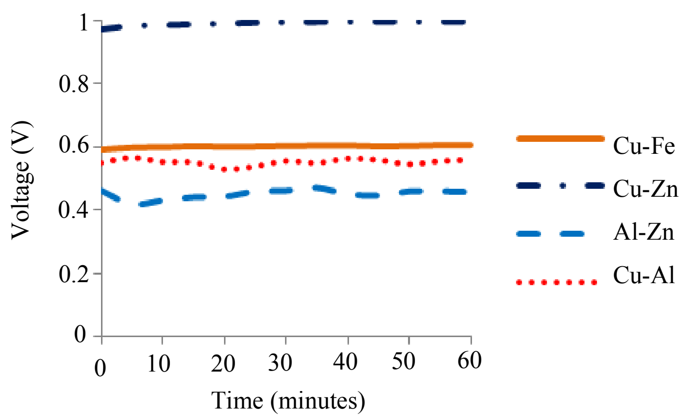

Figure 4: Voltage profile over time obtained from aloe vera using different pairs of electrodes

3.2 Power Output Optimization

It was found from the previous section that Cu-Zn produces the highest voltage with aloe vera as energy source among the tested combination of electrode pairs and plants. The investigation was continued to determine the effects of using additional electrodes pair and also using external conditioning circuit for output optimization attempts.

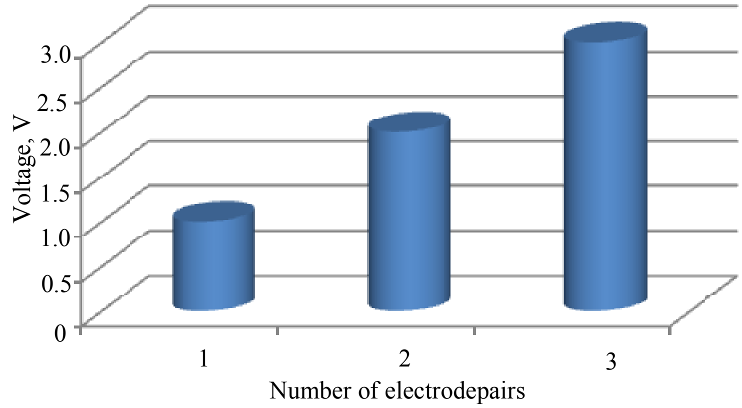

Figure 5: Voltage profile over number of electrode pairs with the combination of Cu-Zn and Aloe Vera in open circuit connection

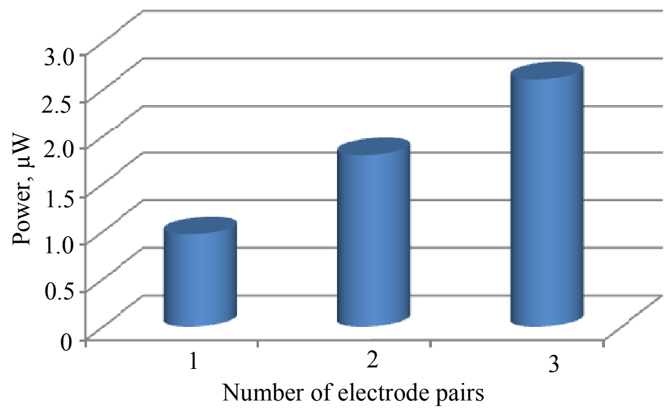

Figure 6: Power profile over number of electrode pairs with the combination of Cu-Zn and Aloe Vera in closed circuit connection with 100kΩ resistor

Figure 5 and 6 revealed that when more number of electrodes embedded, higher power output can be harvested. The open circuit output voltage for two pairs of electrode embedded is almost doubled, which is 1.970 V, as compare with single pair of electrode (0.972 V) in Fig. 5. With such high voltage supply, the LED can be light up even without the use of the conditioning circuit. Similar pattern of increment is also observed in the power profile as shown in Fig. 6.

Table 1 summarizes the LED conditions in different modes of application. A single pair of Cu-Zn embedded on aloe vera in direct connection, it was unable to light up a light emitting diode (LED). However, this is made possible when an external conditioning circuit that consists of a transistor, a resistor and an inductor coil as harvesting circuit, is employed, which is shown in Fig. 7. Although the value of the harvested voltage is still remain the same as 0.945V, the use of the harvesting circuit provides a more stable output than using a pair of electrode alone, thereby providing a constant power enough to light up the LED.

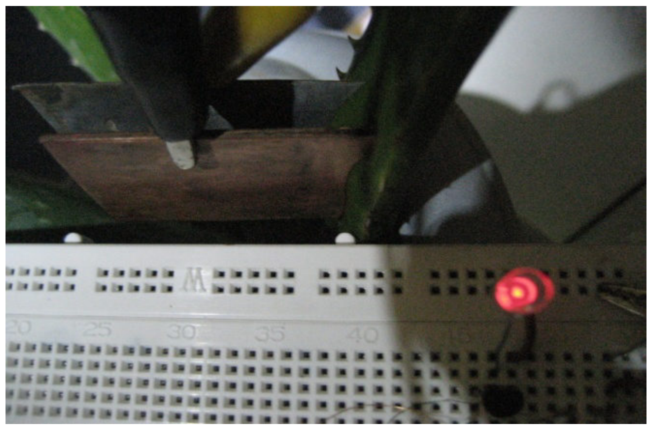

Figure 6: The LED produce light by only one pair of electrode with the aid of harvesting circuit.

Table 1: Performance of LED when using Cu-Zn pair of electrodes inserted in an aloe vera leaf

Methods	Performance of LED	
	Lit	***Not lit***
Direct connect to LED by using one pair of electrode (≈0.945±0.001)V		√
Connect the LED with harvesting circuit by using one pair of electrode (≈0.945±0.001)V	√	

3.3 Test on Some Practical Application

The previous section suggests that voltage output optimization could be realized by increasing the number of electrode pairs and employing an external conditioning circuit to stabilize the power output. It could be interesting if this new organic energy source is capable to run some practical applications. In order to check its potentiality, two low power consumption electronics appliances had been used as test device; they are digital clock and a scientific calculator.

Figure 7 shows the digital clock is functional when connected to two pairs of Cu-Zn electrodes with aloe vera as organic energy source. The digital clock requires a single AA 1.5V battery to operate. Longer periods of testing time were carried out and it was found to be in an operation mode for more than half day.

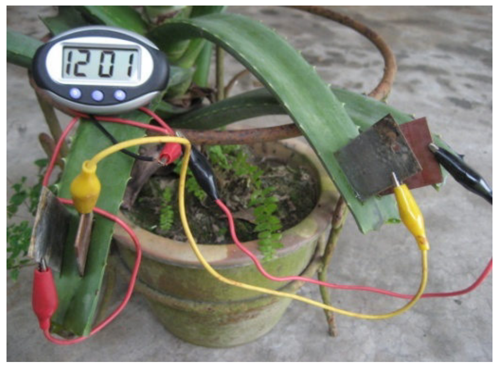

Figure 7: A digital clock powered by organic energy source

Similar result was observed when scientific calculator was used. Figure 8 shows that the calculator can be switched on and show numerical input on its screen. Not only that, the calculator is also capable of performing scientific calculation with this new organic energy source as shown in Fig. 9.

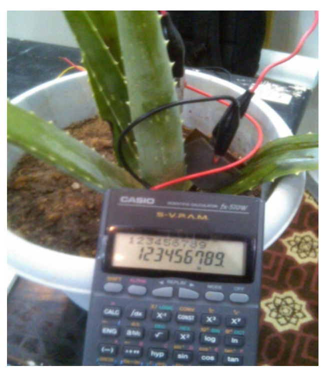

Figure 8: A scientific calculator showing simple numerical input

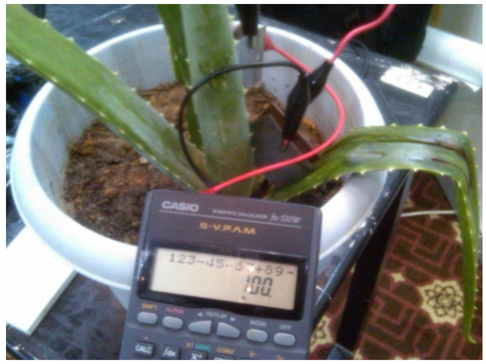

Figure 9: A scientific calculator showing numerical calculation

4. CONCLUSION

In this paper, a new renewable energy source from living organic plants was investigated. The electrical power from the organic energy source was harvested using pair of electrodes embedded into the plant. It was found that the electrodes combination influences the harvested energy output. Optimization of its voltage output was obtained as the number of electrodes pair connected in parallel increases. Besides that, the type of plant also influences the output voltage. Till this end, it was shown that using this new organic energy source, low power electronics instruments can be powered up to perform their operation.

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