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The Role of the Slope on Taro Leaf Surface to Produce Electrical Energy

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Abstract. This research focused on Electrical Energy Harvesting using taro leaves *colocasia esculenta* L coated electrode and water droplet passed. The advantage of this research lies in the concept of hydrophobic using natural material from taro leaves *colocasia esculenta* L, so it is environmentally friendly. In this study using an external circuit of capacitors and bridge rectifier that are connected with aluminum foil as electrodes. From the results, shows that optimal voltage and stable at three drops/second with a slope of 150 degrees produces 78 mV. Electrical energy can be produced because there are energy triggering electrons to jump. Energy obtained from the repulsion of the structure of the leaf surface morphology and the attraction of the element O (oxygen) in the water droplet triggers the surface to become more superhydrophobic. The superhydrophobic surface of the leaf as a membrane to deliver ion flows through the electrode as the way charge flows to the capacitor that is read as the voltage on the oscilloscope. Between the water droplet and the leaf surface, generate the contact angle, so the leaf surface to become superhydrophobic. The role of superhydrophobic properties and slope of the leaf surface is significant to produce electrical energy.

Keywords : electrical energy, water droplet, superhydrophobic surface, taro leaf.

1. Introduction

Harvesting energy arises because it does not cause pollution effects for the environment, sources are in abundance. Performed on a small scale in an attempt to capture wasted energy but the results are amazing. Energy sources commonly used in energy harvesting include ambient radiation, biomechanics, pyroelectric, thermoelectric, electrostatic, biofuel cell (blood sugar or glucose), metabolic activities of trees, electroactive polymers, or mini generators, acoustic oscillating droplets [1]. Harvesting energy with solar power technology is now more efficient and growing rapidly, but there is still a big problem that solar cells cannot generate energy when it rains.

In recent years an interesting study has been developed for discovery to produce large negative charges by using neutral fluoro hydrophobic polymers when in contact with water. Such polymers have been used widely and thus require a deeper understanding. Although this model has not been universally accepted yet there is sufficient evidence to show a negative charge as a result of preferential adsorption or O-H group orientation near the surface of the hydrophobic polymer [2-5]. For more comprehensive, systematic and



well-defined molecular modeling in experimental studies when there is electrical contact with water and a better understanding of the underlying mechanisms is needed [6].

Harvesting electrical energy can be accomplished by passing water droplets on the surface of hydrophobic polymers coated under the metal film as electrodes [7]. Using a fluorinated ethylene propylene film (FEP) as a hydrophobic polymer medium with an aluminum film embedded in the form of a polymethyl methacrylate plate.

In the process of this research, excellence lies in the concept of superhydrophobic using natural materials from plants so it is environmentally friendly. The morphology of this plant has characteristic superhydrophobic that is using taro leaves *Colocasia esculenta*. L. On phenomenon of taro leaves, the force that occurs between water and taro leaves is the adhesion force, whereas the force between water molecules is the cohesion force. In this case, the adhesion force that occurs between the water and the taro leaves (which is coated by the wax layer) has a smaller attraction than the cohesion forces that occur between water molecules that are capable of forming granules on the surface of the taro leaves. Attraction force in this greater cohesion force causing the water not to be able to wet the taro leaves. But as it is said that the water only forms water grains on the surface of the taro leaf. As well as the surface tension that occurs between the water with the superhydrophobic surface of the taro leaves which generate all forces into the water surface produces a minimum surface area.

Much research has been done before on electrical energy harvesting but it is still rare to investigate the effect of the superhydrophobic character of taro leaf surface to generate electrical energy. The droplet phenomenon when in contact with the surface of the taro leaves will be observed in more detail by varying the number of fall of the water droplet above the leaf surface and the slope of the leaf surface. So the secret of the superhydrophobic nature of taro leaves can be revealed. So it becomes a must to conduct more in-depth research in the field of energy harvesting.

2. Methods

A series of all research installation units using an external circuit of capacitors and bridge rectifiers with a red cable connected to aluminum foil as an electrode attached to a taro leaf, with another bridge rectifier connected to the ground with a black cable. An oscilloscope is connected to the capacitor to measure the voltage. So it becomes a must to conduct more in-depth research in the field of energy harvesting. When the water droplets are flowed vertically from above, the movement of voltage values and wavelengths will be recorded on the laptop screen that has been connected to the oscilloscope. Then the measured voltage changes are observed when the water droplet passes through the surface of the taro leaves, with a variation of the fall of the droplet per second which is 3 drop/s, 2 drop/s, 1 drop/s. Slope variations of 0° , 15° , 30° , dan 45° .

Each water droplet has a mass of 0.04744gram (using the Toledo mettle electronic digital scale type XPE205, readability 0.00001. The voltage measuring device uses the DDS 120 Oscilloscope smart design model that has been calibrated using the 9000 series transportable calibrator. From the variations made it is expected to reveal the phenomena Taro leaves surface that has superhydrophobic properties is able to obtain electrical energy in the form of measured voltage as much as possible.

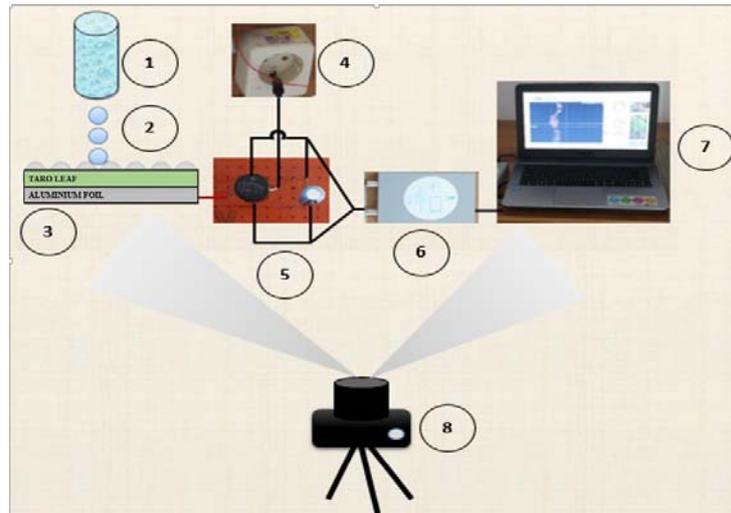


Figure 1. Research Installation.

Figure 1 shows the installation of the research conducted with the description (1) Water reservoir, (2) Water droplet $\varnothing = 4\text{mm}$, (3) Leaves attached aluminum foil on the bottom side, (4) Ground, (5) Bridge Rectifier consists of 1 diode & 1 Capacitor, (6) Oscilloscope, (7) Laptop, (8) High Speed Camera. The research conducted was experimental research. Focused on the concept of hydrophobic properties possessed by a material. Taro leaf surfaces that flowed by water droplets in the form of rolling or jumping will cause a measurable voltage difference. When the water droplet falls / above the leaf surface, it will form a contact angle that will cause surface tension, to create an electric voltage that can measure as mV (millivolt).

3. Results and Discussion

From the experimental process, the results are obtained in the form of data plotted into graphical form. Figure 2. is a graph of transient time at 50 seconds. Shows the relationship of the water droplet (drop / s) against voltage (millivolts) with an angle with the slope 0° , 15° , 30° , and 45° .

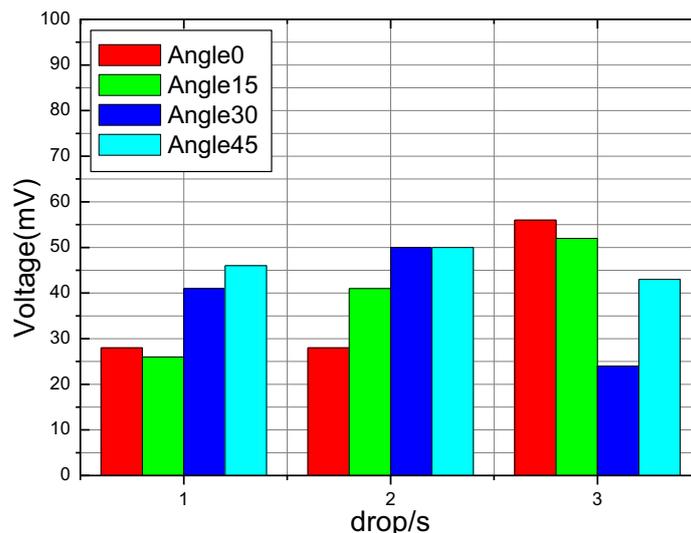


Figure 2. Transient time at 50 seconds, a graph of water droplet relationship (drop/s) to voltage (mV)

With a variation of the shape of the bar graph 2 means one drop/second, two means two drops/second, three means three drops/second. The colour red means the angular inclination 0° ; the colour green means the angle of inclination is 15° ; the colour blue means the angle of inclination is 30° , the light blue means the angle of the angle 45° . At the beginning of data collection from 0s to 50s there is an increase in voltage because the more droplets that hit the leaf surface, the greater the voltage value is reached, and the capacitor filling process is in progress.

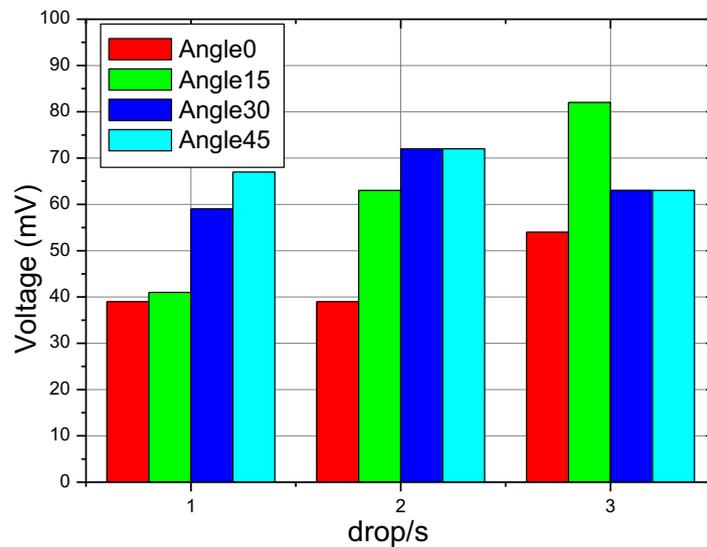


Figure 3. A quasi-time steady at 50-3000 seconds, a graph of the relationship of the water droplet (drop/s) to voltage (mV)

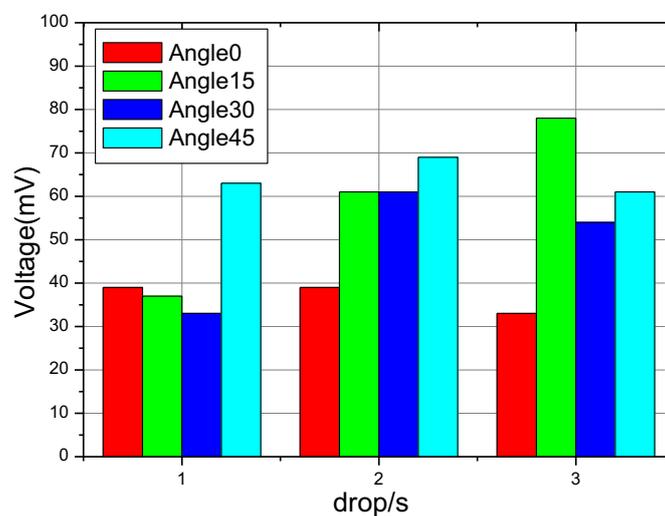


Figure 4. Steady time at 3000-3600 second, a graph of water droplet relationship (drop/s) against voltage (mV)

Figure 3 shows the relationship when the voltage reaches a quasi-time steady at 50-3000s. The highest voltage value reaches 82 mV at three drops/second at the slope of 15° . Figure 4 shows the relationship when the voltage reaches a steady time of 3000-3600s. In this condition, the voltage starts to stable, and there are no sharp fluctuations. The capacitor filling process continues. The highest voltage value reaches 78 mV at three drops/second at the slope of 15° . The slope variation with the number of droplets this is the most

optimal. During the process, there are three types of graphs showing different trends. Whereas at the beginning of the research when the transient time (figure 2) occurred an increase. The number of droplets that fall in each second, the higher the voltage generated. In the middle time when it began to enter quasi-steady, it reached the second to the 50-3000s the trend of the graph was increasing. Until the end of the condition has been steady when 3000-3600s there is a voltage drop which finally reaches a stable. Data collection was carried out during 3600s with horizontal leaf position without slope which was 0° and then with a slope of 15° , 30° and 45° .

As in Figure 5 in one water droplet there are H_2O molecules. The molecule on the surface a water droplet has fewer molecules than in the surface. As a result, molecules on the surface experience attraction force (Concepts of Adhesion and Cohesion) between molecules that are weaker than molecules in the surface center. This causes the molecules on the surface tends attracted to the center liquid. Surface tension occurs when the water touches the hydrophobic taro leaves. The stronger attraction between molecule droplet in hydrophobic surface makes the more significant the surface tension that arises.

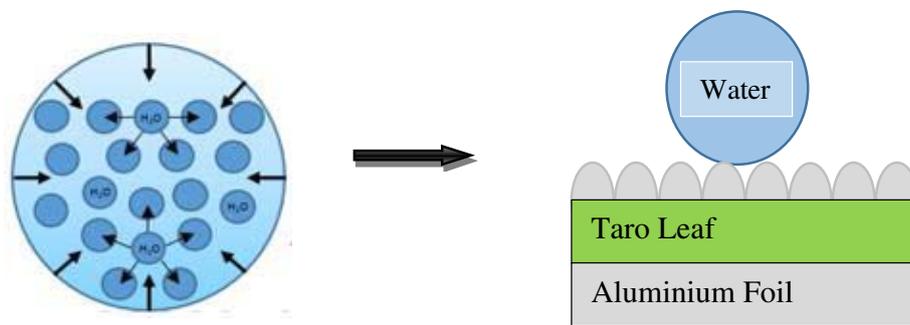


Figure 5. H_2O molecules in water droplets

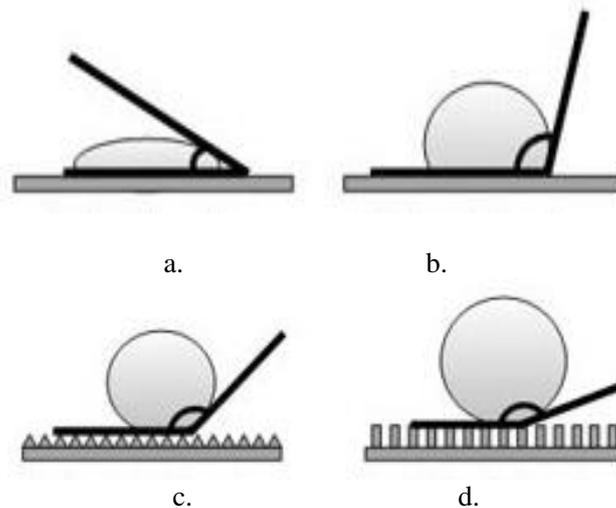


Figure 6. Water droplets angle on different hydrophobicity.
Source: Muzenski et al. 2013

To find out the size of the surface tension value, one can be seen from the size of the contact angle formed. When the droplet is dripped onto a surface, there will be a contact angle, the amount of which is very dependent on its hydrophobicity as shown in Figure 6. The contact angle (Θ) is the angle formed by the water droplet when dripped onto the surface creating a tangent to its contact line with a line which through

the bottom of the water droplet. Based on the appearance of the water droplet and the contact angle formed can be clarified as shown in Figure 6a. The hydrophilic surface when the contact angle formed is $\Theta < 30^\circ$; 6b. The hydrophobic surface when the contact angle formed is $90^\circ < \Theta < 120^\circ$; 6c. Overhydrophobic surface when contact angle $120^\circ < \Theta < 150^\circ$; 6d. The superhydrophobic surface when the contact angle is $\Theta > 150^\circ$.



Figure 7. The contact angle between the water droplets with taro leaf surface

Experimental results measuring water droplet with a diameter of 4 mm above the surface of taro leaves placed horizontally at a slope of 0° obtained the value of the contact angle is 167.498° this angle is more significant than 150° means that the surface of the taro leaves is a superhydrophobic surface. When the water droplet falls on a superhydrophobic leaf surface will have a surface tension, giving the pressure of triggering the ends of the vibrating superhydrophobic surface to disturb the stability of the atoms in the leaves to be unequal. The atoms of nanoparticles can vibrate because the falling water droplets crash the hydrophobic surface producing energy.

Electrons can move from one energy level to another. Switching these electrons because they get extra energy from the outside, one of them can come from alpha radiation and beta radiation. If electrons move from low energy levels to high energy levels, energy will be absorbed to carry out the process. Electrons that move from low energy levels to higher energy levels cause the electrons excitation. However, the condition of this electrons excitation is unstable so that electrons return from high energy levels to low energy levels accompanied by the release of energy in the form of radiation (Deeksitasi).

So, in this case, the energy is obtained from repulsive force or the reflection force of the leaf surface, so there is a center of voltage, and from the pull or received by O (Oxygen). If the droplet falls on the surface of hydrophilic or non-hydrophobic it will glow (not droplet) then it will not be able to vibrate the ends of the hydrophobic surface of the leaf. So there must be a sizeable droplet-shaped force with the smallest diameter possible to push in and vibrate it.

Electrons will always move to an easier place. Grounds are easier to attract electrons than to oxygen. So that the electron will jump to the ground before it reaches oxygen. Leaf superhydrophobic surfaces as membranes to deliver ions flow through electrodes as the path of all positive charges will flow in the capacitor and other negative atom charges such as OH to OH⁻ will flow as well but with the bridge rectifier in the form of diode will direct the positive into the capacitor and the negative enter to ground. Finally, the positive charge stored on the capacitor will be read as the voltage on the oscilloscope.

4. Conclusion

A large contact angle between the water droplet and the leaf surface causes the leaf surface to become superhydrophobic. Taro leaf surface is a superhydrophobic surface with a value above 150° that is $167,498^\circ$. This can be proved from the results of data collection with various variations of 3drop/s, 2drop/s, 1drop/s and slope 0° , 15° , 30° , 45° produces a measurable voltage. The most stable and optimal voltage values reach 78 mV in variations of 3 drops / second slope of 15° .

Electrical energy can be generated due to an electron leap. Electrons can jump because of energy. Energy is derived from the repulsion of the morphological structure of the leaf surface and the pull of the O (oxygen) element in the water droplet. The superhydrophobic surface of the leaves as a membrane to deliver the ions flows through the electrodes.

So that the surface of taro leaves has unique properties that crucial superhydrophobic role to generate electrical energy.

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References

- [1] Lee Y R, Shin J H, Park I S, Rhee K, and Chung S K, 2015 *Energy harvesting based on acoustically oscillating liquid droplets*, *Sensors Actuators, A Phys.* 231 8–14. doi:10.1016/j.sna.2015.03.009.
- [2] Beattie J K, 2006 *The intrinsic charge on hydrophobic microfluidic substrates*, *Lab Chip.* 6 1409. doi:10.1039/b610537h.
- [3] Kudin K N, and Car R, 2008 *Why Are Water - Hydrophobic Interfaces Charged ?*, *J. Am. Chem. Soc.* 130 3915–3919.
- [4] Baer M D, Kuo I W, Tobias D J, and Mundy C J, 2014 *Toward a Unified Picture of the Water Self-Ions at the Air – Water Interface: A Density Functional Theory Perspective*.
- [5] Tandon V, Bhagavatula S K, Nelson W C, and Kirby B J, 2008 *Zeta potential and electroosmotic mobility in microfluidic devices fabricated from hydrophobic polymers: 1. The origins of charge*, *Electrophoresis.* 29 1092–1101. doi:10.1002/elps.200700734.
- [6] Burgo T A L, Galembeck F, and Pollack G H, 2016 *Where is water in the triboelectric series?*, *J. Electrostat.* 80 30–33. doi:10.1016/j.elstat.2016.01.002.
- [7] Helseth L E, 2016 *Electrical energy harvesting from water droplets passing a hydrophobic polymer with a metal film on its back side*, *J. Electrostat.* 81 64–70. doi:10.1016/j.elstat.2016.03.006.
- [8] Muzenski S, Vivian I F, and Sobolev K, 2013 *Hydrophobic engineered cementitious composites for highway applications*, publication in *Cement and concrete composites*.

Biographies



Komang Metty Trisna Negara Completed her undergraduate study at Udayana University, Bali, in 2009, later in the same year continued his master degree in mechanical engineering at Udayana University, Bali and completed his studies in 2012. Currently, she is studying S3 in Universitas Brawijaya, Malang. Areas of interest are Energy Conversion, Energy Harvesting, as well as several topics related to the field of energy harvesting.



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