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Batteries with Liquid Electrolyte Using Bamboo, Limestone and Turmeric

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ABSTRACT

Development of environmentally friendly electrical energy production technology. Development of power plants made of bamboo, limestone, and turmeric to increase the jump of electrons in electrolyte solutions. This research aims to reveal the role of turmeric as a catalyst in making electrolyte solutions from bamboo and limestone. The initial stage of this research began with a high energy milling (HEM) process to reduce the size of the bamboo material to nano size. Furthermore, bamboo and limestone dissolved in water with a ratio of 1:1. The electrodes used are aluminum and copper. Turmeric is used as a catalyst and increases the number of atoms. Comparison of bamboo, lime with turmeric 1:1:1. The limestone dissolves in water into ions by activating dipole forces and has crystalline properties. The test results show that the voltage generated from the bamboo and limestone materials before being mixed with turmeric is 508 mV. Furthermore, the addition of turmeric produces a voltage of 1631 mV.

1. INTRODUCTION

Energy needs will continue to increase in the coming years [1]. Increased energy needs result from the number of vehicles produced. Along with the increase in car production, the number of cars sold in the market has also increased. That has an impact on people's purchasing power of vehicles. Furthermore, fuel consumption increases with vehicle activity [2]. That affects air pollution and reduces fossils [1]. Therefore, researchers continue to develop alternative energy and energy storage systems [3-5]. Reliable and inexpensive alternative energy source is needed [6, 7]. Advanced development of energy storage/battery [3]. Alternative energy sources develop in supercapacitors [1], lithium-ion batteries, fuel cells, and solar cells [3]. In addition, supercapacitors have change-discharge capability, long cycle times, and high endurance [3]. Battery development is reviewed, from electrochemical performance, pore structure, chemical properties, electrode materials, and conductivity [2, 3].

Electrolyte performance is affected by redox reactions, electronic conductivity [8], mechanical stability, battery performance [9], chemical reactions, ion mechanisms, and phase transitions [10-14]. The advancement of electrolytes has provided extensive insights and innovations for power grid generation. On the other hand, electrolyte methods offer choices in solutions. Electrolyte solutions are energy storage [15]. Therefore, it is necessary to develop batteries using environmentally friendly, abundant [16] and non-hazardous and recyclable raw materials. The development of multivalent ion batteries based on contained ions has been growing. The electrolyte solution must be alkaline. Alkaline solutions contain many oxygen and hydrogen atoms [17]. Oxygen and hydrogen atoms are abundant in water and organic materials. The development of organic materials is attracting attention because of its abundant resources [18, 19], environmentally friendly, controlled design, and ease of recycling [20]. The organic material used is bamboo. Bamboo is an abundant plant, offering high porosity, carbon structure, and nano cellulose as energy storage [21]. Bamboo has a fiber content consisting of cellulose (15-40%), hemicellulose (20-40%), and lignin (30-50%). Bamboo has physical, chemical [22] and mechanical properties [23]. Bamboo is renewable, environmentally friendly, abundant, and compatible. Bamboo has low-capacity carbon fibers [24]. Bamboo nanomaterials as electrolyte materials. Bamboo nanomaterials have a hexagonal structure and have phenol, alkali, and alkane functional groups. The phenol functional group can release hydrogen when interacting with water.

Electrolyte solution consists of bamboo, limestone, and turmeric. Limestone consists of calcium carbonate ($CaCO_3$) containing minerals. Limestone is widely used as a solar power plant [25]. Limestone has a calcium carbonate content of ± 97%. Turmeric is a catalyst to accelerate the rate of chemical reactions at certain temperatures [26]. Thus, new bonds will form in solution [27]. When the reaction rate increases, the activation energy of the reaction decreases through alternative reaction mechanisms. Curcumin has antioxidant properties [26, 28-31] and electrochemical properties. Curcumin can interact with various metal ions, including Fe^{3+}, Fe^{2+}, Cu^{2+}, and Cd^{2+}. Electrolyte solutions play a role in interactions, storing energy, and delivering ions to electrodes [32].

Electrolyte solution is rich in atoms consisting of carbon, oxygen, hydrogen, calcium, magnesium, potassium, and phosphorus atoms. Atoms mixed in the electrolyte solution will increase the temperature of the solution. Bamboo has a phenol functional group (hexagon) and can attract energy. Limestone contains calcium [25], and turmeric has antioxidant properties and double oxygen bonds in the middle [26, 29]. Thus, the battery will have efficient voltage and energy efficiency. Therefore, this study focuses on cheap, safe, or sustainable materials [33]. The electrolyte solution will play a role in porosity, low resistance, and activation when the reaction occurs. The electrode has fast ionic conductivity and ion transfer [34]. The results of battery testing and material characterization are in the results and discussion sections. The discussion section discusses the working mechanism of the system based on the results obtained.

2. MATERIALS AND METHODS

2.1 Material preparation

Material selection using bamboo ater. Bamboo is shaved using a shaver machine so that the material becomes lebaran fiber. The sheet fiber is dried using sunlight at a temperature of 25-32℃. The material that has become sheet fiber is then blended into powder. The powder material is finely blended until it reaches a mesh size of 270 (53 micro). Material making uses high-energy milling (hem). The hem process uses ball milling so that there is a collision between the bamboo and the ball milling [22]. The finely ground bamboo measuring 53 μm is put into a glass container and mixed with ball milling. Nanomaterial making uses hem for 8 × 24 hours with 240 cycles per minute. Constant speed in collision to break covalent bonds. In addition, it breaks the long cellulose chain into a short one. The speed decreases when the material is small or smooth. Thus, a collision will occur and cause nano-cracks. Nano-crack is the breaking of chemical bonds between atoms caused by the collision of ball milling or material trapped in ball milling. The smaller the cellulose structure, the easier the material will deform and absorb energy. Thus structure of alkali, alkene, and phenol can be detected so that oxidation ability can occur. Bamboo that has become powder is then stored.

2.2 Alkali solution

The use of limestone is easy to obtain and more economical. The electrolyte solution consists of limestone and distilled water. The easier it is for limestone to interact with water, the easier it is to obtain CaO content. In addition, redox reactions also occur when limestone dissolves in water. The study used 2 ml of limestone and 6-8 ml of water. So that limestone is easily dissolved, the limestone that settles is separated, while the floating limestone is used for testing. Ecosterem reactions occur in limestone with water. Limestone solutions often experience a temperature increase of ± 6℃ from normal temperature.

2.3 Turmeric

Turmeric is an antioxidant compound that has a double bond in the middle. In addition, turmeric has an oxygen atom (o) in the middle. Turmeric mechanisms can promote rapid chemical reactions at low temperatures [35]. Aromatic compounds have phenol functional groups that have long chains [26, 36]. Turmeric has nonpolar covalent properties, which are insoluble in water and act as a mechanism of action [28]. Turmeric is an antioxidant [26, 28, 29]. Figure 1 is the chemical structure of turmeric. Turmeric can increase chemical reactions rapidly at low temperatures as a catalyst. In electrolyte reactions, turmeric helps the reaction to take place quickly so that the temperature of the electrolyte solution does not increase significantly. In addition, turmeric also helps donate hydrogen to the solution. Turmeric has a phenol functional group.

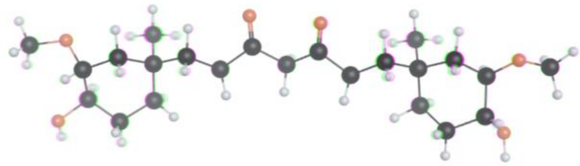


Figure 1. The chemical structure of turmeric

2.4 electrolyte reaction

This study used 1.13 grams of bamboo, 1.23 grams of limestone, and 1.29 grams of turmeric. Aquade water is an independent variable that will be combined with the main ingredients. The first stage is to make a water solution with bamboo in a measuring cup. The second stage is to make a water solution with limestone. The third stage is to make a water solution with turmeric. The solution that has been made is mixed into a 50 ml measuring cup and stirred. In the mixing process, the ambient temperature and the temperature of the electrolyte solution are measured using a thermometer. The measurement process is to determine the difference in temperature between room temperature and the temperature of the electrolyte solution. The test uses the concept of a hele-shaw cell with a solution in the middle. The test uses aluminum and copper electrodes. The test process uses aluminum electrodes as positive and negative poles. Furthermore, copper electrodes are used on the positive and negative poles. Aluminum and copper electrodes as positive and negative electrodes [34].

2.5 Determining chemical and morphological properties

This study determines the physical, chemical, and morphological properties of the materials made by conducting tests including Scanning Electron Microscope (SEM), Energy Dispersive X-ray Spectroscopy (SEM-EDS), Fourier Transform InfraRed (FTIR), X-ray Diffraction (XRD) and Ultra Violet-Visible (UV-VIS). SEM testing to determine the surface structure and chemical composition of bamboo, limestone, and turmeric. Analysis using EDS (Energy Dispersive X-ray spectroscopy) and SEM-EDS testing using the Quanta FEG 650 machine equipped with the Oxford X-Act instrument as an EDS detector. FTIR (Fourier Transform InfraRed Spectroscopy) testing using shimadzu IR Prestige 21. XRD (X-ray diffraction) testing using PANalytical X'PERT-3 powder with a scan range of 100e900, a step size of 0.01670. UV-Vis testing using Specord 200 Plus, Jena Analytics. The wavelength emitted is in the range of 200-1100 nm.

2.6 Determining quantum energy

UV-Vis testing of electrons' ability to absorb wavelengths at 200-800 nm. Testing using bamboo samples, turmeric, electrolyte solutions, and test results attached to the electrode section. Furthermore, the UV-Vis test results can calculate the energy gap based on the quantum energy equation.

$$\text{Energy} = \text{Planks contant} \times \frac{\text{speed of light}}{\text{wavelength}} \quad (1)$$

Eq. (1) is used to calculate the energy absorbed by atoms. Thus, the absorbed energy can be known from the emitted wavelength. The atom that absorbs energy can be known by the size of the atom. The results of the UV-Vis test in the form of the absorbed wavelength can be used to measure Homo-Lumo energy in kcal/mol [37].

Equation 1 to calculate the energy absorbed in atoms. Thus, the absorbed energy is seen from the wavelength received. Atoms that absorb energy will affect the size of the atom. The results of the UV-Vis test in the form of absorbed wavelengths used to measure Homo-Lumo energy in kcal/mol.

2.7 Electrochemical method

Figure 2 Multimeter Sanwa CD-770 tool for measuring voltage, current, and resistance. DCV measurement ranges from 400m-600V with an accuracy of ± (0.5% + 2) and a resolution of 0.1 mV. ACV measurement ranges from 4-600 V, with an accuracy of ± (1.2% + 7) and a resolution of 0.001 V. Sampling rate three times/second. Use of a mobile phone to record voltage data. Multimeter calibration using a resistor or battery with a capacity of 1.5 V.

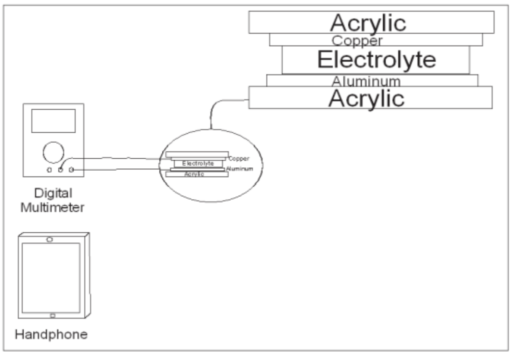


Figure 2. Battery voltage measurement

3. RESULTS AND DISCUSSION

In this study, we gain insight into how to produce energy from bamboo and turmeric. The bamboo used is already in powder form. While the turmeric used is generally available. This study conducted simulations using the molecular operating environment (MOE)and studio materials. Bamboo is composed of cellulose with a long-chain chemical structure. The chemical chain consists of various functional groups and atoms that are connected. In addition, bamboo has hydroxyl or phenolic properties. The atomic content of bamboo is carbon, oxygen, hydrogen, silica, and potassium.

The electrodes used in this study are copper and aluminum. This study uses the concept of voltaic and redox reactions. Copper (Cu) has 29 electrons, and the outermost orbital has 1 electron. Copper has an oxidation number of 1+ and 2+, an ionization energy of 7.69 (eV), an electronegativity of 1.9, and an affinity of 118.4 (kJ/mol) as a conductor. Furthermore, aluminum (al) has 13 electrons and 3 electrons on the outermost part. Aluminum has an oxidation number of 3+, an ionization energy of 5.95 (eV), an electronegativity of 1.61, and an affinity of 42.5 (kJ/mol).

Bamboo mixed with water composition of 2 ml bamboo and 6 ml water. Limestone is as much as 2 ml, and water is as much as 4 ml. Furthermore, there will be an interaction between water and limestone between $CaCO_3$ and H_2O. Room temperature testing under normal conditions is 25°C. Furthermore, there is an increase in temperature in the solution produced from limestone with water. Water provides ionization energy in the dissolution process [33]. Thus, there is an increase in temperature, and an exothermic reaction occurs. The Ca atom will release 2+ electrons, 6- oxygen, and 1+ hydrogen. Thus, the atom will have positive and negative poles due to the polar nature of the atom.

3.1 Morphology and surface

Figure 3 shows the SEM EDX test on of various materials, including (a) bamboo, (c) Limestone, Turmeric, Bamboo, water, (e) turmeric, and (g) Bamboo, $CaCO_3$, turmeric, and electrode. Bamboo particles stick to the surface of aluminum and copper electrodes. After testing materials such as bamboo, limestone, and turmeric, Figure 3(a) shows the SEM analysis of a bamboo sample at a magnification of 20 microns, and Figure 3(b) presents the composition of bamboo as revealed by EDX testing. After testing, bamboo contains carbon, oxygen, silica, and potassium atoms. The test results show that bamboo has a carbon content of 59.28%. The hexagonal structure of phenol can interact with water solutions and dissolved limestone. Thermodynamics [15] plays a role in breaking the bonds between oxygen atoms with carbon and hydrogen. Figure 4(a) displays the results of SEM-EDX testing on bamboo to analyze the surface structure. Using ImageJ software, simulations were conducted to assess the surface contour and light absorption properties. The analysis aimed to determine whether the surface contour is predominantly upward or downward. The figure shows a yellow-white contour on the upper surface, indicating the presence of positive ions. The middle to bottom surface contour is red to black as negative ions.

Figure 3(c) shows the results of SEM-EDS testing on bamboo, limestone, turmeric, and water with a magnification of 300 nano. The electrolyte decomposes into atomic particles with electrically charged atom groups. The particles decompose into ions that move freely in solution. Electrolyte solutions have cation ions and anion ions. These ions conduct electrons to the electrodes. Positively charged ions will move towards the anode. While negatively charged ions move toward the cathode. Figure 3(d) presents the SEM-EDX test results for the same composite sample, with simulations using ImageJ software to analyze the surface shape. Figure 4(b) shows a yellow-white contour on the upper surface. The lower surface contour is red to black. The bright upper contour indicates positive ions. The dark lower contour indicates negative ions. This process combines bamboo, limestone, turmeric, and water solutions. The ImageJ simulation results show a dark sample.

Figure 3(e) depicts SEM test results at a magnification of one micron. Figure 3(f) details the EDX testing used to determine the atomic composition of the sample, which includes carbon (C), oxygen (O), potassium (K), aluminum (Al), silicon (Si), calcium (Ca), magnesium (Mg), phosphorus (P), and chlorine (Cl). Figure 4(c) shows the ImageJ simulation of these results, where the image appears bright with dark red and purple areas. Figure 4(c) has dark red and purple parts. In addition, turmeric has hydrogen-bonding properties [27]. Hydrogen bonds are double bonds in the aromatic center. Hydrogen bonds can interact with atoms in water. On the right and left sides, there is a hexagonal benzene structure. The structure of benzene is similar to phenol, capable of releasing hydrogen atoms when interacting with water. Furthermore, the phenol functional group has oxygen and hydrogen atoms.

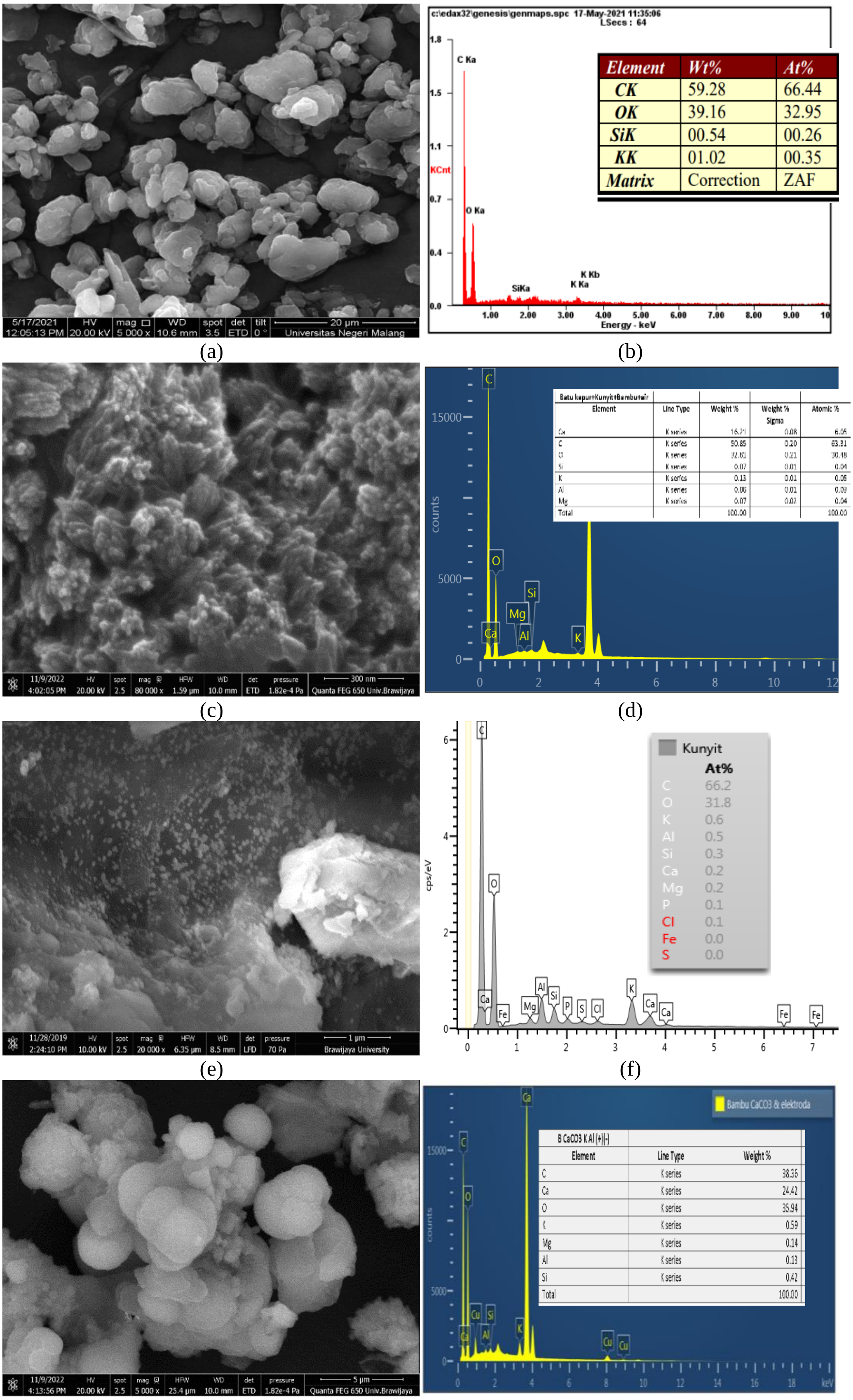
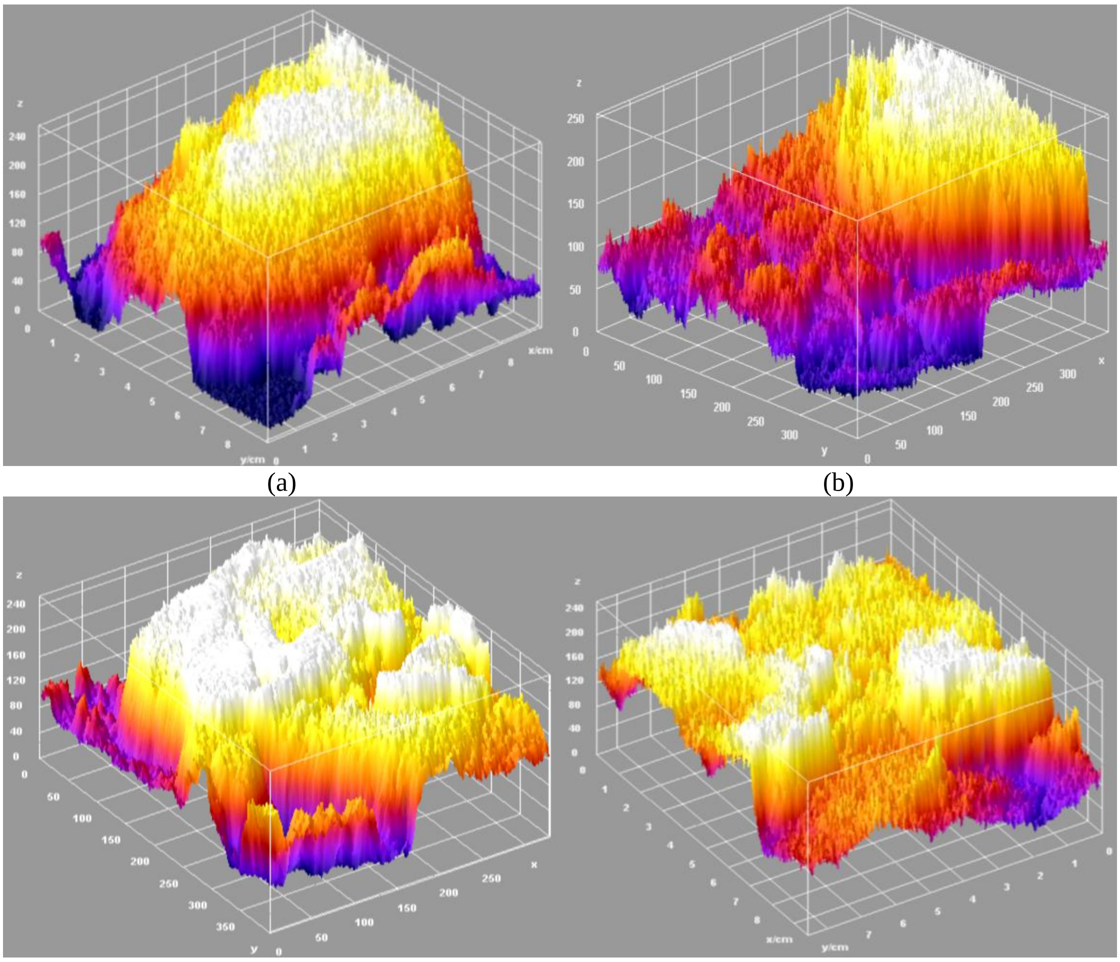


Figure 3. SEM test results (a)-(b) bamboo, (c)-(d) lime, turmeric, bamboo, water, (e)-(f) turmeric, and (g)-(h) bamboo, $CaCO_3$, turmeric and electrode



(a) (b)

(c) (d)

Figure 4. ImageJ simulation of (a) bamboo, (b) lime, turmeric, bamboo, water, (c) turmeric, and (d) bamboo, $CaCO_3$, turmeric and electrode

Figures 3(g)-(h) display SEM-EDX test results for a composite sample consisting of bamboo, $CaCO_3$, turmeric, and electrodes. The electrolyte solution enters the test sample for testing. The test results show a voltage of 1631 mV. The voltage produced by bamboo is polar, hydrophilic, and micro-sized. The atoms contained in the electrolyte solution create dipole-dipole moments. The resulting dipole moment increases the temperature in the electrolyte solution and produces thermodynamics (exothermic). An increase in temperature (exothermic) in the solution will cause van der Waals forces. Thus, the covalent bonds formed interact, and an attractive force occurs. An increase in temperature in the solution causes the atomic bonds to break [38]. Broken bonds cause the atoms to start moving. The movement of atoms makes the ions electrically charged. Both cations and anions, these ions move towards the electrodes, both cathodes and anodes. The anode releases positive electrons through the copper wire and is visible to the multitester. The electrons read on the multitester go to the cathode. This process continues until the solution becomes empty.

Some materials have polar or oxidizing properties. Hydrogen atoms will be excited into the electrolyte solution. The increase in temperature in the electrolyte solution is caused by an exothermic reaction. Exothermic reactions cause atoms to have dipole-dipole moments. The resulting attractive forces keep the molecules bound between molecules through electrostatic forces. The attractive forces occur between oxygen and magnesium atoms, while the van der Waals forces on oxygen and calcium occur between molecules. Thus, the molecules will tend to organize themselves. Thus, the equilibrium surface concentration involved in the Faraday potential is related to the electrode potential through the Nernst equation. Mass transfer plays a role in electrochemical dynamics [39]. SEM test results simulated with ImageJ software in Figure 4(d), shows a yellow-white contour on the upper surface marked positive. The lower surface contour is red to black with a negative sign.

To get the desired voltage, you need to test the electrolyte solution. After testing, the electrolyte solution produces voltage. Electrolyte solutions can produce ions, both cations and anions [16]. Electrolyte solutions produce ions between cation and anion ions, which begin to move toward the electrodes. The movement of ions towards the electrodes is due to the attractive force between atoms produced from the positive and negative poles. The moving ions have different electronegativity values and ionization energies. The ions begin to organize due to the differences in positive and negative poles. The attractive force between atoms moves quickly from the van der Waals force. The occurrence of redox reactions causes changes in charge. Electrically charged ions transfer electrons [4] and produce electrical energy. Thus, metals are easily oxidized to release electrons (donate).

3.2 Phase form and surface groups

Bamboo has a long chain of chemical bonds. Bamboo has carbon, oxygen, and hydrogen atoms. These atoms are bound to each other to form chemical bonds and functional groups. Van der Waals forces help in the formation of cellulose structures and form crystalline regions [40]. Cellulose is a long chain of ± 500 glucose molecules. The process of photosynthesis causes the formation of glucose. Cellulose is a polysaccharide that is arranged in parallel to form cellulose microfibrils. Long-chain polysaccharides are structured of hundreds to thousands of monosaccharides, binding microfibrils, and hydrogen bonds.

Cellulose is a straight-chain polysaccharide with D-glucose monomers. The molecular bond forms 1, 4-beta glycosidic, through two OH^- groups connected by an acetal-type oxygen bridge [40]. Cellulose has a long chain that has covalent bonds [19]. Cellulose is a hexagonal structure that forms a honeycomb [11, 19].

x-axis with a wavelength of 0 to 2000 cm^{-1} in Figure 5 shows the material is hydrophobic. While 2000 to 4000 cm^{-1} is hydrophilic. Materials that have hydroxyl groups can increase voltage [4]. FTIR test results for black bamboo, limestone, turmeric, bamboo, red water, green turmeric, and bamboo, $CaCO_3$, turmeric, and blue electrodes. FTIR test results contain functional groups: alkenes, alcohols, alkanes, aromatics, esters, alkynes, hydrogen, alkanes, and phenols. Bamboo contains alkanes (C-H), esters (C-O), alkanes (C-H), aromatics (C=C), and esters (C=O). Turmeric contains alkenes (C-H), alcohols (C-O), alkanes (C-H), aromatics (C=C), and esters (C=O). Bamboo is a mixture (limestone, water, and turmeric) of alkenes (C-H), alcohols (C-O), alkanes (C-H), aromatics (C=C), and esters (C=O). Bamboo is mixed (limestone, water, turmeric, and electrodes) with alkenes (C-H), alcohols (C-O), alkanes (C-H), aromatics (C=C), and esters (C=O). While on the left side of the bamboo there are alkynes (C≡C) and alkenes (C-H). Turmeric contains alkyne (C≡C), hydrogen (O-H), alkanes (C-H), and phenols (O-H). Bamboo is mixed with alkyne (limestone, water, and turmeric) (C≡C). Bamboo mixture (limestone, water, turmeric, and electrodes), alkyne (C≡C), hydrogen (O-H), alkanes (C-H), and phenols (O-H).

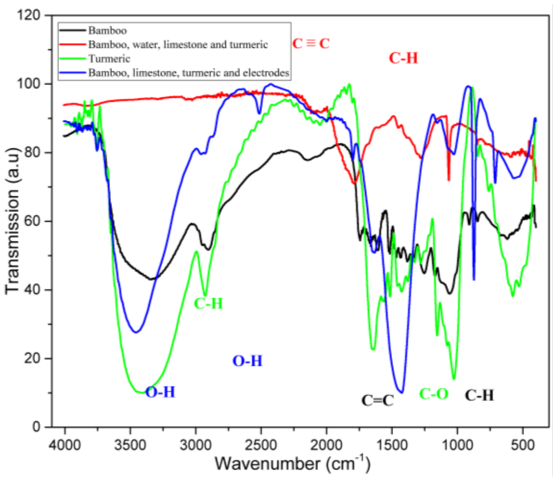


Figure 5. FTIR test results

Figure 5 presents FTIR test results for bamboo samples, depicted with black stripes. Bamboo with a black graph has a functional group content of C-H alkene 675-995, C-O carbon site, ester 1050-1300, C=C aromatic ring 1500-1600. Functional groups in bamboo can capture and release electrons. Bamboo has oxygen and hydrogen atoms that can release hydrogen when interacting with water while oxygen can interfere with or attract electrons in water. Atoms can exert attractive forces in a solution.

FTIR Test results of Limestone, Turmeric, Bamboo, and Water are red. Limestone, turmeric, bamboo, and water with red graphs have functional groups C-H alkene 675-995, C-H alkene 1340-1470, C≡C alkyne 2100-2260 hydroxyl groups contained in bamboo and turmeric. The samples are mixed and become electrolyte solutions. Electrolyte solutions can be used as materials for making batteries. Electrolyte solutions consist of polar and nonpolar atoms. These atoms become ions to conduct electricity. Turmeric mixed with water occurs under normal conditions. So, the interaction does not change significantly. However, there is an increase in the pH of the water surface from normal conditions of 7 to 8. The increase in pH causes the solution to become alkaline. The centrum base solution has more OH^- atoms or electrons. Turmeric contains enough hydroxyl and phenol as well as hydrogen and oxygen atoms.

FTIR test results for turmeric samples are indicated with green lines. Turmeric is an aromatic compound and contains carbonyl [26, 27, 36]. Turmeric has hydrogen bonds that can cause attractive forces between atoms in electrolyte solutions. Green turmeric contains functional groups C-H alkenes 675-995, carbon sites C-O, esters 1050-1300, C≡C alkynes 2100-2260, and C-H alkanes 2850-2970. In this study, turmeric contains hydrogen, which can quickly interfere with lime and bamboo. The properties of hydroxyl and phenol can release hydrogen in water. In addition, hydroxyl can increase tension in solution [4]. Hydroxyl is polar, interfering with water by creating a dipole. Positive and negative ions are like spins that stand up and down. The spin rotates like the north and south poles of a magnet. Turmeric has a hexagonal atomic structure (benzene) that attracts electrons in electrolyte solutions, causing the formation of double bonds (π-π) [26]. Electrons in the valence band jump (excited) to the conduction band. Atoms bound to the valence band cause the material to become polar, conductive, or semiconducting. Thus, the energy gap becomes smaller because it is closed by turmeric as a catalyst.

FTIR test results for a composite of bamboo, $CaCO_3$, turmeric, and electrode samples are highlighted with blue lines. The test results of the blue sample contain alkene functional groups C-H 675-995, carbon sites C-O, esters 1050-1300, alkenes C-H 1340-1470, hydrogen bonds O-H 2500-2700, and O-H hydrogen bonds, phenols 3200-3600. This content contains hydrogen bonds, and the electrolyte solution is base. Alkaline solutions have more OH^- and H^+. Turmeric contains OH^- or hydroxyl functional groups. In this range, 675-995 are alkenes, and 1340-1470 are alkanes. Furthermore, the OH^- content can release hydrogen atoms [41]. Hydrogen atoms interact with air containing H_2O [41]. So, hydrogen interactions occur with oxygen or hydrogen. This interaction creates dipole-dipole moments. Polar atoms will produce van der Waals forces. Oxygen atoms interact with hydrogen. In addition, the electronegative difference between oxygen and hydrogen of 1.24 causes hydrogen to have an attractive force with oxygen. Thus, the electrons in hydrogen are excited towards the oxygen atom. Oxygen requires 1 (one) hydrogen atom to be stable. Oxygen becomes stable after 8 (eight) electrons fill its orbital. Oxygen and hydrogen form polar covalent bonds from redox reactions.

Electrons moving in the conduction band provide energy from electrons. Electrolyte solutions produce electrons and then continue to the conduction band. Electrolyte solutions conduct positive and negatively charged ions [16]. Ions move towards the cathode and anode [4]. Redox reactions occur on the electrode surface or in the electrolyte solution.

3.3 Phase form and crystal structure analysis

XRD test in Figure 6 determine whether the sample is amorphous or crystalline. The samples used are a) bamboo, b) limestone, turmeric, bamboo, water, c) turmeric, d) bamboo, $CaCO_3$, turmeric, and electrode, and e) limestone. Figure 6 Bamboo with black lines has amorphous properties. The amorphous property appears because bamboo has become a nanomaterial. Bamboo has a hexagonal structure in the form of long chains and bonds to each other form covalent bonds. Bamboo has covalent bonds. In bamboo, nanocracks occur due to the breaking of covalent bonds. Thus, bamboo turns into a nanomaterial. Red lines of limestone, turmeric, bamboo, and water in Figure 6 have amorphous properties. The sample has amorphous properties because the sample has dissolved. Blue lines of turmeric have amorphous properties. Turmeric in powder form has a microparticle size. Bamboo, $CaCO_3$, turmeric, and electrodes with purple lines have amorphous properties. In this condition, the sample is in a dry electrolyte solution. Limestone with green lines in Figure 6 has crystallized. The amorphous material found in the study has micro and nanomaterial sizes. Limestone is the result of a long natural process (limestone).

Thus, bamboo has crystalline properties. Crystals arrange the attractive forces of atoms evenly through heating and cooling. In addition, chemical bonds are arranged unevenly in amorphous materials and have greater energy mobility. In this case, the interaction of amorphous with water produces energy faster. Thus, amorphous properties have the energy to transfer ions to the electrodes [2]. Crystalline materials form ionic and covalent bonds. Limestone forms covalent bonds with the presence of van der Waals forces.

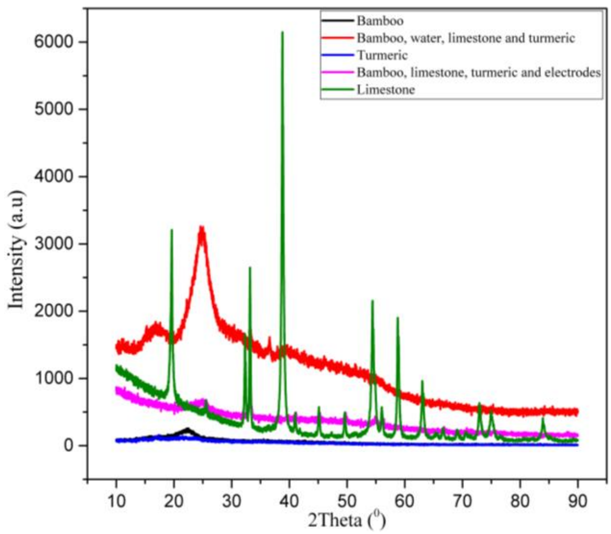


Figure 6. XRD testing

3.4 Quantum energy

UV-Vis testing was used to obtain wavelength and energy absorption in Figure 7. The samples used were a) bamboo, b) limestone, turmeric, bamboo, water, c) turmeric, and d) bamboo, $CaCO_3$, turmeric, and electrodes. After testing, absorption occurred up to 800 nm. Furthermore, the light that comes out is absorbed by the material. The absorption process affects the particle size. The smaller the particle size, the shorter the absorption wavelength. The smaller the material, the greater the impact interaction with light. In addition, light with a short wavelength is more stable. In contrast to longer wavelengths, waves have more OH^- bonds.

Table 1 shows the energy absorption and Homo-Lumo in bamboo, turmeric, electrolyte solution, and test samples. After testing, UV-Vis produces an absorption wave of 200-224 nm. Furthermore, the light emitted through the UV-Vis test can be absorbed by bamboo, turmeric, and limestone. Thus, electrons in the valence band (Homo) are excited to the conduction band (Lumo) [42]. The energy absorbed into molecules or atoms produces electron jumps. So electrons move from Homo to Lumo. When electrons are in Lumo, they move freely. Max Planck light has particle properties. De Broglie particles have wave and particle properties. Therefore, electrons have small particles. In this study, limestone contains Ca and CaO. Bamboo contains carbon, oxygen, hydrogen, and potassium. Turmeric contains carbon, oxygen, hydrogen, and potassium. The light that propagates (radiation) hits the atom and is absorbed. Carbon in bamboo has 2 electrons in the first orbit (K). The second orbit contains 4 electrons (L) moving around the atomic nucleus (protons and neutrons) with centripetal force.

UV-Vis testing in Figure 7 calculates the amount of energy absorption from the wavelength. UV-Vis testing is to determine the amount of energy absorption. Turmeric has an energy gap of 0.66 eV, and bamboo has an energy gap of 0.54 eV. In this case, bamboo is a nanomaterial. Nanomaterials can accelerate ion transfer and electron transfer [1]. So, the shorter the wavelength, the higher the frequency [37]. Energy absorption affects the energy of photons emitted and absorbed by the sample. Bamboo samples have molecules or atoms. Molecules or atoms have protons, neutrons, and electrons. The emitted photon energy (radiation) will be captured by electrons. The photon energy accumulated in electrons provides energy for excited electrons [42]. Electrons are excited from the valence band to the conduction band. The energy required is 140 kcal/mol with an absorption length of 200 nm. Table 1 also calculates the Homo-Lumo that occurs in each sample.

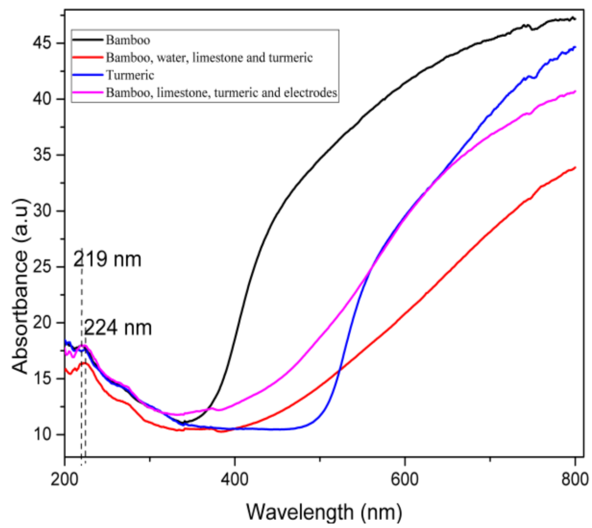
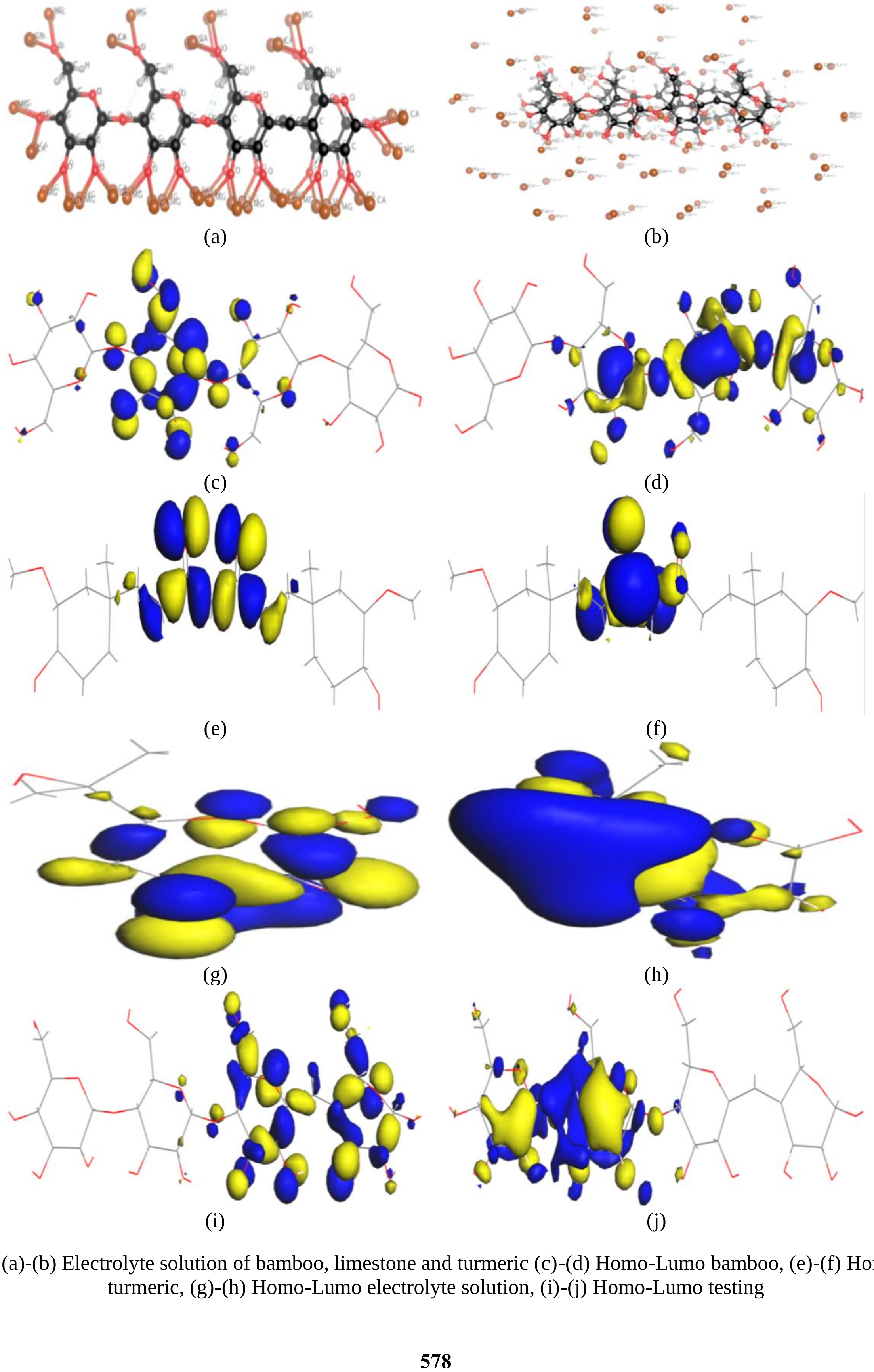


Figure 7. UV-Vis testing, quantum size and shape spectrum

Table 1. Energy absorption and Homo-Lumo

No.	Sample	Peak Absorption (nm)	E = hc/λ (eV)	E (eV)	Homo-Lumo (kkal/mol)
1	Bamboo	200 219	6.19 5.65	0.54	140 128
2	Bamboo, water, limestone and turmeric	201 222	6.16 5.58	0.58	140 126
3	Turmeric	200 224	6.19 5.53	0.66	140 125
4	Bamboo, limestone, turmeric and electrodes	200 220	6.19 5.63	0.56	140 128



(a) (b) (c) (d) (e) (f) (g) (h) (i) (j)

Figure 8. (a)-(b) Electrolyte solution of bamboo, limestone and turmeric (c)-(d) Homo-Lumo bamboo, (e)-(f) Homo-Lumo turmeric, (g)-(h) Homo-Lumo electrolyte solution, (i)-(j) Homo-Lumo testing

Table 2. Energy of Homo-Lumo interaction using DFT orbital

Name	HOMO	LUMO	Bandgap	Total Energy
Bamboo	-0.2727 eV	0.0226 eV	-0.2953 eV	-2663.463858 kcal/mol
Turmeric	-0.2306 eV	-0.0277 eV	-0.2029 eV	-1432.1772070 kcal/mol
Bambu, batu kapur, dan kunyit	-0.26293 eV	0.0197 eV	-0.28263 eV	-809.5727438 kcal/mol
Pengujian	-0.2493 eV	0.00857 eV	-0.24498 eV	-2625.4645133 kcal/mol

Figures 8(a)-(b) depict an electrolyte solution containing bamboo, $CaCO_3$, turmeric, which sticks to the electrode surface. In Figures 8(a)-(b), the carbon (C) content from bamboo is shown interacting within the electrolyte solution. Bamboo contains carbon atoms. Carbon atoms have 1s2, 2s2, 2p2, and oxidation numbers (0,-1,-2,-3,-4,+1,+2,+3,+4). The outer shell of the C atom only has four (4) electrons. The C atom requires 4 electrons to be stable. So, electron transfer occurs with a redox reaction. Redox reactions can increase the temperature in the electrolyte solution. Increasing the temperature provides energy for atoms to give up electrons. Molecules that have polar properties will have a positive pole. Nonpolar molecules have a negative pole. This reaction produces dipole-dipole moments and the formation of van der Waals forces. Thus, molecules or atoms that have oxidizing properties will release electrons. Atoms that have reducing properties will accept atoms. In this case, the reduced carbon molecule or atom will receive electrons. Furthermore, the interacting molecules or atoms will produce positive and negative poles. Thus, the electronegativity value and ionization energy can determine the type of covalent bond, whether polar or nonpolar.

Cellulose in long-chain bamboo in Figure 8(c)-(d) has energy in the Valence band. Energy in the valence band is the base energy contained in each atom. Meanwhile, the conduction band energy is the energy at the top that has passed the energy gap. Figure 8(c)-(d) is a DFT simulation of the valence and conduction bands. Valence band or Homo and conduction band or Lumo. The results of the DFT test in Table 2 bamboo with Homo energy of -0.2727 eV and Lumo energy of 0.0226 eV. Bamboo has a band gap of -0.2953 eV and a total energy of -2663.463858 kcal/mol.

Figure 8(e)-(f) is a DFT simulation of turmeric by measuring the energy on Homo - Lumo, Table 2 with turmeric testing obtained energy on Homo -0.2306 eV and energy on Lumo -0.0277 eV. Turmeric has an energy gap of -0.2029 eV and a total energy of -1432.1772070 kcal/mol. Figures 8(g)-(h) show a DFT simulation of bamboo, limestone, and turmeric with Homo energy -0.26293 eV and Lumo 0.0197 eV. Bamboo, limestone, and turmeric have an energy gap of -0.28263 eV and a total energy of -809.5727438 kcal/mol.

Figures 8(i)-(j) show testing of the material in the form of an electrolyte solution to measure the generated voltage. The electrolyte solution produces a voltage of 1631 mV. The electrolyte solution is then simulated with DFT to see the interaction, Homo energy -0.2493 eV and Lumo energy 0.00857 eV in Table 2. The band gap is -0.24498 eV, and the total energy is -2625.4645133 kcal/mol. The simulation results require energy of -0.24498 eV to move from the valence band to the conduction band. Energy comes from the interaction of electrolyte solutions in the form of ions that move and arrange themselves on the electrodes. The ions then arrange themselves on the positive and negative electrodes. The arrangement occurs because of the difference in poles between the positive and negative poles.

3.5 Bamboo's ability to generate electricity

Figure 9 focuses on tests conducted to measure the electrical voltage produced. Figures 9(a), 9(b), and 9(c) each display different voltages obtained during the testing. In Figure 9(c), the electrodes used are identified as aluminum and copper. In addition, aluminum can transfer higher charges [5]. Aluminum has 3 electrons on the outside. Copper has 1 electron on the outside. Aluminum can lose Three (3) electrons to become 3+. Copper loses two (2) electrons to become 2+ or Cu^+. Aluminum has an electron configuration of 3p1. Copper has an electronic configuration of 4s1. The sample in liquid form is an electrolyte solution, while the paste is a dry material. In this case, the sample is taken using a syringe and injected into the test site. In this case, place the paste sample on the electrode surface. The test results in Figure 8(c) the voltage value of 508 mV the addition of turmeric increases to 1631 mV. The smaller the size of the material used will affect the interaction in the electrolyte solution. Figure 9 shows the interaction in the electrolyte solution affects the energy released [4]. Therefore, it is necessary to develop a different energy storage system, which is being developed globally [4].

Bamboo, limestone, and turmeric solutions combined in water will cause an electrochemical reaction. Furthermore, nanofluids play a role in fluid mechanics, thermal conductivity, and chemical and electrochemical reactions [43]. Dissolved bamboo (cellulose) decomposes into nano or micro-sized particles [1]. Electrolyte solutions containing ions have cation (positive ion) and anion (negative ion) properties. Furthermore, the freely moving ions conduct electric current through the solution [1]. Electrolyte solutions are solutions that produce electric current.

Bamboo in the form of nanoparticles will interact with the atoms around it. Increasing the temperature of the electrolyte solution causes the atoms to interact. Polar and nonpolar properties will affect the formation of chemical bonds. Polar atoms will provide an attractive force with polar atoms. While nonpolar tries to keep its distance from the poles. Because polar compounds can interact with nonpolar solutions or tend to separate themselves, these dipole-dipole moments then interfere with the interaction of molecules. With interaction, Van der Waals forces strengthen the interactions between molecules. Van der Waals forces produce attractive and repulsive forces on nanoparticles [35, 44, 45]. Van der Waals forces create an electric field and produce electrostatic forces. Nanoparticles indirectly increase thermal conductivity and heat transfer coefficients [35].

Bamboo (nanoparticles) with a smaller surface area can shorten the ion diffusion path [2]. Particles undergo dispersion or splitting and are evenly distributed in water. Chemical reactions can increase energy in electrolyte solutions through ion movement [4]. Exothermic reactions occur in $CaCO_3$ and H_2O, changing form to $Ca(OH)_2$ and CO_2 and releasing heat energy. The released heat energy causes an increase in temperature in the surrounding environment.

Bamboo has a long chain cellulose structure and has covalent bonds [19]. Cellulose is a hexagonal honeycomb structure [11, 19]. The structure formed forms a noncrystalline or amorphous area [40]. Cellulose is a polysaccharide that is arranged parallel and has hydrogen bonds. Polysaccharides have OH^- functional groups, which cause cellulose to become crystalline and insoluble. Nanoparticles have a hexagonal or honeycomb structure with OH^- and CH^- groups. The OH^- and CH^- functional groups will release hydrogen atoms and interact in electrolyte solutions. Carbon and oxygen atoms in glucose can interfere with atoms in electrolyte solutions. Glucose has hydrophilic or polar properties and can interact with Ca, O, K, and Cu atoms. The electrodes used for aluminum are placed at the bottom, as shown in Figure 9, while copper is at the top. Micro-sized bamboo will settle with turmeric and limestone. While the nano-sized ones will float at the top. Thus, hexagonal (nano) bamboo, turmeric, and limestone will be the connectors.

This study measured the room temperature and electrolyte temperature before testing. Limestone can increase the temperature of the test room by about 20-50℃. Increasing the temperature will make it easier for electrons to be excited [10]. Exothermic reactions reduce the temperature and the rate of heat release and reduce the danger [46]. Molecules contained in limestone, turmeric, and bamboo require energy to break atoms. Bond energy is the strength of the bond between atoms in a molecule. The C-C bond has a strength of 358 kJ/mol and the O-O bond is 146 kJ/mol in one bond. The reactants here are bamboo, limestone, and turmeric. The multimeter detects the voltage released from the electrolyte solution. The atomic content in the electrolyte solution can indicate molarity. So, the mixture that reacts depends on the size of the molarity of the substance. The reaction rate results in a decrease in the amount of reactants or an increase in concentration over time. So, the reacting molecules cause movement and friction between atoms. The movement of atoms results from the particle size and molarity of a substance. The larger the surface area (atomic or nano) can provide contact with the transformation of electrolyte ions [1].

The atoms in the electrolyte solution are ionic compounds that interact. These atoms form molecular compounds. Thus, the molecules have minimum energy to react. Electrolyte solutions undergo chemical reactions and require minimum energy. Thus, increasing turmeric causes small activation energy [42], and the reaction is fast. The greater the activation energy, the slower the reaction. The molecules contained in the electrolyte solution have kinetic energy above the activation energy. Kinetic energy can produce electrical energy and electrical energy in a minimum amount to pass through the reactants. Catalysts are used to lower the energy barrier but do not affect the energy of the reactants or products [47].

Electrochemical cells as Faraday current flows in galvanic cells or electrolytic cells. Chemical reactions that occur in electrolyte solutions cause electron transfer in the form of ions, thus producing electrical energy [48]. Ions in electrolyte solutions provide attractive force interactions on the electrode surface [39]. Electrolyte solutions contain H^+, Mg^+, K^+, P, and Ca^+ ions that carry these ions. These ions interact with copper and aluminum electrodes, and the difference in electrical potential on the electrode surface is equal to the relative energy. Electrochemical cells function as potential generators and produce current responses to time, thermodynamics, and kinetic energy [39]. Furthermore, ionic compounds contained in the electrolyte begin to move towards the electrodes. Increasing temperature [42] causes ionic compounds to move rapidly in their own arrangement. The movement of ions towards the anode is caused by the van der Waals force between the cation and anode ions. Anions exert van der Waals forces with the cathode. Atoms are indirectly attracted and arrange themselves. Thus, electrons dissolved in electrolytes will exert van der Waals forces on atoms that have greater electronegativity and ionization values [49].

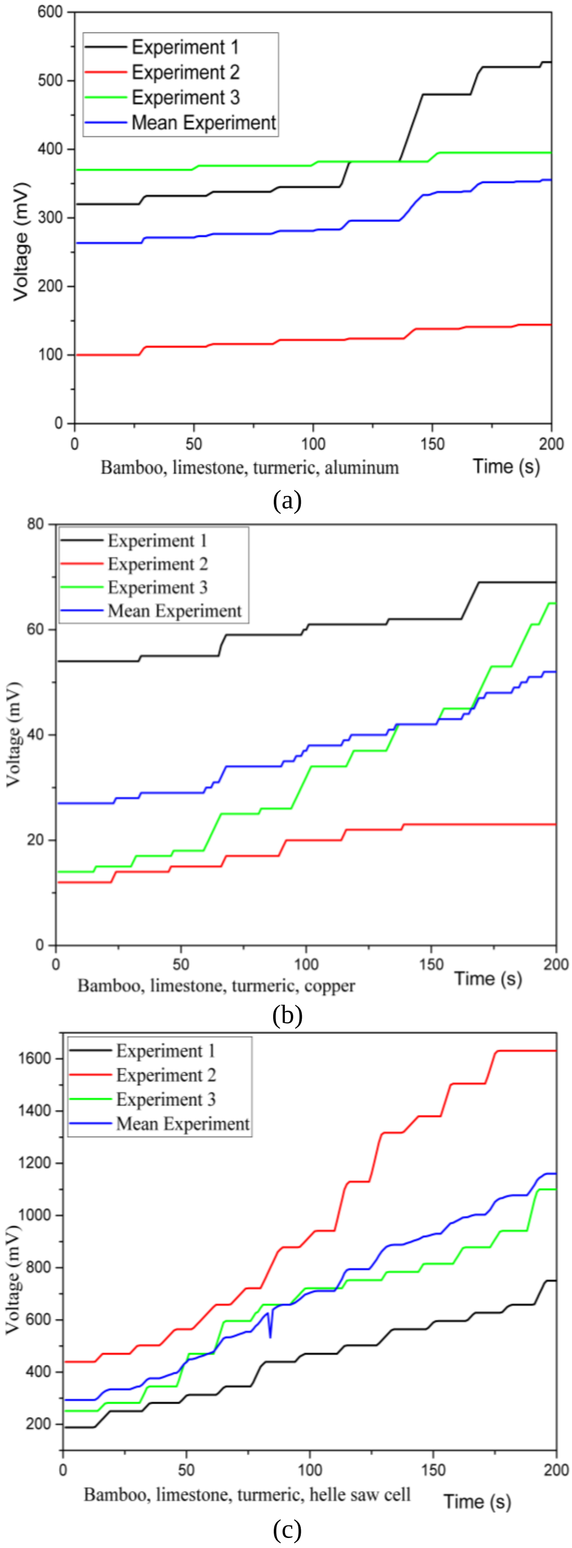


Figure 9. Use of electrodes: (a) Aluminum electrode (milliVolts), (b) Copper electrode (milliVolts), (c) Aluminum and copper electrodes (milliVolts)

The Volta concept can provide an overview in determining the use of electrodes. Electrolyte solutions that hit the electrodes provide potential energy and increase the reaction rate. Van der Waals forces cause ionic compounds to experience attractive forces, forming covalent bonds. Atoms with low electronegativity values will be attracted to atoms with high electronegativity values. Furthermore, electrons in atoms begin to be disturbed, and electrons that are tightly bound to protons begin to vibrate (Coulomb's law). Heat energy causes electrons to move in orbitals, and electrons begin to be excited towards the conduction band. Electrons on the electrodes, aluminum, and copper, begin to be excited. It takes 0.56 eV of energy to jump. Empty orbitals in the valence band (electrodes) are filled by molecules or atoms attached to the electrodes [37]. Heat energy continues to work on the sample, and the reaction rate and catalysts help process the donated electrons faster. Electrolyte solutions provide electrons to fill empty orbitals in the valence band.

Turmeric has a hydroxyl group that can release H (Hydrogen) atoms and interact with water [26]. Polar properties also affect the attractive force between molecules in solution and produce enthalpy between atoms. If the negative electrode potential moves to a positive potential, the molarity of the substance will be oxidized (reducing agent) [39]. The transfer of electrons causes an oxidation or reduction reaction. If Faraday's law applies, a reaction will occur between the electrolyte solution and the electrode.

The electrochemical process is a redox (oxidation-reduction) reaction in which oxygen binds and releases hydrogen or electrons. In addition, a redox reaction is a reaction that obtains and releases electrons. Cu^{2+} (aq) + e^- → Cu^+(s), Cu releases electrons for oxidation. Al^{3+} (aq) + $3e^-$ → Al(s), Al is reduced. Thus, the atoms in the electrolyte solution undergo a redox reaction. Releasing electrons causes the number of positive atomic charges (protons) to increase or remain the same. The captured electrons cause an increase in the negative charge of the atom [50]. The magnitude of the oxidation number can follow the Lewis formula [16]. As the reaction progresses, the number of oxidizing elements increases. There is a transfer of electrons from the negative pole to the positive pole. Redox reactions occur when atoms, molecules, or ions are released and form new bonds, covalent bonds, and ionic bonds. The ions that interact in the electrolyte solution are converted into electrical energy [8].

Redox reactions cause the transfer of electrons from atom to atom. Therefore, redox reactions produce electrical energy. The unidirectional movement of electric current is produced from the flow of electrons. Atoms contained in electrolytes or chemicals act as electric currents. Releasing electrons causes the number of positive charges (protons) of atoms to increase. Thus, capturing electrons causes the addition of negative charges (atoms) [50]. Oxidation reactions produce positive charges on atoms. Atoms in electrolyte solutions will form molecules. Dissolved atoms release electrons. Electrons experience attractive forces with electrodes and produce redox reactions. The Lewis formula Mg in Figure 10 has an atomic number of 12 and has an electron configuration of 2.8 and 2. The Mg atom has 2 electrons. To achieve stability, Mg must release 2 electrons on the outside [50]. So, Mg has a charge of +2 or Mg^{2+}.

$$Mg + \frac{1}{2}O_2 \rightarrow MgO \ \Delta\mathrm{H} = -601{,}83 \ \mathrm{kJ}$$

The element O has an atomic number of 8, so its electron configuration is 2 and 6. Furthermore, the electron configuration in O has 6 electrons. So to achieve stable O requires 2 electrons. So, O has a charge of -2 or O^{2-}.One of the contents of limestone is magnesium (Mg). The Mg content in limestone can improve battery performance. Thus, Mg dissolves into an electrolyte [7]. Limestone or magnesium interacts with water (H_2O) producing oxidation-reduction. Electron transfer (Homo-Lumo) increases the oxidation number of the element [50]. Redox reactions occur between atoms, molecules, or ions that transfer electrons to each other. The energy released from the redox reaction becomes electrical energy. Thus, the transfer of electrons produces movement in the same direction as the electric current produced by the electrons. Voltaic cells consist of electrodes (anode and cathode) where the redox reaction occurs. The electrolyte fluid that enters the electrode contains chemicals [16] and can produce an electric current. Furthermore, with the release of electric current, electrons cross the solution and attach to the electrode surface, and a reaction occurs [39, 49]. Next, electrons spread from the solution phase to the electrodes. 5.95 eV, there is an attractive force between atoms in the electrolyte solution, and reduction occurs. Thus, there will be electrons flowing towards the metal. Electric current flows from the cathode with lower ionization energy to the anode with higher ionization energy. Current is generated from the anode to the cathode due to the difference in electrical potential energy between the electrodes. Electromotive force is measured from the cell by the amount of electrical potential passing through the electrodes.

The molecules contained in the electrolyte solution become polar materials with polar molecular dipole moments. Dipole-dipole moments cause an imbalance in the distribution of electrons. Electrons will be attracted to the positive electrode, and the positive nucleus will be attracted to the negative electrode. The dipole moment produces an electric field, and polarity occurs. Thus, molecules that have polar properties will form covalent bonds. With the formation of covalent bonds, the role of the dielectric constant is greater. Electrons become more polar when moving towards an electric field. The resulting electric and magnetic fields affect electromagnetic waves. Waves propagate from energy originating from photons. Lower waves mean more photon energy.

Electrons in Figure 10 are particles that move in the electron cloud, and their motion follows its trajectory. The electron cloud in Mg, Ca, and Fe atoms has 2 electrons in the outermost part. The two electrons will move clockwise and counterclockwise, according to the movement in quantum spin [35]. Opposite magnetic fields are needed to balance the existing electric repulsion. Electrons move one clockwise and one counterclockwise [51]. The rotating electric charge produces a magnetic field, and its direction depends on the spin.

The electron configuration of copper (Cu) atoms has electrons in different orbitals and energy levels. The filling of electrons follows the Aufbau, Paulin, and Hund principles. So we can see that the 1s orbitals are +½ and -½. The two electrons must be opposite electrons with opposite spins (paired electrons). Both electrons rotate through the axis in opposite directions like two arrows. The electron configuration of K^+ and Cl^- ions. 19K: 1s2 2s2 2p6 3s2 3p6 4s1 When the k atom loses 1 electron, a K^+ ion is formed which has 19 protons and 19 - 1 = 18 electrons. The electron configuration of the K^+ ion K^+ ion: 1s2 2s2 2p6 3s2 3p6. The excited electron configuration has electrons occupying orbitals with higher energy levels. 1 electron in the 2s orbital is promoted to the 2pz orbital (energy level 2pz > 2s) so that it becomes an excited state.

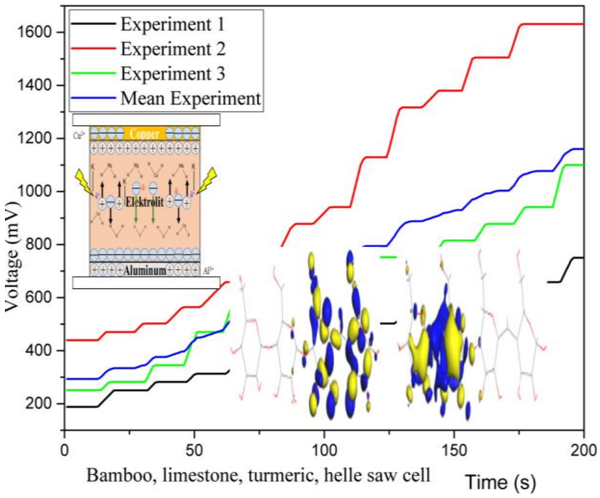


Figure 10. Addition of turmeric, and the difference in electrodes increases the electrical energy

The electrical conductivity of metals is good at conducting electricity. Conductor materials that do not have a gap between the valence band and the conduction band can conduct electricity quickly. Thus, atoms or electrons can move through the sample. Electrons absorb and release photons with many frequencies when moving between the valence band and the conduction band. Thus, the positive metal ion layer can move through each layer and is always protected from electrons that are mutually delocalized [51]. Thermal conductivity When the metal is hot, electrons at the highest energy move as kinetic energy along the wire. When the metal conducts electricity, electrons begin to move. The electrical energy read by the multimeter is the movement of electrons from high potential to low potential. Electrons moving from the negative pole of the battery (anode) will flow to the positive pole (cathode).

During the testing process, the electrolyte solution will increase the temperature in the test room. Increased temperature and testing process will affect battery degradation [52]. Degradation occurs at testing temperature and usage time. During the testing process, there is degradation of atomic movement in the electrolyte solution [53]. The longer the use, the lower the ability of atoms to interact. Thus, researchers innovate technology, by increasing battery life and performance.

4. CONCLUSION

Battery development continues to increase from electrolyte and electrode materials. Electrolyte solutions using natural materials are promising research with various aspects of composition and renewable, such as green energy. Organic materials such as bamboo and limestone are easy to find and process. The test results show that the voltage produced from bamboo and limestone before being mixed with turmeric is 508 mV. Turmeric is an antioxidant, has properties as a catalyst in accelerating reactions, and has aromatic rings and hydrogen bonds. After adding turmeric, it produces a voltage of 1631 mV. Turmeric has oxygen and hydrogen content that can increase energy. The addition of turmeric increases the solution to become alkaline and increases the content of OH^- and H^+. Research development requires testing of ampere, Tem, development of catalyst materials, and degradation factors.

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