DESIGN AND DEVELOPMENT OF SALTWATER LAMP (ALUMINUM-COPPER SALTWATER LAMP & ALUMINUM-AIR SALTWATER LAMP)

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ABSTRAK

Kajian ini bertujuan untuk mereka bentuk, membangun dan membandingkan lampu air masin aluminium-udara dan aluminium-kuprum untuk menentukan pilihan terbaik untuk kegunaan. Metodologi melibatkan reka bentuk lampu air masin, menghasilkannya, dan menjalankan ujian untuk mengumpul data mengenai bacaan voltan, arus dan kecerahan. Keputusan menunjukkan bahawa kedua-dua lampu air masin berjaya dihasilkan dan lampu air masin aluminium-udara menghasilkan pencahayaan yang lebih tinggi berbanding lampu air masin aluminium-kuprum disebabkan oleh bacaan arus dan voltan yang lebih tinggi. Kesimpulannya ialah reka bentuk dan pengeluaran kedua-dua lampu air masin telah berjaya, dan lampu air masin aluminium-udara adalah pilihan yang lebih baik untuk memberikan cahaya. Cadangan untuk penambahbaikan pada masa hadapan termasuk menggunakan katod dan anod yang lebih kecil, menggabungkan teknologi solar, menggunakan pemangkin alternatif untuk menggantikan grafit, dan menggunakan lampu air masin sebagai panduan untuk mencipta penjana kuasa.

ABSTRACT

This study aimed to design, develop, and compare aluminum-air and aluminum-copper saltwater lamps to determine the best option for usage. The methodology involved designing the saltwater lamps, producing them, and conducting tests to gather data on voltage, current, and luminance readings. The results showed that both saltwater lamps were successfully produced and that the aluminum-air saltwater lamp produced higher luminance compared to the aluminum-copper saltwater lamp due to higher current and voltage readings. The conclusion is that the design and production of both saltwater lamps was successful, and the aluminum-air saltwater lamp is the better option for providing light. Recommendations for future improvements include using smaller cathodes and anodes, incorporating solar technology, using alternative catalysts to replace graphite, and using the saltwater lamp as a guide to create a power generator.

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List of symbols

%	Percent
mℓ	Millimeter
H_2	Hydrogen
$2H^+$	Hydrogen ion
$2e^-$	Ion
O_2	Oxygen
H_2O	Water
Ni	Nickel
Co	Cobalt
Cu	Copper
NaCl	Sodium Chloride
Na+	Sodium ion
Cl–	Chloride ion
CO2	Carbon Dioxide
Min	Minute
Al	Aluminum
A	Ampere
W	Watt
MW	Megawatt
Mm	millimeters

List of abbreviations

CFL	Compact fluorescent lamp
UPS	Uninterruptible power supply
LED	Light-emitting diode
USB	Universal Serial Bus
3D	Three-dimension
PEMFC	Proton exchange membrane fuel cells
PTFE	Polytetrafluoroethylene
PAFC	Phosphoric acid fuel cell
SOFC	Solid oxide fuel cells
YSZ	Yttrium-stabilized zirconia
MCFC	Molten Carbonate Fuel Cells
OER	Oxygen evolution reaction
ORR	Oxygen reduction reaction
CER	Chlorine evolution reaction
CRR	Chlorine reduction reaction
NASICON	Sodium Super Ionic Conductor
PLA	Polylactic acid

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CHAPTER 1

INTRODUCTION

1.1 Project Background

As a result of industrial development and population expansion, worldwide energy consumption has risen dramatically in recent years. Energy demand, particularly liquid fuels, has been increasing since the early 2000s, resulting in a bottleneck that has led to the present energy crisis. Malaysians are now facing an energy crisis as local resources are depleted, there is a greater reliance on imported fuels, and those imported fuels are becoming more expensive. Oil, gas, and coal presently account for 94% of global energy output, but with growing electricity demand and the likelihood that these natural resources will ultimately run out, greater diversity of power supply sources is required (Aminuddin et al., 2014).

Electricity is a vital requirement in everyone's everyday life but laying grid cables hundreds of kilometers over challenging terrain and dense rainforest to service a small distant town is not economically feasible. High tension electrical cables from a huge hydroelectric plant travel through rural settlements in Sarawak, Malaysia, but the expense of scaling down the power to serve these little towns proved too expensive. As a result, local governments frequently choose interim solutions such as installing modest diesel generators and solar panels in isolated settlements. Diesel generators, on the other hand, are proven to be costly to operate and maintain in Sarawak's low-income isolated settlements. Fuel must be carried across great distances by river or on washed-out roads (Anyi et al., 2010).

For now, the best option to help with this problem is improving lighting availability in Malaysia's rural areas, according to this study, by developing battery cells that utilize saltwater as an electrolyte. Seawater or saltwater is a viable alternative to renewable energy sources for generating low-cost, efficient, and environmentally friendly power for a variety of applications, including military and commercial equipment. Emergency lights, reserve power, long-lasting quiet power for communication equipment and lighting on boats and other nautical items, and illumination for camping and small-scale fishing have all been produced using seawater batteries. In fishing, it was used in a fixed lift net. Fixed lift nets are a type of small-scale fishing gear that uses artificial light to lure phototaxis fish to the fishing gear as it is being fished. Fishermen typically utilize a gasoline generator to power many compact fluorescent lamps (CFLs) as light sources (Susanto et al., 2017). This method also can be applied to the lamp as we can replace seawater with water that mix with salt as a battery for the lamp in rural areas.

1.2 Problem Statement

For developing countries like Malaysia, electrification of remote rural regions without access to the national electrical grid is a critical issue. Access to electricity is influenced by a variety of social and geographic factors, and rural places do not all have the same topography or socioeconomic indices. In general, there are differences between Peninsular and East Malaysia in two factors which are the number of people living in rural regions and the amount of electrification. According to current data, 99.7% of residents in Peninsular Malaysia have access to electricity, but electrification in Borneo (Sabah and Sarawak) is lower than in Peninsular Malaysia (Izadyar et al., 2016). Distant rural regions are the locations where energy is unavailable. Due to geography and cost, these isolated places are typically not linked to the national electrical system. And the current energy is supplied by high-cost fuel that must be transported from far away.

Fuel cell technology is a viable replacement for fossil fuels in remote locations where there is no connectivity to the public grid or where cabling and transmitting power is too expensive. Fuel cells can also be used as a source of energy in applications with critical secure electrical energy requirements, such as uninterruptible power supply (UPS), power-producing stations, and distributed systems. Despite this, there are a few drawbacks to using fuel cells. Pulse demands and contaminants in the gas stream, for example, reduce the life duration of fuel cells. Other problems for fuel cell technology development include low power density per volume, accessibility, and durability (Mekhilef et al., 2012).

For ages, people have known about the notion of saltwater energy. The technological challenges surrounding saltwater energy, on the other hand, are rarely mentioned since the technology is not yet ready for broad usage. Because saltwater energy is made up of electrodes and seawater, it's crucial to figure out the impact of different electrode combinations, the number of cells, electrode durability, and saltwater salinity (Bani et al., 2018). This aims to ensure the construction of a cost-effective new salt-water-powered illumination system for rural and isolated areas in Malaysia and throughout the world. Furthermore, this new technology will serve as a power bank, which will come in handy during times of floods, which is a typical occurrence in Malaysia during the rainy season.

1.3 The objective of study

I. To design and develop the aluminum-air saltwater lamp and aluminum-copper saltwater lamp.

II. To find the best saltwater lamp between the aluminum-air circuit and aluminum-copper circuit that can provide the best luminance for usage.

1.4 Scope of study

The scope of the study would be to design, develop, and compare the performance of aluminum-air and aluminum-copper saltwater lamps. This would involve the design and fabrication the saltwater lamps, including the selection of appropriate materials and components. Then, the characterization of the electrical and optical properties of both types of lamps, including the measurement of voltage, current, and luminance. After that, comparison of the performance of the aluminum-air and aluminum-copper saltwater lamps, including an assessment of the luminance, efficiency, and overall quality of the light produced. And finally, identification of the best saltwater lamp between the two types based on the results of the comparison and evaluation of their performance.

The study should consider the practical applications and limitations of aluminum-air and aluminum-copper saltwater lamps as sustainable lighting solutions. The limitations include the availability and quality of materials, the cost of materials and components, and the efficiency of the lamps. Additionally, the luminance of the lamps can be affected by factors such as the voltage, current, and composition of the electrolyte solution, and can also vary with changes in temperature and humidity.

1.5 Significance of study

While Malaysia still can be considered one of the developing countries, there is still part of the country that experiences no electricity and is far from the main source of basic needs. That rural area is not connected to the main road and people must get through the thick forest to get to them. Not just that, their main source of electricity came from using fossil fuels that are not just expensive to buy, but costly to transport from the main city to their area. The study of making saltwater lamp is to help those people in need of luminance at night to help their children study, and not just that, to reduce the use of fuels for lamps when the fuels can be used to generate electricity for other electrical equipment.

Malaysia experiences monsoon season every single year and flood is like a yearly phenomenon especially, on the east coast of Malaysia. But with a recent event that happen during the school holidays at the end of 2021, Malaysia faced great despair when a flood occurred in the west part of the country and a lot of people has been stuck on the roof of their houses waiting for rescuers to come and help them. Some prepare power banks to keep their phone battery from shut down to request help while some can only shout from afar to notify the rescuers. The production of the saltwater lamp can help not just as a lamp during that horrendous situation, but also help charge the smartphone to keep it on. It is hoped that only a few spoons of salt and water can make the lamp work.

CHAPTER 2

LITERATURE REVIEW

2.1 Fuel cell

Fuel cells are electrochemical devices that transform the chemical energy of fuel gas into electrical energy and heat without the need for direct combustion, resulting in substantially better conversion efficiencies than typical energy conversion systems. Furthermore, as compared to internal combustion engines, this technology does not emit substantial amounts of pollutants such as nitrogen oxides. As a result, fuel cells are becoming more popular in transportation, stationary, and distributed power producers. The need for pure hydrogen or hydrogen-rich fuel is a significant barrier to commercializing fuel cells (Sun & Stimming, 2007).

The components of a fuel cell are like those of a battery. Both feature anode and cathode electrodes that complement each other. The anode is responsible for supplying electrons, while the cathode is responsible for absorbing them. They are separated by an electrolyte, which can take the form of a solid or a liquid. To complete the electrochemical cycle system, the electrolyte must be capable of transferring ions from the electrode. Nonetheless, the way fuel is delivered distinguishes both systems. Fuels are kept in a predetermined quantity in a battery system and must be refilled according to their consumption. Hydrogen (fuel) and oxygen are delivered to the anode and cathode, respectively, in a conventional fuel cell. The reaction between oxide ions and hydrogen ions produces electrons that create electricity and water as a by-product at electrodes, depending on the kind of fuel cell (Raduwan et al., 2022).

2.2 Type of fuel cell

2.2.1 Alkaline fuel cell

Among the different varieties of fuel cells, the alkaline fuel cell is the earliest and most investigated, primarily for use in space. Alkaline fuel cells were one of the earliest fuel cell technologies to be invented, and they were the first form of a fuel cell to be widely employed in the United States space program to create electrical energy and water onboard spacecraft. Because of the pace at which chemical reactions occur in the cell, these cells can be considered high-performance fuel cells. Alkaline fuel cells are identical to acidic proton exchange membrane fuel cells (PEMFCs) (Ferriday & Middleton, 2021). They're also extremely efficient, with 60 percent efficiency in space applications. This fuel employs an alkaline electrolyte as the electrolyte, such as 30% aqueous potassium hydroxide in water, and may use several non-precious metals as a catalyst at the anode and cathode. The chemical reaction is as below:

Anode reaction	$2H_2+4OH^- \rightarrow 4H_2O+4e^-$
Cathode reaction	$O_2+2H_2O+4e^- \rightarrow 4OH^-$
Overall cell reaction	$2H_2+O_2 \rightarrow 2H_2O$ +electric energy+heat

Figure 1 shows the chemical reaction of Alkaline fuel cell.

The electrodes are made up of two layers which are an active electrocatalyst layer and a hydrophobic layer. The active layer is made up of a ground organic combination (carbon black, catalyst, and PTFE) that is then rolled at room temperature to cross-link the powder and produce a self-supporting sheet. Rolling a porous organic layer, again to cross-link the layer and form a self-supporting sheet, creates the hydrophobic layer, which prevents the electrolyte from leaking into the reactant gas flow channels and assures diffusion of the gases to the reaction site. The two layers are then pushed together onto a metal mesh that conducts electricity. Sintering is the final step in the process. The entire electrode thickness is between 0.2 and 0.5mm (Mclean et al., 2002).

2.2.2 Phosphoric Acid fuel cell

Phosphoric acid fuel cells are the first generation of contemporary fuel cells. It is one of the most developed and first commercially utilized cell kinds. It comprises a silicon carbide structure that retains the phosphoric acid electrolyte, as well as an anode and cathode made of a finely scattered platinum catalyst on carbon and an anode and cathode made of a finely dispersed platinum catalyst on carbon. Protons flow through the electrolyte to the cathode in phosphoric acid fuel cells, where they react with oxygen and electrons to form water and heat. The electrolyte of a PAFC is concentrated phosphoric acid, and the positive and negative electrodes are noble metal-catalyzed gas diffusion electrodes.

The phosphoric acid fuel cell (PAFC) is one of the few commercially available batteries. Globally, hundreds of these batteries have been placed. There have also been constructed 1 MW and 5 MW power plants. Most of these offer 50 to 200 kilowatts of power. The largest plant installed to date generates 11 megawatts (MW) of alternating current (AC), which corresponds to a distribution network. 40% is the power generating efficiency of PAFCs. Their working temperature ranges from 150 to 300 degrees Celsius. At low temperatures, PAFCs are weak ion conductors, and carbon monoxide (CO) tends to severely poison platinum in the catalyst (*Phosphoric Acid Fuel Cells Introduction to Hydrogen Technology*, n.d.).

In the first equation, which depicts the oxidation of hydrogen at the anode, the hydrogen molecules are divided into two protons and two electrons. The second equation illustrates the cathode reduction that combines oxygen, proton, and electrons to form water. Chemical reaction as below:

Anode: $2H_2 = 4H^+ + 4e^-$

Cathode: $O_2 + 4H^+ + 4e^- = 2H_2O$

The by-product water may be used for a combined heat and power process that increases the PAFCs' efficiency from 40% to 70% at operating temperatures of 160°C-220°C. Another advantage of PACs is the fuel's versatility, since CO2 and 1.5 percent CO may both be used as fuel.

2.2.3 Solid Oxide Fuel Cells

Solid oxide fuel cells run at temperatures between 900 and 1000 degrees Celsius, which is greater than any other form of the fuel cell. Fuel composition isn't a concern at these temperatures since, in the presence of enough water vapour and oxygen, full oxidation can be done even without catalytic materials. Waste heat recovery allows for high overall system efficiency. In a SOFC, the electrolyte material is yttrium-stabilized zirconia (8–10 mol%) (YSZ). At SOFC working temperatures, this material is solid with a stable cubic structure and very high oxide ion conductivity. Water is created when mobile oxide ions travel from the cathode to the anode.

Chemical reaction to Anode is $H_2 + O_2^{-} = H_2O + 2e^{-}$

The high operating temperatures of SOFCs allow for fuel versatility without the requirement for costly catalysts in the electrodes. The cathode of a solid oxide fuel cell is commonly composed of Sr-doped lanthanum manganate with a perskovite crystal structure (LaMnO3). The anode substance is a Ni cermet (ceramic and metal composite). On yttrium-stabilized zirconia (YSZ) support, it includes metallic Ni for catalytic activity. Overall, because of their high working temperatures, SOFC systems can tolerate contaminants. Due to the high operating temperatures, SOFC Sulphur tolerances can be as much as two orders of magnitude greater than those of conventional fuel cell systems. Using energy-efficient, high-temperature Sulphur removal techniques, the Sulphur content of the gas is reduced to below 10 ppm. In addition, the high working temperatures of SOFCs can result in significant material difficulties, such as thermal and chemical incompatibilities and corrosion (Brunaccini, 2017).

2.2.4 Molten Carbonate Fuel Cells

Electrolytes in Molten Carbonate Fuel Cells are a mixture of alkali (Li, Na, and K) carbonates stabilized in a LiAlO2 ceramic matrix. The electrolyte should be substantially devoid of alkaline earth metals and pure. More than 5–10 mol percent CaCO3, SrCO3, and BaCO3 contamination might result in performance reduction. An external circuit conducts electrons from the anode to the cathode, while ions transmit a negative charge from the cathode via the electrolyte to the anode. At the anode, water is created, and CO2 is eliminated. CO2 must be recycled back into the fuel cell to preserve the electrolyte composition. This complicates the setup for Molten Carbonate Fuel Cells.

The chemical reaction is $CO + H_2O = H_2 + CO_2$

Molten carbonate fuel cells (MCFCs) operate at temperatures between 600°C and 700°C, allowing for excellent system operating efficiency and greater fuel flexibility. CO from biomass and coal gasification product gas and reformed hydrocarbons is not directly utilized as a fuel, but when combined with water vapor, it can create extra hydrogen through the water–gas shift reaction. An appealing design integrates a fuel reformer inside the fuel cell, eliminating the need for a separate fuel processor. A higher operating temperature also allows for the use of less costly materials for the electrocatalysts in the electrodes. Unfortunately, NiO is soluble in molten carbonates, which may result in the dissolution of the cathode and the dispersion of metallic nickel in the electrolyte and may cause the electrodes to short-circuit. This is a significant issue that must be resolved to enhance the long-term operability of MCFC systems. (Viswanathan, 2017).

2.3 Saltwater Battery

The saltwater battery stores electrical energy through NaCl aqueous solution electrochemical processes, which are readily accessible and inexpensive. A ceramic solid electrolyte divides the anode and cathode chambers. Only a current collector and seawater are found in the cathode, which serves as both a Na+ source and a catholyte. A hydrophilic network-structured carbon paper with many microfibers is used for the positive current collector. It has a huge surface area and many reaction sites, as well as high wettability. When compared to a hydrophobic carbon paper, the hydrophilic carbon paper dramatically reduced the overpotentials caused by charge/discharge operations.

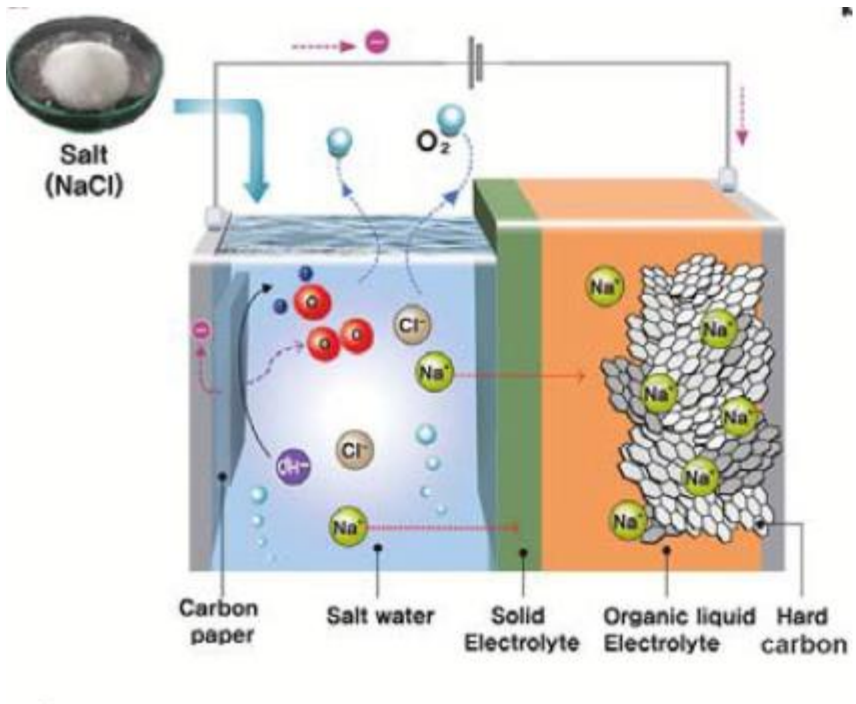

Figure 2 shows the charging process of the saltwater battery.

During charge/discharge cycles, the saltwater battery exhibits gaseous phase evolution/reduction reactions, notably oxygen evolution reaction (OER)/oxygen reduction reaction (ORR) and chlorine evolution reaction (CER)/chlorine reduction reaction (CRR) at the cathode. Sodium ions are carried from the catholyte to the anode via NASICON and reduced to Na metal during charging, whereas during discharging, Na metal is oxidized and

Na+ is returned to the catholyte. Because the pH of seawater (1 M) is neutral (7.0), the following two sorts of overall responses may be predicted, namely during charging as below:

$4NaCl\ (aq) + 2H_2O\ (l) \rightarrow 4Na(s) + O_2\ (g) + 4HCl\ (aq)$

$E^o = 3.53\ V\ (pH=7)$

$2NaCl\ (aq) \rightarrow Cl_2\ (g) + 2Na\ (s)$

$E^o = 4.07\ V$

During discharging:

$4Na(s) + 2H_2O(l) + O_2(g) \rightarrow 4NaOH(aq)$

$E^o = 3.53\ V\ (pH=7)$

As options for post-LIBs, Na-based batteries have attracted significant interest. In addition to being abundant and inexpensive, sodium possesses an appropriate electrochemical potential. Due to their high theoretical energy density, Na-air batteries have been actively explored. In comparison to aprotic Na-air batteries, whose discharge products are insoluble Na2O2 and/or NaO2, aqueous Na-air batteries have superior reversibility due to the solubility of their discharge product, NaOH. However, frequent plating and stripping of the Na metal anode during cycling would diminish this reversibility, hindering the development of aqueous Na-air batteries. Due to its strong reactivity with electrolytes and subsequent dendritic development, it can potentially provide safety concerns (Park et al., 2016).

2.4 Aluminum-air battery

The metal-air battery is gaining popularity due to its high energy density and environmental friendliness. A dual electrolyte aluminum-air battery based on polypropylene is created to absorb electrolytes, isolate the anode and cathode, and control hydrogen creation. Parametric research is conducted to explore the influence of electrolyte content and polypropylene separator thickness on battery performance.(Tan et al., 2023)

The thickness of the separator and polypropylene pad, as well as the concentrations of anolyte and catholyte, are critical parameters influencing the performance of the dual electrolyte aluminum-air battery. According to the study, 0.4 mm of separator generated the best battery performance, and thin polypropylene pads are preferred over thick ones. The discharge investigation revealed that a high concentration of catholyte reduces the battery's discharge duration. A comparison of single and dual electrolyte batteries was performed, and it was discovered that dual electrolyte systems outperformed single electrolyte systems in terms of open circuit voltage, discharge voltage, and specific discharge capacity.

On the design factor of the aluminum-air battery, research has been made by (Wu et al., 2020) the design of aluminum-based anode, electrolyte, and cell components has been studied to improve energy density and lifespan. Interfacial modification techniques have been developed to reduce anodic passivation and self-corrosion in efficient Al-air batteries. These solutions are implemented in modularized prototypes to sustain continuous high-power output, but ion migration behavior at the aluminum-electrolyte interface is critical for reducing anodic polarization and avoiding excessive aluminum consumption.

Despite having extremely high theoretical energy densities, primary aluminum-air has an irreversible shelf life due to anodic hydrogen evolution degradation. Current corrosion-suppression technologies, on the other hand, frequently involve major concessions in terms of energy and power density. A study has been made by (Xie et al., 2022) to increase the aluminum-air shell life. Carbonaceous nanomaterial-reinforced aluminum matrix composites were created as anodes for reversible passivation, avoiding self-corrosion in an open-circuit condition. Homogeneous microstructures of composites created by extreme plastic deformation enable the production of passivation layers against hydrogen evolution processes.

The reversible passivation characteristic of fluorinated graphene nanoplatelet reinforced aluminum matrix composites made using DDM methods was demonstrated for primary aluminum-air batteries. Homogeneous microstructures of composites caused by extreme plastic deformation enable the production of nanosphere-structured passivation coatings against hydrogen evolution processes. The strong linkages formed by the magnesium-containing aluminum hydroxides and the fluorinated graphene nanoplatelet improve the stability of the homogenous nanosphere-structured passivation layer. The fluorinated nano reinforcements enable the discharge process-induced reversible adsorption and exfoliation.

In aluminum-air cells, this composite anode achieves a 424% increase in effective energy density during intermittent discharge, with a significant anode energy utilization of 37.5% and an intermittent discharge efficiency of 95.3 3.1%. This method is important for overcoming the self-corrosion difficulties of alkaline aqueous aluminum-air batteries, which is vital for the design of strong anodes to accomplish high-power-density performances for practical applications. These composite anodes can also be used for rechargeable aluminum-ion batteries in a nonaqueous [EMIm]Cl-AlCl3 system.

Current studies on the interfacial reaction occurring on an aluminum anode are mostly based on traditional structural characterization, which is insufficient for understanding the behavior of the multi-ion reaction process. Future research should focus on elucidating the anodic passivation and self-corrosion mechanisms by real-time monitoring of the aluminum anode surface during discharge and shelf cycles. The electrolyte should be a key component in realizing the high-efficiency Al-air battery, but most current research focuses on improving existing electrolyte systems. New electrolyte systems or hybrid electrolyte systems are required, the compatibility between electrode and electrolyte must be enhanced, rational aluminum anode design, exploration of relevant electrolytes, and development of acceptable cell prototypes. Innovative solutions for developing rechargeable Al-air batteries should be developed to address the reversible dissolution and deposition of aluminum.

2.5 Aluminum-copper batteries

Galvanic corrosion happens when two metal materials with different electrochemical characteristics come into touch and create a loop with the surrounding environmental medium. Corrosion of metals with greater potentials will be decreased, whereas corrosion of metals with lower potentials will be accelerated (Du et al., 2014). A study has been made by (Cheng et al., 2022) where in 3.5 wt% NaCl solution, the galvanic corrosion behavior of ADC12 aluminum alloy and copper was investigated using open circuit potential (OCP), polarization curve, electrochemical impedance spectroscopy (EIS), and galvanic corrosion tests, which were combined with scanning electron microscope (SEM), optical microscope, and X-ray photoelectron spectroscopy (XPS).

The variations of the OCPs of aluminum alloy and copper are significantly different from that without coupling, demonstrating that the galvanic effect between them significantly changes their electrochemical behaviors, and their OCPs are more negative than that before coupling. Meanwhile, the amplitude and change of coupled potentials between them with time are closer to that of the OCP of aluminum alloy in coupled state, indicating that the anode and cathode processes of galvanic corrosion are similar. In the early stages of galvanic corrosion, the galvanic effect between them lowers corrosion by increasing the film impedance on the anode and cathode surfaces, resulting in a drop in galvanic current density. With increased immersion time, the corrosion rate of aluminum alloy increases gradually due to the destruction of corrosion scales caused by hydrogen evolution, whereas the corrosion rate of copper decreases gradually due to the formation and build-up of corrosion products, eventually resulting in a relatively stable galvanic current density between them. The galvanic interaction between them prevents pitting on the surface of aluminum alloy while encouraging pitting on the surface of copper.

2.6 Graphite

Graphite is a naturally occurring crystalline carbon substance. It is a mineral that occurs naturally in metamorphic and igneous rocks. Graphite is an extreme mineral. It has a very low specific gravity and is exceedingly soft, cleaving with very minimal pressure. In contrast, it is exceedingly heat resistant and almost inert in almost any other substance. Because of its exceptional qualities, it has a wide variety of applications in metallurgy and industry. Graphite is a mineral that formed when carbon is heated and compressed in the Earth's crust and upper mantle. Graphite requires pressures of 75,000 pounds per square inch and temperatures of 750 degrees Celsius to be produced. These are the granulite metamorphic facies.

In a study that was made by (Panatarani et al., 2018), They manufacture the Al-air battery using low-cost components and tune the settings to get improved battery performance. Graphite and TiCl3 are employed as catalysts, and graphite is supplied from natural resources. Because of its strong electrical conductivity, graphite is predicted to boost the battery's current capacity. Aluminum 5083 (aluminum alloy with Mg and traces of Mn and Cr), air cathode with naturally available graphite as carbon source, black paint (maxwille) as binder, 5% TiCl3 as catalyst, nickel substrate (in the form of a net) with dimension of 300 as current collectors and 10% NaCl as electrolyte concentration, distilled water as electrolyte solvent, and acrylic for battery fabrication are the materials used for Al-air battery fabrication. As anode materials, several aluminum alloys such as Al 6061 and Al 7075 with varied percentages of metals such as Mg, Mn, and Cr are tested.

The performance of an Al-air battery is influenced by process factors such as an electrode, catalyst concentration, electrolyte concentration, and current density. When compared to Al 6061 and Al 7075 as electrode materials, Al 5083 has a longer discharge time for a single cell. The use of graphite in the air cathode, in conjunction with TiCl3 as a catalyst, increases the discharge performance of an Al-air battery. The battery's stability was evaluated by doing a lifecycle study for four consecutive cycles with a discharge duration of 7h and a current capacity of 20 mAh-1. The inclusion of strongly conducting graphite in the cathode active material accounts for the higher current capacity. It offers the essential conduction channel for the redox process to occur and increases the battery's current capacity.

2.7 Saltwater lamp design

2.7.1 3D Printing

By printing out tiny layers of material and then joining them together, three-dimensional (3D) printing is an additive manufacturing technique that turns a computer design into a real thing. Some sectors, like those that produce hearing aids, aero planes, and automobiles, utilize 3D printing to make prototypes and then mass-produce their goods using personalized scans. The manufacturing logistics and inventory management sectors might potentially be severely disrupted by 3D printing technology, even though it is now too slow to be employed in mass production. To create 3D structures, polyjet printing employs nozzles to spray one or more types of photosensitive resin droplets onto a mobile collecting platform. The drops are subsequently cured by ultraviolet (UV) radiation (Lai et al., 2022). In comparison to subtractive manufacturing techniques like drilling, welding, injection molding, and others, 3D printing can produce elaborate and complicated designs with less material. More invention, experimentation, and product-based companies are possible because of faster, simpler, and less expensive prototype production.

2.7.2 Eco-friendly material

In terms of material used, plastic is the most widely used raw material for 3D printing now. Available in translucent form and vivid hues, with red and lime green being the most popular. Plastic filaments are offered on spools and may have a matte or glossy finish. Typically, plastic objects are manufactured with FDM printers, in which thermoplastic filaments are melted and formed layer by layer. As one of the most eco-friendly solutions for 3D printers, polylactic acid is derived from biodegradable materials such as sugar cane and corn starch. Available in both soft and hard forms, polylactic acid-based polymers are anticipated to dominate the 3D printing market in the future years. Hard PLA is the most durable and optimal material for a wider variety of items.

CHAPTER 3

METHODOLOGY

The methodology is a means to determine the outcome of a certain research project given a challenge. This chapter will explain how to choose a sample strategy, support it with evidence, and show how to apply various approaches and tools to get the anticipated results for a particular research subject.

3.1. Methodology flow chart

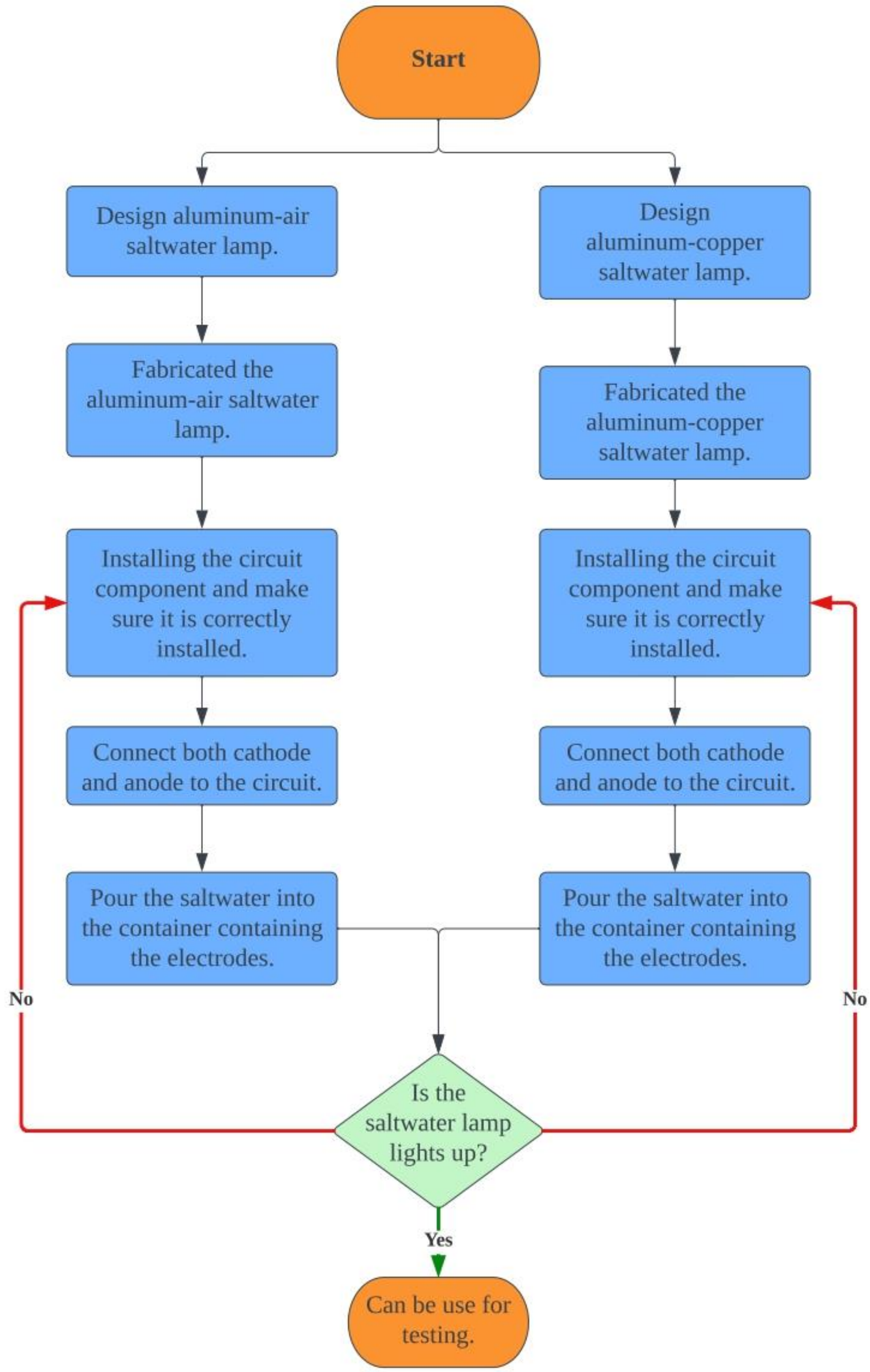

Figure 3 shows the flow chart.

3.2. Design both saltwater lamp

3.2.1. Material and equipment

The equipment used was SolidWorks and a laptop. Since it was only designing, the SolidWorks is a software where the drawing of 2D model and 3D model was made.

3.2.2. Designing the aluminum-air saltwater lamp

The design of the saltwater lamp is carried out by getting the right measurement for the saltwater lamp to make it portable and easy to carry everywhere. A series of references have been made on the different types of the portable lamp to get the measurement. After a few measurements have been accounted for, the measurement of 12cm x 34 cm (before fold) and 12cm x 22cm (after fold) for aluminum-air saltwater lamp, the measurement of 10cm x 23 cm of the lamp has been accounted for aluminum-copper saltwater lamp. The 2D sketch of the saltwater lamp has been drawn using AutoCAD software and the 3D drawing of the saltwater lamp has been drawn using SOLIDWORKS.

3.2.3. Fabricating saltwater lamp

The fabricating of the saltwater lamp is carried out after the 3D drawing of the saltwater lamp has been made. Since a 3D printer is not available and is not in possession of the researcher, the fabrication of the product has been made in the concept of D.I.Y (Do It Yourself). The material consists of recyclable material for some parts, led lamp was taken from used lamp while the electrode was bought. The container of the saltwater was using the reengineered purchased saltwater lamp where the lamp was modified with using a tracing paper for aluminum-air saltwater lamp. For aluminum-copper saltwater lamp, using recyclable material (plastic container) and the LED lamp was taken from used lamp. The product must follow the drawing measurement so that the components of the saltwater lamp can fit inside it.

3.4. Installation of the LED light, and switch

3.4.1 Material

The material used for the installation part is an electrical circuit board. The second material is a 2W LED light that has a brightness of 150 lumens. The third material is the wire that used to connect the plate with the board. And the last material is the switch for turning on and off the lamp.

3.4.2 Installation of the circuit board

The installation of the circuit board is supposedly to be done after the fabrication of the saltwater lamp is completed. Since the fabrication is not completed, the circuit board was installed to only aluminum-air saltwater lamp since the original saltwater lamp was reused with it board was already there to help connect with the lamp. The suitable circuit board must have enough power to light up the lamp and at the same time, charge electrical appliances. The circuit board was installed between the saltwater storage and the lamp.

3.4.3 Installation of LED light

The installation of the LED light is done by connecting the lamp to the circuit board. The type of LED lamp chosen is a 2W 150 lumens to make sure that the battery cell can support the power to the lamp and the lamp has high brightness. The LED bulb must be a disc-type bulb because the lamp is foldable as the bulb will be attached to a rubber inside the lantern space where the bulb will stay in the middle of the lamp.

3.4.4 Installation of switch

The installation of the switch will be connected to the circuit board as the principal of the switch is to turn on/off the lamp.

3.5 Connecting the cathode and anode into the circuit

3.5.1 Material and Equipment

The material used for this saltwater lamp is copper and aluminum for aluminum-copper saltwater lamp, while for aluminum-air the material used is aluminum plate and reused purchased saltwater lamp container that has graphite wall that connected to the copper conductors to make sure the electricity is flow.

3.5.2 Connecting aluminum and copper

The aluminum and copper plate were bought with the measurement of 6.65cm x 4.95cm x 0.3cm for the aluminum plate (figure 8). While copper plate measurements (figure 9) are 6.75cm x 4.5cm x 0.2cm. The Copper act as its cathode while the aluminum act as its anode in the electrolysis process. Wires was solder for each copper and aluminum plate and since soldering won’t glue the wire and the plate together, the wire was put together by using a super glue. The plate then was put in each cell (plastic container) and the wire from the copper plate was connected to the wire of the aluminum plate. Meaning that the positive charge went to the negative charge making it a series connection. One copper plate with wire and one aluminum plate with wire was not connected with each other making the aluminum plate as negative charge wire to the circuit while the copper plate as positive charge wire to the circuit. Inside each cell, the separator was put by using an infra board to make sure the aluminum and copper plate didn’t touch each other so that it won’t affect the electrolysis process. Total of four battery cell was made and put together inside the container that work as base for the saltwater lamp. Inside the cell, the aluminum plate will face corrosion as it is reacted with the saltwater that act as electrolyte to produce the electric. Each cell produces around 1-1.25 volt making the battery cell produce around 4–5-volt electricity charge.

3.5.3 Connecting the aluminum-air electrode

The Aluminum plate is the same as what was used in the aluminum-copper saltwater lamp. Since the aluminum-air saltwater lamp was using the purchased aluminum-air lamp, the container and conductor was reused. On top of the container, there is the lamp base that contain a small copper conductor to conduct the electricity between the aluminum and the air. The container was made with graphite material to make it as separator between the aluminum and the surrounding air. The aluminum plate was connected to the lamp base that link to the copper conductors. There is also another copper pin that connect the conductor from the graphite to the copper conductor to make one series circuit for the battery cell. Total of four aluminum plate was used and there are four pins connect to the four-graphite wall. When the saltwater was poured inside the container, the aluminum will corrode to make a reaction to produce electricity to the lamp.

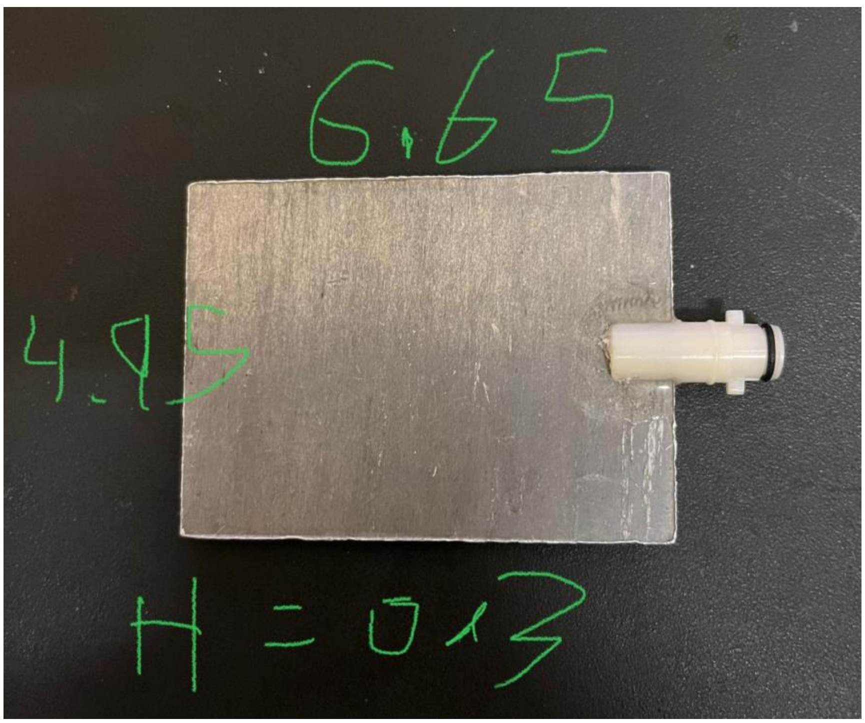

Figure 4 shows the aluminum plate.

Figure 5 shows the copper plate.

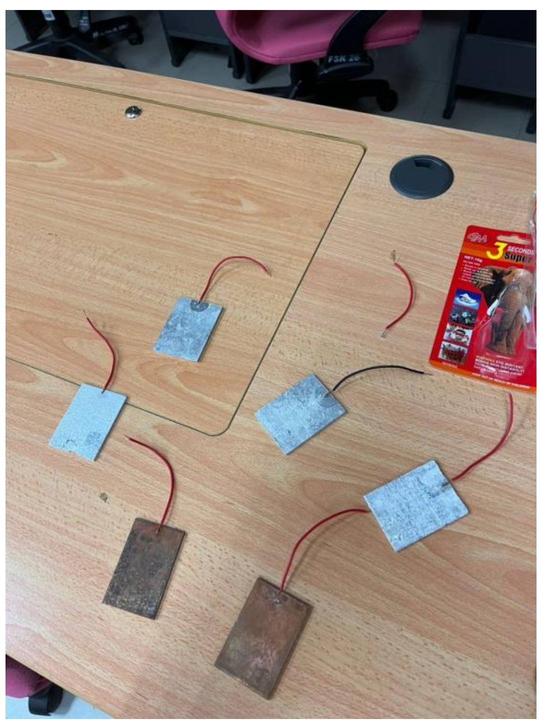

Figure 6 shows the connection of wire to the plates.

3.4 Pouring the saltwater solution into the container

3.4.1 Material and equipment

Saltwater solution (NaCl) electrolyte was used. It is believed that increasing the concentration of an electrolyte improves its conductivity and viscosity, affecting battery efficiency. As studied by (Huang et al., 2022) the peak power density of the battery grows from 12.00 mW cm2 to 26.24 mW cm2, and the short-circuit current density increases from 98.40 mA cm2 to 159.88 mA cm2 when the NaCl concentration increases from 1 M to 4 M. The conductivity of the electrolyte for OH- improves as the NaCl content increases, which improves the oxidation process at the anodic surface and hence decreases the anodic potential. The cathodic potential rises when the NaCl concentration rises from 1 M to 2 M for the same reason. The cathodic potential changes slightly when the NaCl concentration increases from 2 M to 5 M. This is since when the NaCl concentration increases, the electrical double layer polarization grows stronger.

3.4.2 Pouring the solution

The saltwater solution was made by adding a 20gm of salt into a 350ml water and is mixed.The saltwater than was pour into each battery cell container that contains the aluminum plate and copper plate for aluminum-copper circuit while the saltwater was pour into the container that contain the aluminum plate and the graphite for aluminum-air circuit. This is to make sure that the saltwater can react with the electrode to produce the electricity needed to power up the lamp.

3.4.3 Turning on the lamp

After the process of pouring the saltwater solution is done, the lamp will be switched on so that the test can be done with the saltwater lamp prototype. Sometimes, there is an error with the circuit as the electrode is not correctly connect with the circuit and if such things happen, the installation of the cathode and anode will be properly repeated until the lamp can be turn on.

3.5 Getting the data of voltage, current and luminance of both saltwater lamp.

3.5.1 Material and equipment

The material and equipment used to the testing to get the voltage, current and luminance of the aluminum-air saltwater lamp is the saltwater lamp device, the multimeter and the lux meter.

3.5.2 Taking the reading

To measure the voltage, current, and luminance of the saltwater lamp, the preparation has been made by cleaning the aluminum electrodes and fill the electrolyte solution in the lamp, making sure there are no air bubbles. Then, connect the aluminum electrode and the air electrode to the power supply. The luminance is measured by using a lux meter. The luminance is measured with lux unit. The current and voltage readings can be taken using a multimeter. It is important to take the readings at regular intervals to monitor the performance of the aluminum-air lamp over time which in this experiment, it takes 30 minutes.

3.5.3 Collecting data

The data is collected for voltage, current, and luminance for a specified period (30 minutes), and until the performance of the aluminum-air lamp stabilizes. The data collected from the voltage, current, and luminance measurements can be analyzed to determine the efficiency and performance of the aluminum-air lamp. This can include calculating the power output and energy conversion efficiency of the lamp. The performance of the saltwater lamp is compared with each other, which is the aluminum-copper saltwater lamps, to determine which provides the best luminance.

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter explain the result obtained from the design and fabrication of the saltwater lamp to ensure that the result is accordingly to the main objectives.

4.2 Design of the aluminum-air saltwater lamp

The design of the saltwater lamp was made using SolidWorks. The Measurement of every part was made according to the size desired where the requirement of the product must be easy to bring everywhere. There is seven parts drawn in SolidWorks which is the outer base, inside of the base, base of the lantern, the lamp head, the handle, the foldable lamp, and the switch. With each part was drawn, the assembly of the product can be made to make it one complete aluminum-air saltwater lamp. The complete product as shown below.

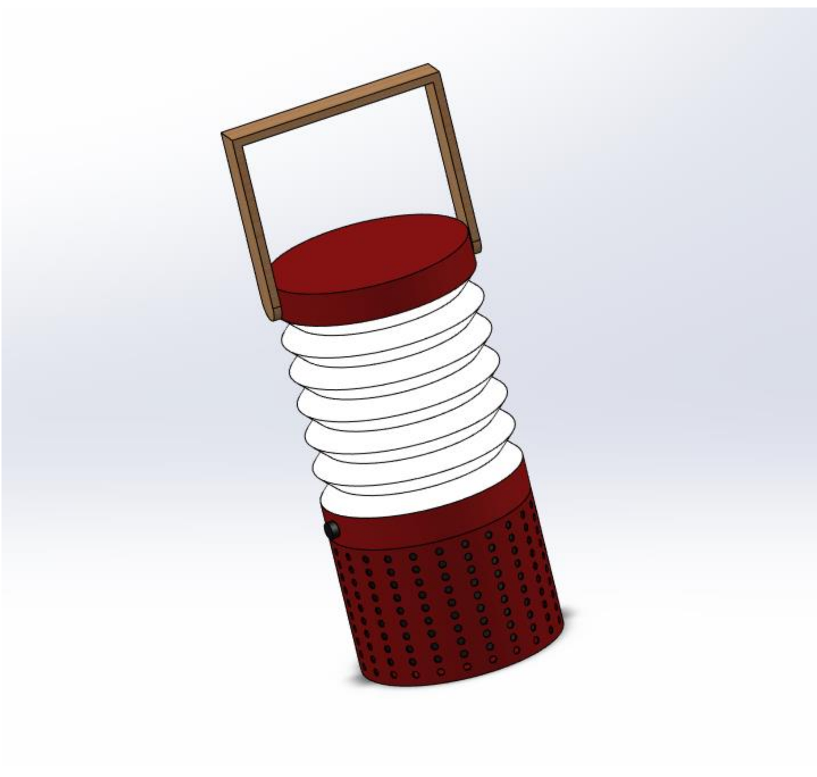

Figure 7 shows the completed product after the part has been assemble.

Every part has its own measurement to make sure it has a size in accordance with the objectives to make it easy to carry while giving enough illumination to provide light during the disaster situation such as flood and easy to hang so it doesn't have to be carry. The measurement of the saltwater lamp is shown in the figure below.

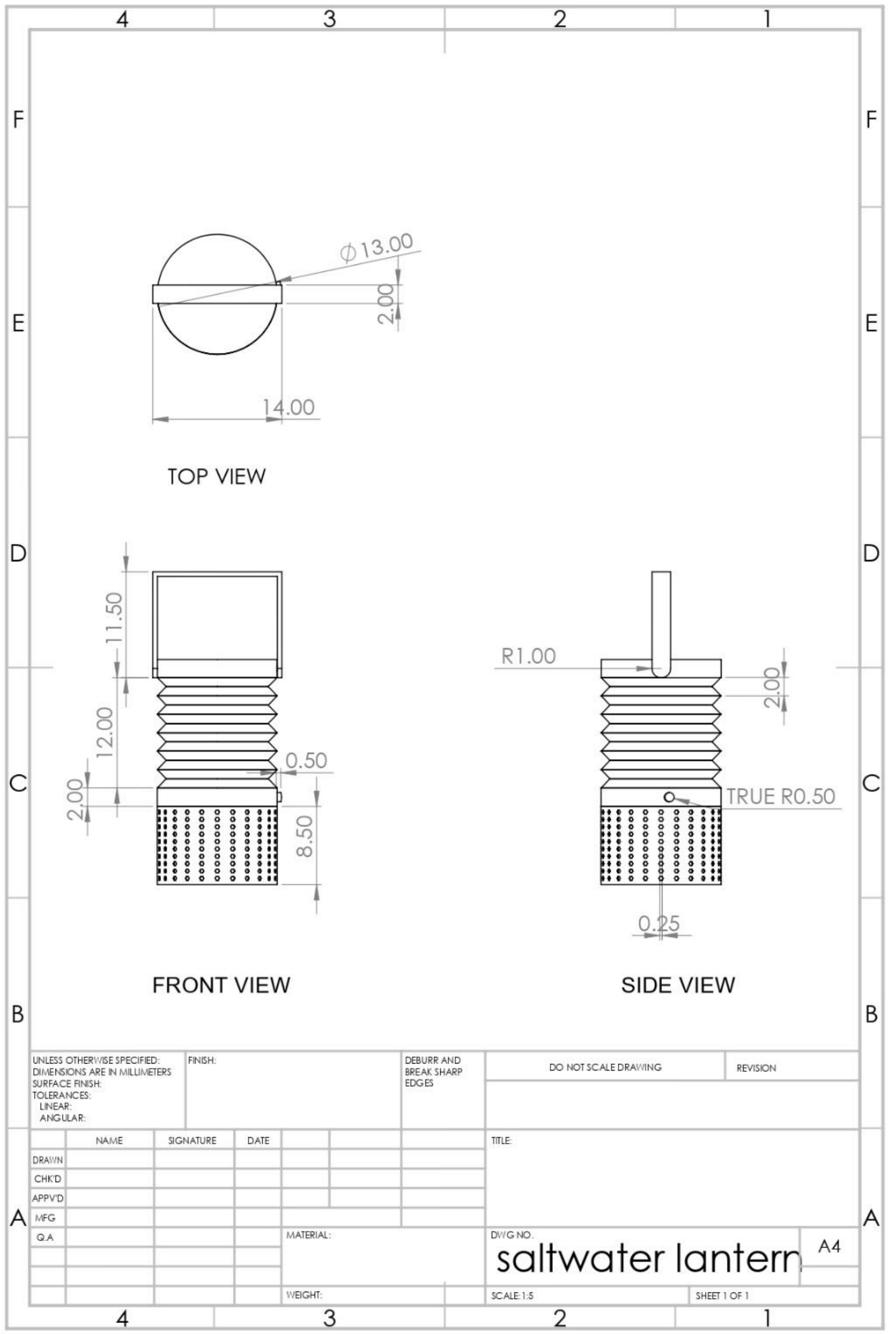

Figure 8 shows the 2d drawing of the aluminum- air saltwater lamp with its measurement.

4.3 Design of the aluminum-copper saltwater lamp

The design of the saltwater lamp was made using SolidWorks. The Measurement of every part was made according to the size desired where the requirement of the product must be easy to bring everywhere. There is eight parts for the aluminum-copper saltwater lamp, which is the lamp container, top of the container, the base of the lamp, the lamp, the top of the lamp, copper plate, aluminum plate, and the circuit board.

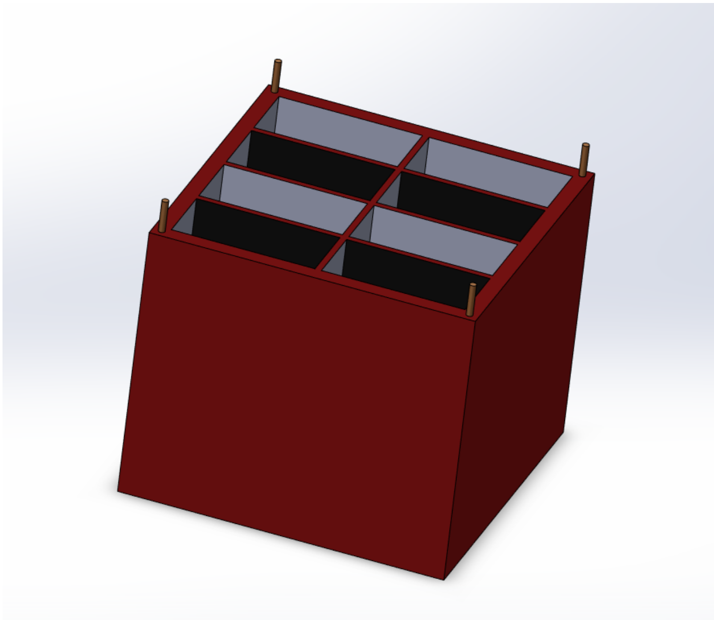

Figure 9 shows the lamp container where the saltwater lamp will be poured.

As shown on the figure above, there is four separated cells where in each cell, one aluminum plate and one copper plate can be insert in it, making it a battery cell that can provide 4-5 volts to produce the electricity.

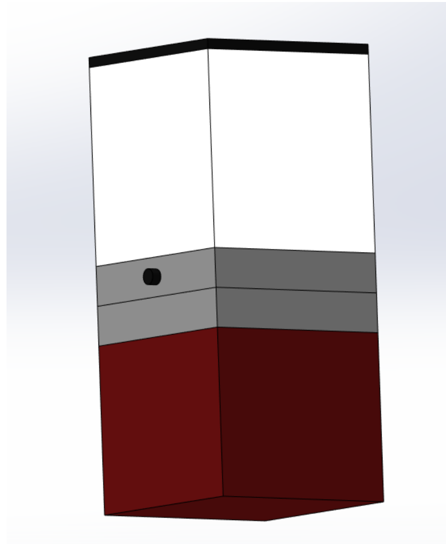

Figure 10 shows the completed product after the part has been assemble.

Every part has its own measurement to make sure it has a size in accordance with the objectives to make it easy to carry while giving enough illumination to provide light during the disaster situation such as flood. It also can be made as a table lamp that focus on giving the illumination needed in the rural area. The measurement of the saltwater lamp is shown in the figure below.

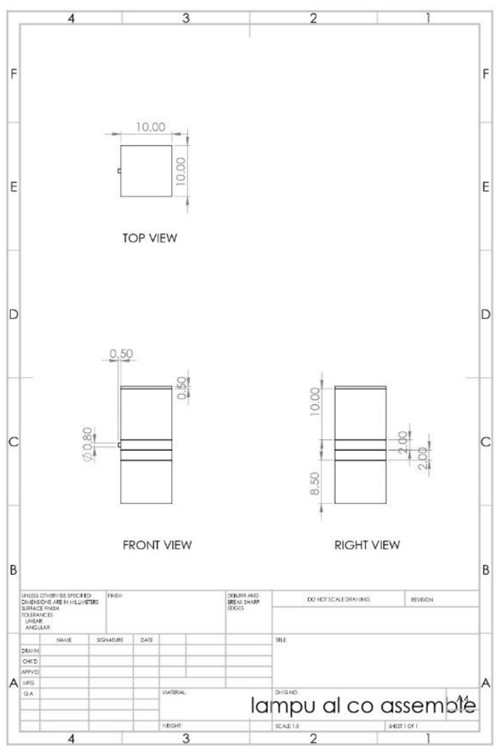

Figure 11 shows the 2d drawing of the aluminum- copper saltwater lamp with its measurement.

4.4 The prototype of the aluminum-air saltwater lamp

After the drawing has been done, the sample of the aluminum-air battery was made by using the re-engineered saltwater lamp with its proper material which is aluminum plate, carbon graphite, and copper conductors. The wiring of the lamp is connected from the copper conductors to the lamp. With the casing of the lamp is tracing paper and is covered on top of it with cardboard.

Figure 12 shows the prototype of the aluminum-air saltwater lamp.

The figure above shown the prototype of the aluminum-air battery where the test can be done with. The aluminum-air battery has the concept as the design except that cannot be fold and the fabrication of it was using easy to get with material and the reengineered saltwater lamp.

4.5 The prototype of the aluminum-copper saltwater lamp

After the drawing has been done, the sample of the aluminum-copper saltwater lamp was made by using a recycled plastic container. Inside the container, there is four different batteries cells that contain one aluminum plate and one copper plate that is separated by infraboard filled with a saltwater solution.

Figure 13 shows the prototype of the aluminum-copper saltwater lamp.

The figure above shown the prototype of the aluminum-copper saltwater lamp where the test can be done with. The aluminum-copper saltwater lamp has the concept as the design except that it don’t have the lamp cover and the fabrication of it was using easy to get with material and the recyclable material such as the plastic container and the used LED from used lamp.

4.6 Parameter testing for the aluminum-air saltwater lamp

The test for the aluminum-air saltwater lamp were recorded for 30 minutes for voltage, current and luminance. The reading of the data is shown in table 4.1.

Data	**0 min**	**5 min**	**10 min**	**15 min**	**20 min**	**25 min**	**30 min**
Voltage(V)	2	2.35	2.65	2.8	2.7	2.7	2.7
Current(A)	0.08	0.13	0.2	0.21	0.34	0.34	0.34
Luminance(lux)	10	16	45	57	60	60	60

Table 1

From the data on the table above, the voltage of an aluminum-air lamp increases from 2 volts to 2.7 volts, the current increases from 0.08 amperes to 0.34 amperes, and the luminance increases from 10 lux to 60 lux in 30 minutes, this could indicate a significant improvement in the performance of the lamp. This is possible because, the increase in voltage, current, and luminance could indicate that the electrochemical reaction between the aluminum electrode and the saltwater is becoming more efficient over time. This could be due to changes in the composition of the electrolyte solution or other factors that influence the reaction. It also possible because the increase in current and voltage could indicate that the resistance of the circuit is reducing over time. This could be due to changes in the electrodes, such as the formation of a more conductive layer on the surface, or changes in the electrolyte solution that improve the conductivity. The increase in voltage, current, and luminance could also indicate an increase in the power output of the aluminum-air lamp. This could be due to improved efficiency in the electrochemical reaction or other factors that influence the performance of the lamp.

4.7 parameter testing for the aluminum-copper saltwater lamp

The test for the aluminum-copper saltwater lamp were recorded for 30 minutes for voltage, current and luminance. The reading of the data is shown in table 4.2.

Data	0 min	5 min	10 min	15 min	20 min	25 min	30 min
Voltage(V)	2	2.25	2.30	2.43	2.55	2.55	2.55
Current(A)	0.03	0.04	0.05	0.08	0.11	0.11	0.11
Luminance(lux)	10	11	13	13	15	15	15

Table 2

From the data on the table above, the voltage of an aluminum-copper saltwater lamp increases from 2 volts to 2.55 volts, the current increases from 0.03 amperes to 0.11 amperes, and the luminance increases from 10 lux to 15 lux in 30 minutes, have far different from aluminum-air saltwater lamp. This could indicate that a significant improvement in the lamp's performance. This is conceivable because the rise in voltage, current, and brightness may imply that the electrochemical interaction between the aluminum electrode and the saltwater becomes more efficient with time. In the experiment made with aluminum-copper saltwater lamp, it shown that the aluminum plate corrodes to produce the reaction with saltwater where the copper plate become rust because of the reaction. Even that, it can’t produce enough current to make the lamp brighter.

4.8 Comparison on between the aluminum-air and aluminum-copper saltwater lamp.

The comparison has been made between the both circuit to determine which give the best luminance to provide the light good enough for uses as emergency light. The data is shown in the table below.

Data	0 min	5 min	10 min	15 min	20 min	25 min	30 min
Lux for Al - air	10	16	45	57	60	60	60
Lux for Al - Cu	10	11	13	13	15	15	15

Table 3

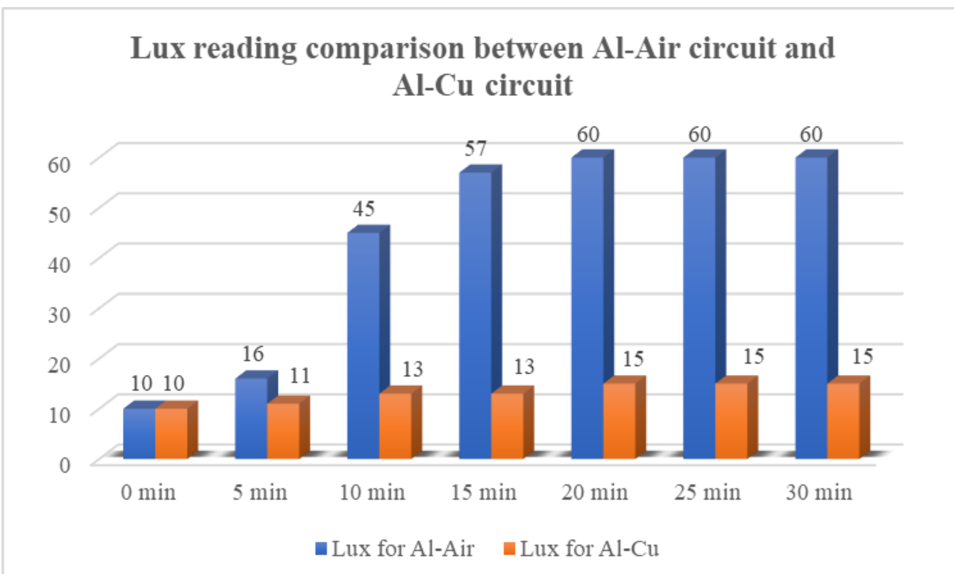

Figure 14 Shows the chart of lux reading between Al-Air and AL-Cu

The comparison between the aluminum-air saltwater lamp and aluminum-copper saltwater lamp reveals some significant differences in terms of their performance. In terms of luminance, the aluminum-air lamp produces significantly brighter, reaching 60 lux, compared to the aluminum-copper lamp, which only reaches 15 lux. This difference in luminance can be attributed to several factors, including the composition and design of the electrodes and the efficiency of the electrolyte solution. In terms of voltage, the aluminum-air lamp reaches a higher voltage of 2.7 volts compared to the aluminum-copper lamp, which reaches 2.55 volts. This difference in voltage can be attributed to the more efficient electrochemical reaction taking place in the aluminum-air lamp. In terms of current, the difference is even more pronounced, with the aluminum-air lamp reaching 0.34 amperes, compared to the aluminum-copper lamp, which only reaches 0.11 amperes. This difference in current can be attributed to the more efficient use of the electrolyte solution in the aluminum-air lamp. Overall, these results suggest that the aluminum-air saltwater lamp is the better performing of the two lamps in terms of luminance, voltage, and current.

Chapter 5

CONCLUSION

5.1 Conclusion

In conclusion, the first objective of designing and developing both the aluminum-air saltwater lamp and aluminum-copper saltwater lamp have been successful. The second objective of finding the best saltwater lamp between the two circuits was also accomplished as it is founded that the aluminum-air circuit provides better luminance compared to the aluminum-copper circuit due to higher voltage and current levels. These results show that the experimentation was successful and have made significant progress towards the goals.

5.2 Recommendation

5.2.1 Using a smaller size of cathode and anode

Using a smaller size of cathode and anode is recommended because it reduces the risk of short-circuiting. A short-circuit occurs when the positive and negative terminals of a power source are connected directly to each other, creating an electrical path with very little resistance. This causes an abnormally high current which can damage electrical components. Reducing the size of the terminal increases the distance between them, which reduces the chance of unintentional contact and prevents a short-circuit. Additionally, smaller terminals are more physically compact, which allows for easier handling and better placement.

5.2.2 Hybrid the saltwater battery with solar energy

It is recommended to use a hybrid saltwater battery with solar energy because of the many benefits the combination offers. With a hybrid saltwater battery, energy from the sun is stored in the form of chemical energy. The energy is released when it’s needed, providing a reliable and consistent source of power for many households. The use of a hybrid saltwater battery can also extend the life of the solar energy system, as it can store excess power produced in the day and use it during the night when solar energy is not available. Additionally, saltwater batteries are safer, more environmentally friendly, and less expensive than traditional lead-acid batteries. Furthermore, saltwater batteries have a much longer service life than other batteries, making them an excellent long-term investment when used with solar energy.

5.2.3 Replacing graphite with other catalyst (silicon)

Graphite has historically been the material of choice for use as the anode material in lithium-ion cells. However, graphite has low electrical conductivity and low theoretical capacity, leading to limited performance in lithium-ion cells. Silicon has emerged as a promising anode material due to its higher theoretical capacity and good electrical conductivity compared to graphite's. The high theoretical capacity of Si significantly increases the energy density of a lithium-ion cell, compared to that of a graphite-based one. Additionally, the improved electrical conductivity of Si can help reduce the Ohmic losses which can be limiting in graphite-based cells. These potential benefits of Si make it an attractive choice as the anode material in lithium-ion cells.

5.2.4 Use the saltwater lamp as a guide for making power generator

Saltwater batteries are an increasingly popular form of energy storage and generation. They are a safe and economical source of energy and are an environmentally friendly form of energy production. Saltwater batteries are made from a combination of electrochemical cells, typically filled with a saltwater solution, which store and generate electricity. This type of battery is suitable for a variety of applications, including powering electric vehicles, charging devices such as laptops or personal electronics, or even providing backup power to a home or business.

As a guide to make a power generator, saltwater batteries are a great option because of their efficiency and long lifespans. Because saltwater batteries can store and release energy quickly, they can provide reliable power over long periods of time, with minimal impact on the environment. Saltwater batteries are relatively cost-effective, making them a good option for powering smaller to medium sized energy generation projects. Additionally, saltwater batteries are well-suited to applications in areas with high temperatures.

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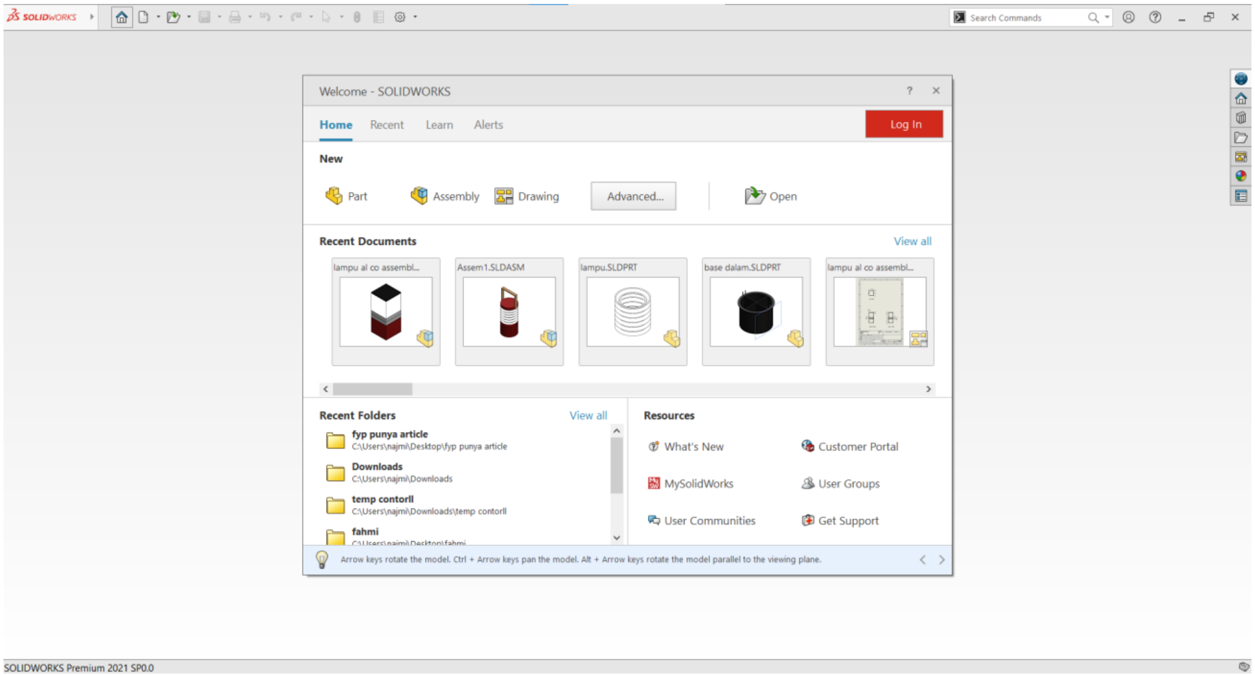
APPENDICES

Appendix A: SolidWorks software



Appendix B: The working aluminum-air lamp

Appendix C: The working aluminum-copper lamp