10 Novel portable aluminium-air battery: A green energy via circular economy approach

2023 淨零碳排科技國際競賽
Net Zero Tech International Contest @ Taiwan

學校名稱School：University Tunku Abdul Rahman 系所Department：Department of Mechanical and Materials Engineering
指導教授Advisor：Dr. Bernard Saw Lip Huat, Dr. Yew Ming Chian 隊長Leader：Tan Weng Cheong 隊員Member：Asrin Awang Selan

團隊介紹Introduction of Team

The team is guided by Dr. Bernard Saw Lip Huat and Dr. Yew Ming Chian. Dr Bernard Saw is an expert in energy storage system and dedicated his research in the energy field. Dr. Yew Ming Chian is an expert in material design, in which he is well known for the fire proofing construction material. Tan Weng Cheong is a PhD student focusing his study on the aluminum air battery. Asrin Awang Selan is currently study her master degree and investigating on the fabrication of the cellulose separator.

創作動機Creation Motive：

The projects aims to solve the problems caused by the invasive plant, water hyacinth which possess severe environmental problem to the aquatic flora and fauna. Water hyacinth grows rapidly over the bodies of water and block the sunlight and eventually perish the life of the other aquatic living organisms. The conventional way of water hyacinth disposal is through burning, which can cause the air pollution. The idea of this project is to extract the cellulose from the water hyacinth, and produce in into cellulose film. The film will then be used as a separator of an aluminum-air battery. Aluminum-air battery is a clean energy storage which utilized aluminum as the anode. The by-product of this battery is the aluminum hydroxide, which later can be recycled to the aluminum through Hall-Heroult process, making aluminum-air battery a truly green energy sources. The purpose of cellulose separator is to separate the anode and cathode, allowing the movement of aluminum ions and hydroxide ions, but preventing the movement of aluminum hydroxide ions from anode to cathode. Hence, it can help to prevent the degradation of cathode since the cathode will be free from the pollution of aluminum hydroxide.
(Figure 2: Water hyacinth on lake)

Figure 2

創作過程Research Process：

In the early stage of the research project, the performance of the aluminum-air battery is studied and the performance is weak due to the poor selection of separator. This generates the idea of developing a new types of separator to improve the performance of the battery. Cellulose based separator is found to be environmental friendly and is an green alternative. Hence, sourcing of raw material for separator begin and eventually leads to water hyacinth. The main reason of using water hyacinth is due to the invasive properties of this plant. Using water hyacinth as raw material for separator can help to solve the environmental issues caused by the water hyacinth. The separator is fabricated from the cellulose extracted from the water hyacinth and used in aluminum-air battery. At current stage, investigation on the performance of the aluminum-air battery with the water hyacinth based separator is studied.
(Figure 3: Water hyacinth drying)
(Figure 4: Water hyacinth processing)
(Figure 5: Blended water hyacinth)

Figure 3

Figure 4

Figure 5

作品介紹Brief of Work：

The separator in the aluminum-air battery incorporates a creative approach by integrating cellulose nanofibers extracted from water hyacinth as a raw material to produce a film. This cellulose-based film will serve as the separator in the aluminum-air battery. The preparation of the film is a complex process that requires various knowledge and techniques, including cellulose extraction from water hyacinth, followed by the processing of raw materials to create the separator.
(Figure 6: Water hyacinth mixing)
(Figure 7: Water hyacinth casting)
(Figure 8: Water hyacinth separator)

Figure 6

Figure 7

Figure 8

It is worth noting that the air cathode is made from a carbon-based material, while the cellulose separator is derived from plant-based materials. These raw materials are inexpensive and abundant. Carbon can be obtained from various sources, including incineration, while cellulose for the separator is extracted from water hyacinth.
Both raw materials are essentially waste products, making the fabrication of the air cathode and separator a form of green technology that helps address waste disposal issues and promotes environmental sustainability.

預期效益Expected Benefit：

This study hopes to solve the environmental issues caused by the water hyacinth. It can help to rescue the aquatic plant while saving the cost and environmental consequences caused by the water hyacinth as conventional ways of disposal is through incineration.
On the other hand, the aluminium-air battery has the potential to be used in marine environment such as power supply for ocean floor mapping, shipwreck detection, and studying marine ecosystems. The battery can self-generate electrolyte from seawater and utilize it to generate electricity. To "recharge" the battery, only a new aluminium plate needs to be replaced. This feature addresses the limitations of lithium-ion batteries, which require charging stations and are impractical for remote or maritime areas.
Based on experimental studies, a single aluminium-air battery can generate a specific capacity of 1300 mAh/g, with an operating voltage of approximately 1.5 V, and provides an approximate specific energy density of 1800 Wh/kg. This capacity is sufficient to power a USB fan and USB light. By combining multiple aluminium-air batteries, the output voltage can be scaled up, resulting in increased energy density. This scalability provides potential for commercialization, offering flexibility for various applications, such as emergency power supply and portable power supply for remote areas. The comparison of the discharge performance of different separators, including the water hyacinth separator, commercial polymer separator, filter paper, and NKK commercial cellulose separators in saltwater is illustrated in Figure 11. The results indicate that the water hyacinth separator, with a composition of 65 wt% water hyacinth and 35 wt% PEG, achieved a discharge duration of 19421 s using a discharge current of 10 mA. In comparison, the commercial cellulose separators, PB100 by Nippon Kodoshi Corporation (NKK) and VL100, exhibited lower discharge performance, with durations of approximately 10091 s and 1171 s, respectively as indicated in Figure 11. The open circuit voltage of the commercial separators was also lower than that of the self-fabricated separator, and the PB100 separator had only half the discharge performance of the water hyacinth separator. Figure 12 shows the comparison of the discharge performance for different concentration of sodium chloride (NaCl) with PVA as binder. As the concentration of NaCl increases, the discharge time is improved under discharge current of 10 mA. Figure 13 compare the discharge performance of the aluminium-air battery using different discharge current and potassium hydroxide (KOH) as electrolyte. The battery can sustain for at most 7.6 hours under discharge current of 200 mA while maintaining operating voltage about 1.3 V. Figure 14 shows the comparison of different energy storage systems in the market.
(Figure 9: Aluminum-air battery prototype)
(Figure 10: Water hyacinth)
(Figure 11: Comparison of the discharge performance of the water hyacinth separator, commercial polymer separator, filter paper and commercial cellulose separator in the seawater electrolyte.)
(Figure 12: Comparison of the discharge performance of different concentration of sodium chloride (NaCl) with PVA as binder.)
(Figure 13: Comparison of discharge performance of different discharge current using KOH electrolyte.)
(Figure 14: Comparison of different energy storage systems.)

Figure 9

Figure 10

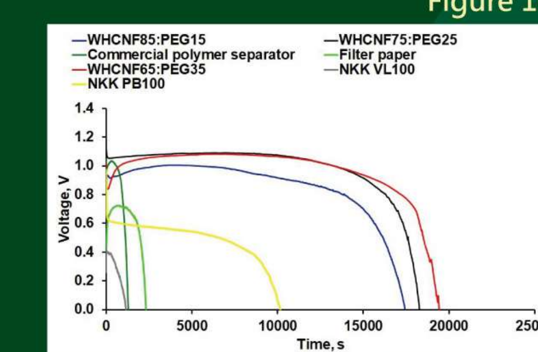

Figure 11

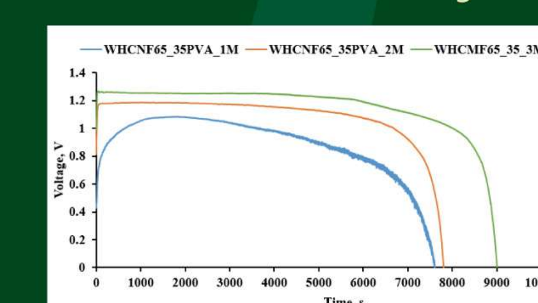

Figure 12

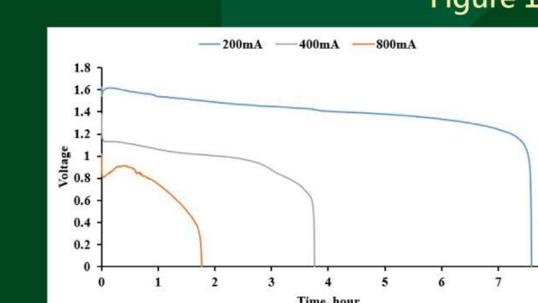

Figure 13

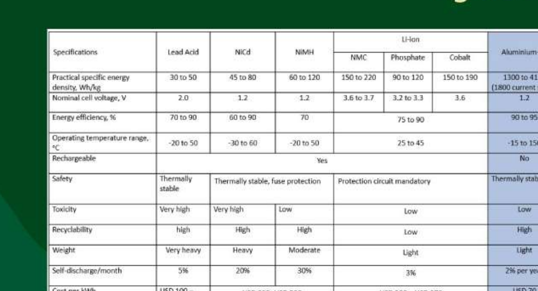

Figure 14

指導 Advisors：教育部 Ministry of Education 經濟部 Ministry of Economic Affairs
主辦 Organizers：財團法人東元科技文教基金會 TECO Technology Foundation 國立臺灣大學 National Taiwan University
贊助 Sponsor：台灣中油(股)公司 CPC Corporation, Taiwan 勝一化工(股)公司 Shiny Chemical Industrial Co., Ltd. 東友科技(股)公司 Teco Image Systems Co., Ltd. 菱光科技(股)公司 Creative Sensor Inc.
協辦 Co-organizers：財團法人工業技術研究院 Industrial Technology Research Institute 臺灣永續治理大學聯盟 Taiwan University Alliance for Sustainable Governance
國立臺灣大學系統 National Taiwan University System 台灣聯合大學系統 University System of Taiwan 臺北聯合大學系統 University System of Taipei