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High Energy Density Aluminum-Air Batteries: A Case Study

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Abstract

Aluminum-air batteries are becoming one of the promising and alternative power sources because of some advantages like abundance of aluminum in the earth crust, high energy density, light weight, low price anode material and mostly use of non-toxic elements in assembling. As the battery uses air as main reactant, we need to use some highly porous material so the reaction can occur easily. In this particular study, different types of graphite were used as cathode and also the amount of cathode material was varied to understand the effect in output. In observation it was found that graphite of good quality and higher amount can produce more electricity. The output current and voltage were low because these were measured at a point of cathode which held a little amount of graphite. The current and voltage produced by cell was low when homemade charcoal was used instead of graphite.

Keywords: Metal-air battery, Aluminum anode, Air cathode

1. Introduction

There is an urgent demand for renewable, clean fuel options for our future energy supply due to fossil fuel depletion and air pollution resulting from its combustion. To reduce environmental pollution for using fossil fuel, the development of electric vehicles and smart grid is urgently required. For this mass use, demand of batteries increasing rapidly. Battery is a device which store energy. Energy storage as the name suggests, the storage of energy. The energy storage technologies available for largescale applications can be divided into several types among mechanical, electrical, electro-chemical and chemic [1]. Among these, electrochemical energy storage approach is popular due to the mechanisms used to store energy [2]. In general, electrochemical energy storage possesses a number of attractive features, including pollution free operation, high round efficiency, long life cycle, low maintenance and energy characteristics such as fast reaction when the contingency occurs to meet various grid functions. Batteries represent great energy storage technology for the integration of renewable resources [3]. Because of fossil fuel depletion and the air pollution emerging from its combustion, there is an earnest interest for sustainable, clean fuel alternatives for our future energy supply [4]. Although rechargeable lithium-ion batteries are broadly utilized in cell phones, computers and similar electronic devices, their energy density is still insufficient to permit their utilization in electric vehicles. The most obscure energy storage technologies, due to the various challenges faced by researchers, are the metal–air batteries. A few metal–air batteries such as iron–air, aluminum–air and zinc–air batteries [5] have been investigated due to their promising energy densities; lithium–air batteries have been found to be the most promising for high-performance applications [6]. However, lithium is delicate to ambient conditions such as humidity and oxygen, and is a rare natural resource in some regions. A battery is a device comprising of at least one electrochemical cells with external connections provided to power electrical devices [7]. At the point when a battery is providing electric power, its positive terminal is the cathode and its negative terminal is the anode [8]. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy [9]. Metal-air batteries for example lithium-air, zinc-air, magnesium-air and aluminum-air batteries are promising for future generations of electric vehicles (EV) since they use oxygen from the air as one of the battery's primary reactants, reducing the weight of the battery and opening up more space devoted to energy storage. Among all these metal-air batteries, lithium-air battery shows the highest theoretical energy density, rivaling the gasoline engine (13000 $Whkg^{-1}$). It has a much greater energy density than other rechargeable batteries [10]. Al-air battery is in development and have received research attention from the researchers.

2. Methodology

This Al-air battery consists of aluminum metal anode, air cathode, graphite which helps air to react with anode and sodium chloride solutions as an electrolyte. Reaction of oxygen with metal aluminum is the basic chemistry of Al-air battery [11]. Al-air battery is non-rechargeable. Aluminum anode reacts with oxygen to form hydrated aluminum oxide and gets consumed in electrolyte which results in stopping electricity production [12]. The electrochemical cell reaction for Al-air cell is: [13]

Anode reaction: $Al+3OH^{-} \rightarrow Al(OH)_3+3e^{-}$

Cathode reaction: $O_2+2H_2O+4e^{-} \rightarrow 4OH^{-}$

Overall reaction: $4Al + 3O_2 + 6H_2O \rightarrow 4Al(OH)_3$

In this study Graphite was heat treated at two different temperatures that is 1000℃ (which will be denoted as G1000) and 1200℃(which will be denoted as G1200). Then those samples were collected carefully and were used to make Al-air batteries. Different amount of Graphite was taken from those samples to fabricate batteries. Voltage and current of those batteries were measured to observe the effect of different types of graphite for different amounts. Later, Charcoal was use to compare with the Graphite.

2.1 Battery Assembly

For assembling the aluminum-air battery, at first an aluminum sheet was taken and an open top cube was made with it. That was the anode of the battery. After that Sodium Chloride (NaCl) salt solution of 1M concentration was made. Then a tissue paper was cut with the same size of the anode surface. The tissue soaked in salt solution was used as separator. G1000 was measured and divided into 1 gm, 2gm, 3gm and G1200 was also measured and divide into 1 gm, 2 gm, 3 gm with precision electric balance. Then those were used in cathode which helped air to react with anode. Separator was placed between anode and graphite as they don't come into contact. Two wires were connected with aluminum and graphite to complete assembly. After assembling the batteries, voltage and current of those batteries were measured and values were noted. Figure 1 shows different type of cells made for this experiment.

Fig. 1: Cells made for observations.

3. Experimental Results and Analysis

Two different types of graphite were used to observe the effect of cathode material in an aluminum-air battery. The amount of cathode was also changed to observe the value. The difference of current and voltage, with respect to cathode amount and cathode type are graphically represented.

3.1 Weight of Cathode Vs Cell Current

Figure 2 shows that Graphite treated at 1200°C for 2 hours is capable of producing more electricity in the aluminum-air batteries than its inherent one which was treated at 1000°C.

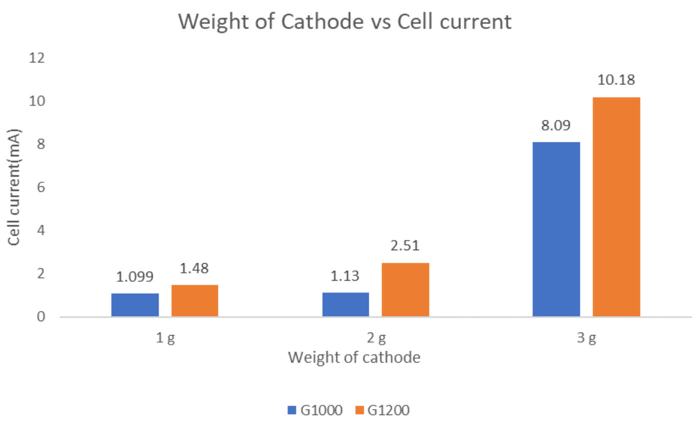

Fig. 2: Weight of Cathode Vs Cell Current.

3.2 Weight of Cathode Vs Cell Voltage

Two types of graphite show almost same voltages with the change of amount in cathode which means both are suitable for construction of aluminum-air batteries which can be seen in Figure 3.

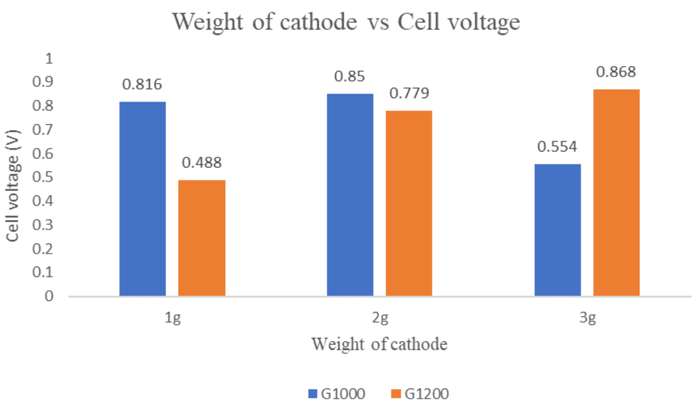

Fig. 3: Weight of Cathode Vs Cell Voltage.

3.3 Cathode Type Vs Cell Voltage

Figure 4 shows that the purest form of carbon is more suitable for aluminum-air batteries.

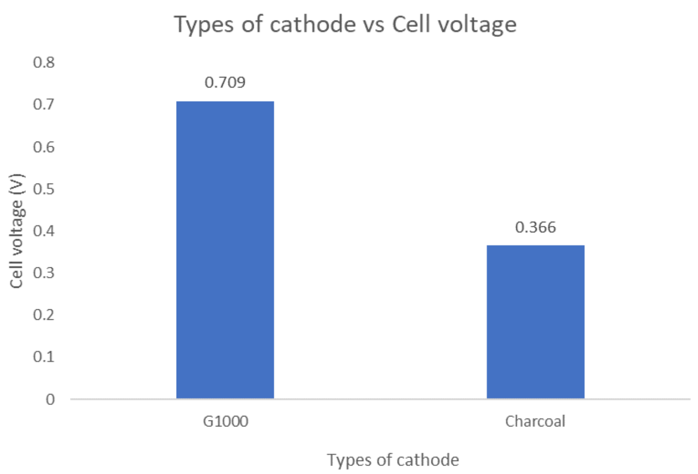

Fig. 4: Types of Cathode Vs Cell Voltage.

3.4 Cathode Type Vs Cell Current

In Figure 5 it can be seen that the finest form of graphite can produce much electricity in aluminum-air batteries than lower grade carbon (like charcoal).

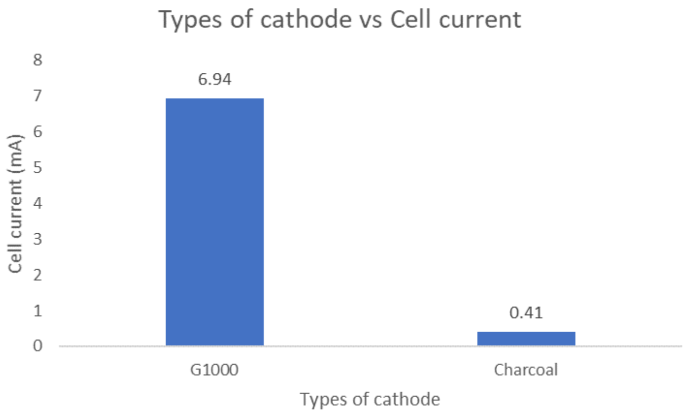

Fig. 5: Types of Cathode Vs Cell Current.

4. Conclusion

Batteries now a days getting more popularity because during operation it supplies green energy and is a very good source of energy reservoir. Metal-air batteries taking all the attentions because of its light weight and high energy density, it can be a great asset for the future of the electric vehicles. Researchers are interested about aluminum-air batteries because of its low cost and abundance. It is a non-rechargeable battery. Assembling aluminum-air batteries with different cathode material and different amount really helped to understand about the characteristics of these batteries. The current and voltage of the cells were low because it was measured at a small point where the amount of cathode was very low as the cathode is powder rather than rigid. If the system was made compact, then the right amount of electricity could be found for this battery. We get the best output using the better form of graphite, G1200 produces more electricity in almost every sample than that of G1000. By increasing the amount of graphite in the cells showed the increase in current and voltage of the cells. The production of current and voltage of the cell also decreased when homemade charcoal was used rather than high quality graphite. Several problems were faced during assembling batteries because aluminum-air batteries discharged so quickly even if they were not connected with any load.

5. Acknowledgement

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6. References

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