HIGH CAPACITY CATHODES FOR LITHIUM-AIR BATTERIES

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Lithium-air batteries consist of lithium anodes electrochemically coupled to atmospheric oxygen through an air cathode. Oxygen gas introduced into the battery through the air cathode is essentially an unlimited cathode reactant source. Theoretically with oxygen as an unlimited cathode reactant, the capacity of the battery is limited by the Li anode. The theoretical specific energy of the Li-oxygen cell with 3 V is 5.4 kWh/kg, and that excluding oxygen is 11.5 kWh/kg, the highest for a metal air battery (1). In addition to this very high specific energy, the Li air battery offers a flat discharge voltage profile, environmental friendliness and long storage life. A cell design utilizing a non-aqueous electrolyte alleviates the parasitic corrosion reactions of the Li anode that plagued past lithium-air batteries based on alkali aqueous electrolytes. The non-aqueous electrolyte-based cell design also overcomes safety concerns of the Li-air system.

In this paper we report the results of our efforts to increase the practical energy density of the Li-air battery through improved air cathode structures. Our air cathodes structures are carbon based double-sided electrodes (Figure 1). These electrodes consist of two carbon layers sandwiched around a current collector, and then covered with a PTFE film. The carbon layers contain the metal catalysts. Metal catalysts incorporated into the carbon electrode enhance the oxygen reduction kinetics and increase the specific capacity of the cathode. Several cathodes were constructed with different metal catalysts such as: manganese, cobalt, ruthenium, platinum, silver, and a cobalt manganese mixture. High surface area carbon powder was also used in these cathodes. The PTFE film acts as an atmospheric water barrier. Preventing water from entering the battery increases safety and performance. The air cathodes were tested using a pouch cell design. The lithium metal anode, separator, electrolyte, and carbon air cathodes are sealed inside the metallized plastic envelope. The air cathode was 10 cm^2 in area while the anode and separator were slightly larger. The electrolyte was 1M $LiPF_6$ in 1:1:1 EC/ DEC/ DMC, and the separator was Setela. The cells were discharged at constant current at 22 ^oC in oxygen gas roughly at 1 atm. The current was 1 mA (current density equal to 0.1 mA/cm^2). Cathodes were analyzed by SEM to elucidate structure and catalyst distribution.

The best performing air cathodes were the Mn catalyzed cathodes followed by the Co catalyzed cathodes. The Mn catalyzed cell had a capacity of 91 mAh with a relatively flat discharge profile (Figure 3). Discharging further to 1.5 volts resulted in 100 mAh total capacity. The corresponding energy yield is 246 mWh. With 0.028 grams of carbon impregnated into the air cathode current collector, the specific capacity is 3137 mAh/g carbon. This is more than double the highest capacity reported in literature for carbon (2,3). The carbon electrodes containing the Co catalyst were the second best performing air with a specific capacity of 2414 mAh/g of carbon. The specific capacities of the two electrodes (Mn and Co respectively) are about 250% and 150% greater than the highest specific capacities reported in literature.

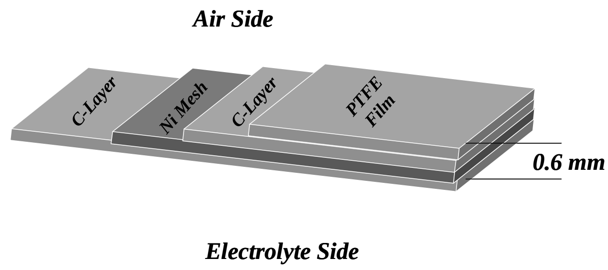

Figure 1. Diagram of the layered carbon electrode used as an air cathode in lithium air cells. The PTFE is a Teflon membrane to repel water from the atmosphere. The “C” is the carbon layer that contains the metal catalysts. Nickel mesh is the current collector.

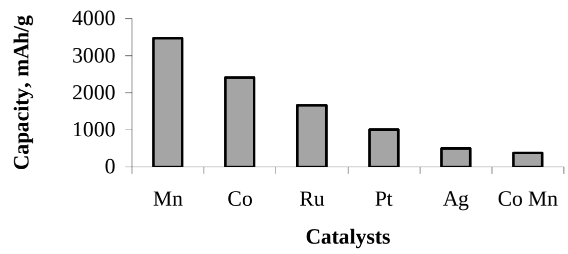

Figure 2 The specific capacities of the air cathode in pouch cells utilizing the various catalysts. The discharge current was 1.0 mA that corresponds to 0.1 mA/cm^2.

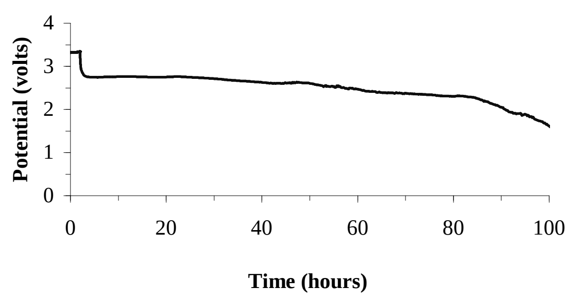

Figure 3 Discharge profile of Mn catalyzed cathode at 0.1 mA/cm^2 shown with an initial open circuit rest of two hours.

Yardney’s experience and technologies in the zinc-air and aluminum-air power sources were adopted in the design of the new air cathode structure and the Li air-cell. These batteries have the potential to power portable electronic equipment, unmanned aerial vehicles, camping equipment, or any equipment where air is present.

ACKNOWLEDGMENTS

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