The Characterization of Electrochemical Cells

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Introduction

The goal of this research is to study electrochemical devices by using methods which include generating discharge curves, formatting a ragone plot and determining the internal impedance for the batteries. From studying the internal impedance, we were able to make conclusions about the relationship between the power density and energy density of a battery.

Methods

Each battery was discharged at different drain rates. Batteries that are meant to be drained using a low current were discharged using a constant resistance. Batteries that are meant to be drained using a high current were discharged using a constant current. From the discharge plots, the energy and power density were extracted to create a Ragone chart.

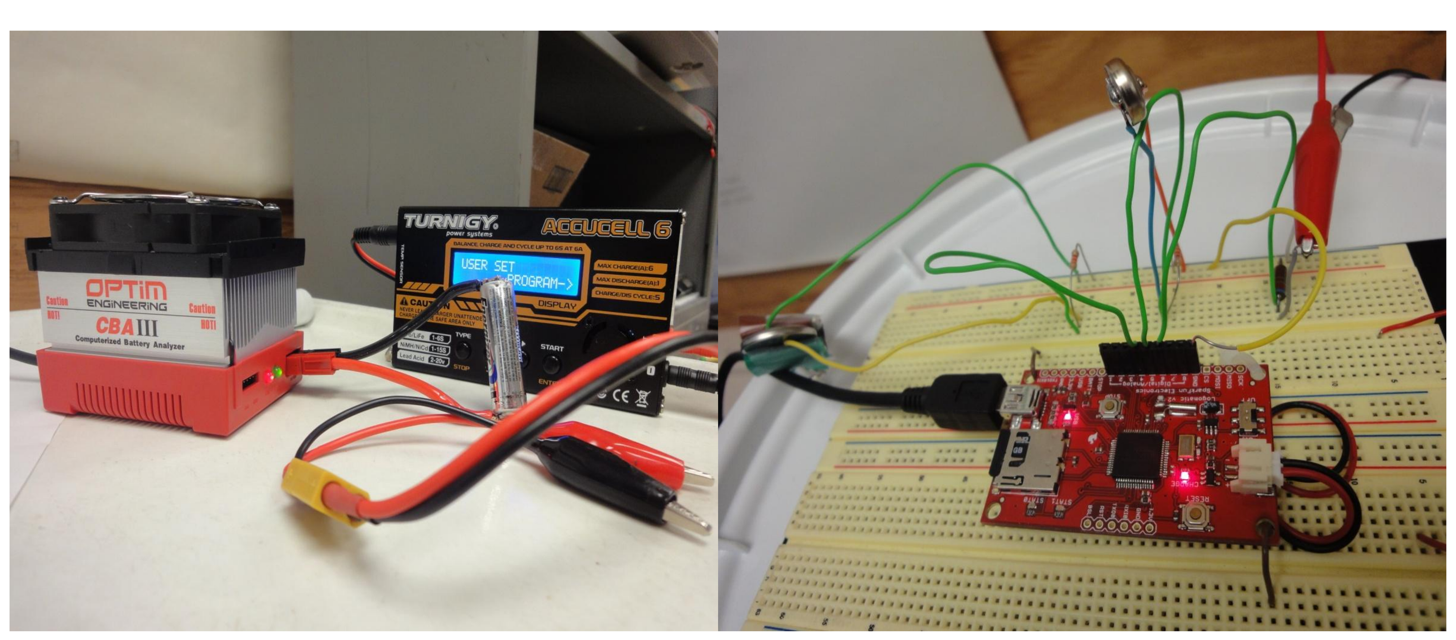

Fig. 1. The test setup for discharging the batteries.

AC Internal Impedance Testing:
AC Internal Impedance tests measure the impedance of the battery at a fixed frequency. An AC current is supplied to the battery in which an impedance is calculated. Batteries are typically tested using a 1 kHz source. This method does not short a cell such as a DC test. [1]

RLC meter:
The internal impedance of the batteries were determined using an RLC meter (GenRad 1689 Precision RLC Digibridge®). A sine wave generator produces a current through the unknown impedance and a fixed resistor. Two differential amplifiers with equivalent gain (k) produce two voltages V1 and V2 respectively. From there, the unknown impedance Zx can be calculated using $Zx = Rs [V1/V2]$. A microprocessor calculates the impedance and then determines the values of capacitance, inductance, and resistance. [2]

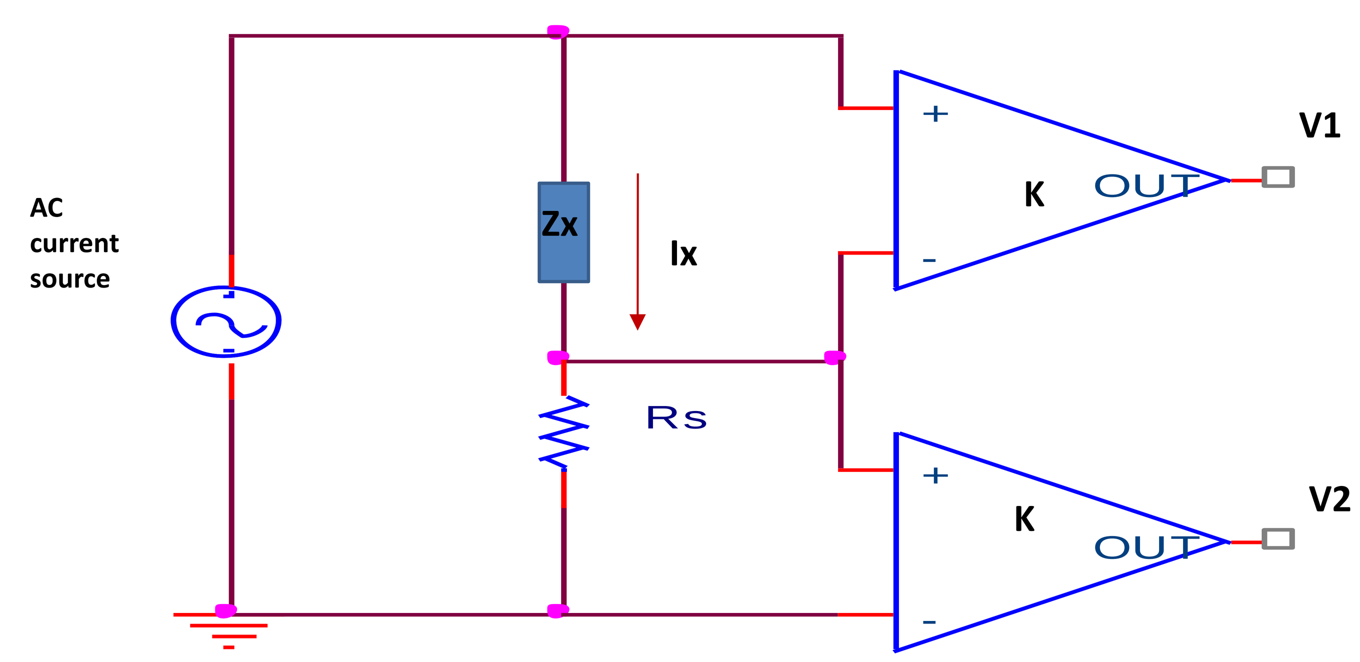

Fig. 2. The circuit diagram for the RLC meter (RLC Digibridge®) [2].

Results

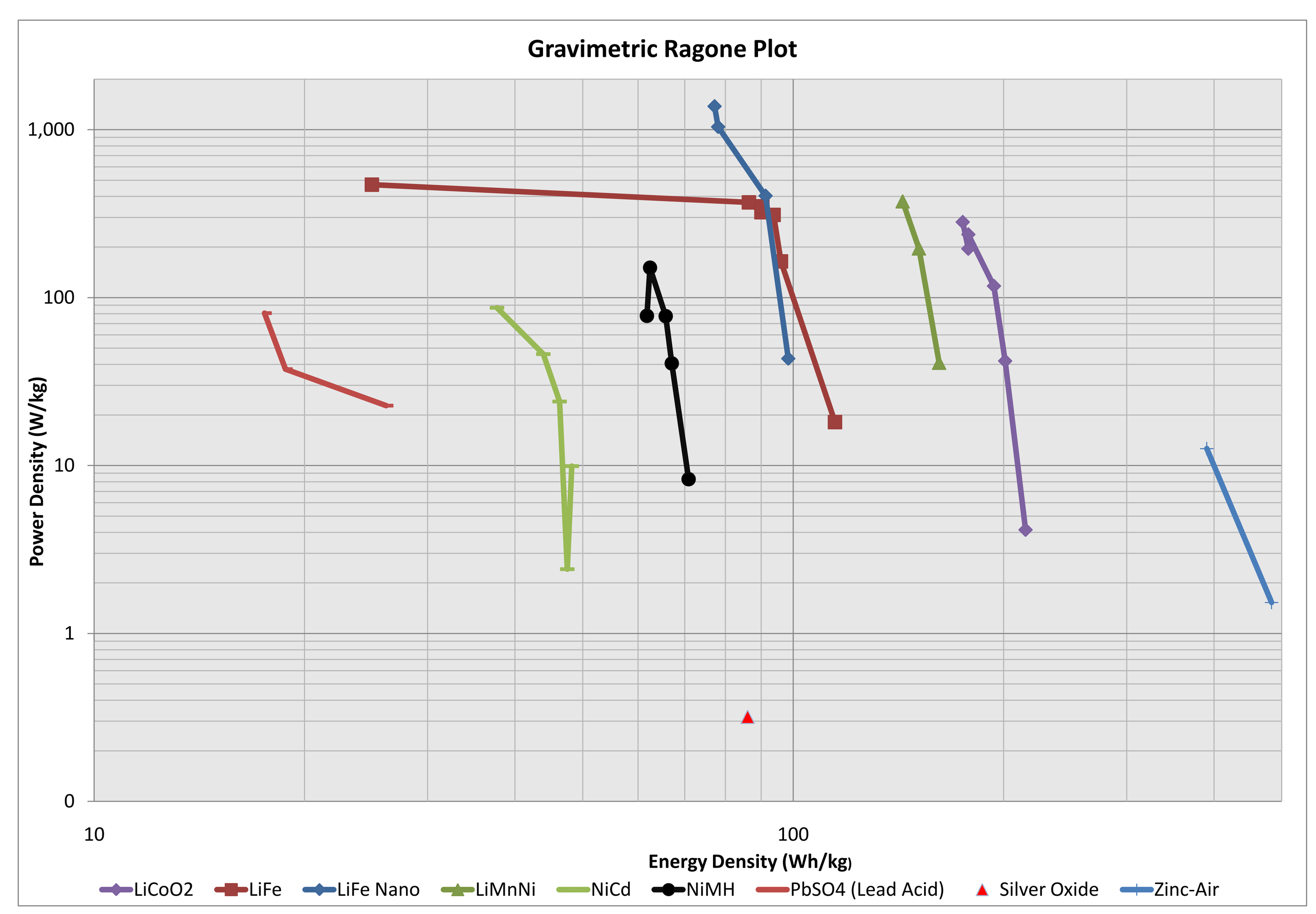

Fig. 3. Ragone Plot (Discharges by research partners Antonio Upia and Michael Sparks).

Table. 1. Internal Impedance Chart that were recorded from the RLC meter.

Battery Chemistry	Internal Impedance (mΩ)	Manufactuer values (mΩ)
Nickel Cadium Size D	17.78	7.5
Lithium Magnanese Nickel	58.87	23
Nickel Cadium	65.32	15
Nickel Metal Hydride	68.75	21
Lead Acid	91.85	30
Lithium Iron nano phospate (A123 cell)	128.68	8
Lithium Cobalt	168.77	70
Nickel Zinc	462.32	N/A
Silver Oxide	9757	3000-10000
Lithium Thionyl	15969	N/A
Zinc Air	24052	12000

Error Analysis

Testing batteries with the RLC meter did not replicate ideal conditions of an AC internal Impedance test. One source of error is that the RLC meter shorted the battery which applied a load to the cell. An AC internal impedance test is not designed to apply a load to the battery. It also caused the voltage to rapidly vary while testing for internal impedance which caused a change in temperature. Internal Impedance varies depending on a specific temperature. [3] It is a future interest to find ways to minimize these errors.

Conclusion

After analyzing the results from internal impedance tests and discharge tests, a close relationship between internal impedance, energy density, and power density was observed. Batteries that have a higher impedance are not able to have a high current drawn from it. However, since they are designed to operate at a lower current, the energy density tends to be higher and the batteries run time lasts very long. On the other hand, batteries with a lower amount of impedance can withstand a large amount of current and tend to produce higher power. Internal Impedance also shows the initial voltage drop for a battery when being discharged. The internal impedance of the battery gives you an idea of the maximum current the battery can deliver which may be useful in applications when a battery needs to provide a specific pulse current.

Future Work

The goal for future research is to design a circuit to test for AC internal resistance that reduces error instead of using the RLC meter circuit. Also, I plan on testing the cells at a different range of frequencies in order to determine the most accurate and precise internal impedance measurements.

References

[1] . Kuphaldt ,Tony R. ,*Lessons In Electric Circuits.* copyright (C) 2000-2002, http://www.opamp-electronics.com/tutorials/ac_bridge_circuits_2_12_05.htm
[2] "GR 1689/1689M Precision RLC Digibridge® Instruction Manuel", GenRad [June 1985]
[3] *Battery Internal Resistance* [online] (December 2005), http://data.energizer.com/PDFs/BatteryIR.pdf [4/4/11]