LAB REPORT OF LAB103

Lithiumion Battery

May 11, 2022

Yubo Cai, Durmus Mehmet Emre

ÉCOLE POLYTECHNIQUE
IP PARIS

CONTENTS

1 Introduction **3**

2 Objectives **3**

3 Electrochemical Processes **3**
3.1 Charging 4
3.2 Discharging 4

4 Experiment **4**

5 Assembly of the battery **5**

6 Experiment: Data Measurement and Analysis **6**
6.1 Analysis 6

7 Improvement **7**

1
INTRODUCTION

The lithium-ion battery is one of the revolutionary inventions in the world. The lithium-ion is a rechargeable battery that works mainly on the movement of lithium ions between the positive and negative electrodes. Lithium is an unstable metallic element with one electron in its outer electron shell. On the other hand, Lithium is one of the smallest atoms in the periodic table and exhibits a large electrochemical potential. Therefore Lithium atoms can easily lose electrons and turn into lithium ions, and energy is released through this chemical process. The first functional lithium battery was created by Stanley Whittingham. It was put into manufacture but was soon suspended because it had brought several explosions. Since then scientists have been working on improving the efficiency and stability of lithium batteries and trying to commercialize the technology. In 1985, Akira Yoshino eliminated pure lithium from the battery, using completely lithium-ions, which are safer than pure lithium. This made the battery workable in practice. (The Nobel Prize in Chemistry 2019, 2021) Today, Lithium-ion battery has been commonly used for portable electronic devices and electric vehicles.

The basic structure of a lithium battery consists of an anode, a cathode, and the electrolyte solution in between. The choice of the anode material is generally $LiCoO_2$, $Li_2Mn_2O_4$. The cathode is formed by an Aluminium foil(acting uniquely as a current collector) and a lithium-based metal oxide. Therefore this brings the problem that the increase of the need for lithium-ion batteries is rich in critical metals—particularly lithium, cobalt, and nickel. The large-scale mining of such metals, to meet increasing battery demands, poses concerns surrounding material exhaustion. The expensive cost of such metal material is also a problem from a societal perspective.

2
OBJECTIVES

In this lab, we want to explore the principle and structure of lithium-ion batteries. It will be performed in three steps: making the electrodes, assembling the battery, and measuring its capacity. Then, we need to test the performance between two batteries and compare them with commercial batteries. The experiment should tell us how to make lithium-ion batteries and what factors will affect the performance of the batteries.

3
ELECTROCHEMICAL PROCESSES

3.1 Charging

Anode: $Li^+ + 1\,e^- \longrightarrow Li$
Cathode: $Li_nMnO_{2(s)} \longrightarrow Li_{n-1}MnO_{2(s)} + Li^+(\text{in solution}) + 1\,e^-$

During charging, lithium ions (present in the electrolyte) gain electrons converting into Lithium metal to ensure electroneutrality, the cathode has to release those electrons and as many lithium ions from its structure into the electrolyte. This is possible as the Mn of MnO_2 has an orbital that allows different oxidation estates.

3.2 Discharging

The chemical process is reversed compared with charging
Anode: $Li \longrightarrow Li^+ + 1\,e^-$
Cathode: $Li_{n-1}MnO_{2(s)} + Li^+(\text{in solution}) + 1\,e^- \longrightarrow Li_nMnO_{2(s)}$

During the discharge, the process is the reverse one, being the Lithium metal, previously accumulated within the graphite structure, kindly and spontaneously releasing an electron (traveling through the external circuit via the current collector). That Lithium-ion created is not stable in the graphite structure anymore and goes into the electrolyte.

At the cathode, the electrons are collected and transferred to the metal oxide compound (via the current collector) that will experience that change of oxidation state to accept one more Lithium-ion (and so keep the electroneutrality of the solution) into its laminar structure.

4 EXPERIMENT

Fabrication of the electrodes
a. Materials:

1. Powder graphite: anode material

2. Lithium Manganese Oxide ($Li_2Mn_2O_4$): cathode material

3. PTFE Binder: polymer to give mechanical stability and robustness to the electrodes (Since The anode and cathode material are powdered materials that need certain mechanical robustness to ensure the long-life operation of the battery. Therefore we need to use PTEF material as a binder which is able to lead into a slurry that will be spread over the current collector. PTFE is a synthetic polymer material that uses fluorine to replace all the hydrogen atoms in polyethylene. This material is extremely chemically stable and

insoluble in almost all solvents, making it the best choice of material for our experiments as a binder.

4. Microfiber filter paper (glass fiber paper): a permeable membrane. This acts as a separator between anode and cathode to avoid shortcuts. It only allows ions within the electrolyte to flow. This will be immersed in the electrolyte solution. - Stainless steel micromesh: acting as a current collector for both electrodes. It can provide a structure of the electrodes before they are strengthened.

b. Materials:
We first use a high-precision scale to measure and obtain0.6g of Lithium Manganese Oxide with 0.3g of graphite and 0.1g of PTFE binder and mix them together with around 1 ml of water in small increments. The mixture is then brought to a consistency similar to toothpaste by stirring the mixture. Spread the electrode material onto a piece of steel mesh.

c. Anode:
The procedure is similar to that of the cathode, except that the material is replaced with 0.9 g of graphite powder with 0.1 g of PTFE binder in a glass vial. Using the same method to make a slurry of graphite and PTFE. Spread it on another piece of steel mesh.

Afterward, we need to eliminate any water as it will be a source of side reactions, so the electrodes are dried at 150 °C in an oven, at least for 30 minutes.

5 ASSEMBLY OF THE BATTERY

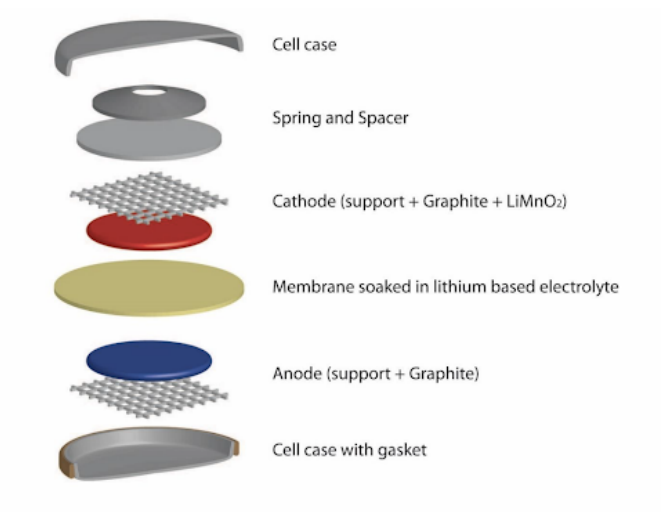

Figure 1: Instruction Graph of the battery

When we assembled the lithium-ion battery, as shown above, there was a leakage of electrolyte and we were not able to make the battery completely closed when using the hydraulic press.

Later, with the help of the professor, we solved the problem by replacing the cell case with a larger size.

6 EXPERIMENT: DATA MEASUREMENT AND ANALYSIS

We first use the USB battery charger and USB charger to charge our battery. We recorded the charging time and use a multimeter to measure the charging current. During this process, we record the charging time and the discharge current and voltage before we charge the battery.

After it is fully charged, we use a multimeter to record the fully-charged voltage. We use an LIR 2032 battery LED gadget to discharge it. We determined whether it is fully discharged by observing the LED illumination status. The total illumination time is recorded with a stopwatch and the discharging current is measured by the multimeter. Then we have the data in this chart. We choose a battery in good condition to measure its capacity

	Charge Current	Discharge Current	Charged Voltage	Discharged Voltage	Charge Time	Charging Time	Weight
Battery 1 (weak one)	Average: (0.67mA+0.54mA+0.68mA)/3 = 0.63mA	2.3 mA	2.54 V	1.2 mV	1 min 52 sec	17 sec	3.516 g
Battery 2 (stronger one)	Average: (1.47mA+2.17mA+2.26mA)/3 = 1.96 mA	14 mA	3.00 V	1.5 mV	8 mins 21 sec	31 sec	3.480 g

Table 1: Caption

*Discharge Capacity(mAh) = Discharge current (mA) * Discharge time (h) = 1.96mA * h = 0.271 mAh*
*Discharge Capacity(mAh) = Discharge current (mA) * Discharge time (h) = 14mA * 0.0086h = 0.1204mAh*
$Coulombic\ efficiency = \frac{discharge\ capacity}{charge\ capacity} \simeq 44.4\%$

6.1 Analysis

Compare to commercial CR2032 lithium-ion battery

Our battery is much smaller in capacity Compared with the commercial lithium-ion batteries CR2032. The CR2032 uses MnO_2 and lithium metal as the materials for each node. Lithium metal is more active than $Li_2Mn_2O_4$ which we used to make our own batteries. For safety reasons, we put graphite in the cathode material instead of pure lithium as the commercial battery. The ratio of conductive agent to graphite for commercial lithium-ion batteries is 1.5:1. lithium manganate is about 15:85 and our ratio is 1:2, which has the potential to reduce energy density.

At the same time, our production process is far inferior to that of commercial lithium-ion batteries. We have problems such as electrolyte leakage, broken anodes, and cathodes in the production process, which causes us to be far inferior to commercial batteries in terms of battery capacity.

7 IMPROVEMENT

Through the analysis of our experimental results and the study of the principles of lithium-ion batteries, we need to prolong the time in the oven. based on the comparison with the commercial battery and our failure, we find that water can affect the battery.

The second point is to improve our production process, we are making cathode and anode when the quality of the material is not measured accurately, and there are too many gaps between Graphite and Cell case.