Stabilized Lithium Metal Powder Coating Machine

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Abstract

Stabilized lithium metal powder (SLPMs) material enables a new generation of Li-ion batteries for applications on the Anode and Cathode. This optimum efficiency reduces the costs and improves the overall battery life. The process of this project will be implemented to create a coating machine that coats the anode side of a Li-ion battery or super-capacitor uniformly via the specified requirements. The project scope states the background of the research conducted for SLMPs to be applied in the building process of the coating machine. A coating machine prototype is expected; therefore, further research is needed in order to have a conclusive draft for the machine specifications. Further, the methodology, exemplifies the basic process to disperse the Stabilized Lithium Metal Powder in a solvent to form a slurry and that is then used to coat the electrodes of the Li-ion battery. Finally a project scope (Gantt Chart) schedule is described for major milestones of the project and completion of the slurry production and machine building.

1 Introduction

The objective of this project is to develop SLMP coated anode electrodes. In addition, the investigation of other components in Li-ion batteries and Li-ion super-capacitors will be conducted. These components include conventional carbons (e.g. graphite and hard carbon) and the high specific capacity silicon (Si) and other alloys. A prototype machine that can uniformly coat SLMP on a flat battery electrode is to be developed. The stabilized lithium metal powder (SLMP) is a relatively new product created by FMC. According to the Safety Data Sheet for SLMP, exposure to elevated temperatures above the melting point (180.5°C/357°F) can result in spontaneous ignition in humid aid. The main application of this metal powder is to be used in existing lithium ion batteries. The methodology improves the capacity of the Li-ion battery by 5 to 15%. Another application of the SLMP is in Li-ion super-capacitor to improve the energy density by 2-4 times.

In order to achieve these specifications effectively, the SLMP should be coated on the anode electrode uniformly. One specification that will be met includes, semi-automatically coating a flat battery electrode with the SLMPs. More specifically, the range for the loading of the SLMPs should be ~0.5-3 mg/cm^2. The uniformity of the coating should be expected to be better than 20% and the coating area of the electrode is variable from 5-12 cm (width) and 5-250 cm (length). The coating time process is expected to be less than ~10 minutes. The hardware for the coating machine is expected to be within a $2,000.00 budget, to furnish the machine with motor, stainless steel plates and rods for the frame.

2 Project Definition

2.1 Background research

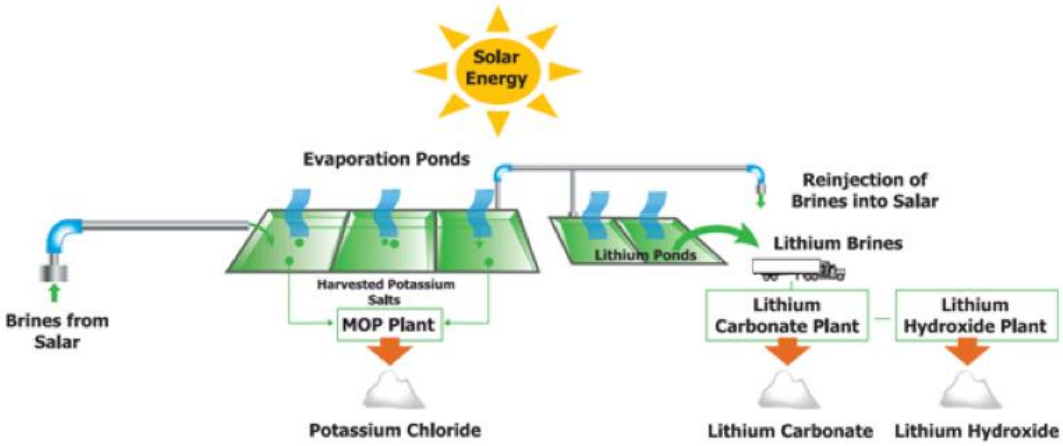


Figure 1. Evaporation Process for Extracting Lithium

Lithium is a highly reactive and flammable alkali metal. It is the lightest metal and least dense element. Lithium will typically react with moisture in the air and corrode, as a consequence it is usually stored in mineral oil. Lithium is not found freely due to its high bonding potential. Instead it is typically found in compounds, minerals, and ocean water. Its high solubility makes the ocean an abundant source of lithium and it can be obtained from brines and clays. Extracting lithium is relatively simple and cost efficient primarily relying on evaporation. A detailed synopsis of the process can be found on Figure 1. Lithium compounds are used in various applications, namely, high strength-to-weight alloys, ceramics, and battery cations. Lithium has a melting point of 453.65K (356.90 degrees Fahrenheit), thermal expansion coefficient of 46 (at 298K), thermal conductivity of 84.8μm/(m*K), and an electrical resistivity

of 92.8 nΩ*m (at 293K). At low temperatures (T<70K) lithium incurs diffusionless phase change transformations. Lithium has the highest specific heat capacity of any solid element of 3.58kJ/(kg*K).

The goal of our senior design project is to make a machine that will uniformly coat a layer of stabilized lithium metal powder (SLMP) on the flat electrodes of flat Lithium-Ion batteries. This SLMP product was developed by FMC and when properly applied to the electrodes it can increase the batteries capacity by 5 to 15% and the energy density by 2 to 4 times [1]. By coating the electrodes with Lithium instead of conventional compound consisting of other compounds is the reason why these are projected to increase so highly. The capability to store more energy allows for batteries to be smaller than before but still output the same amount of energy. In addition to the extended output and longer life for batteries this stabilized lithium metal powder also greatly reduces the risks that were previously associated with Lithium. The stability allows for the powder to be shipped and handled conventionally reducing initial costs. Now giving more possibilities for the application process such as spraying the product or applying it through a slurry. SLMP is also not pyrophoric like other forms of lithium meaning that there is not a danger of spontaneous

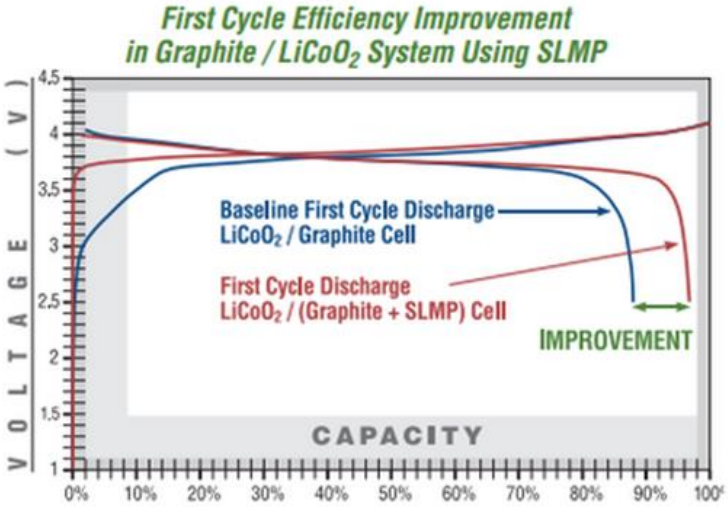


Figure 2. First Cycle Efficiency Improvement Using SLMP [1]

combustion if not handled properly. Another way that costs are reduced is that the stabilized lithium metal powder can be used with non-lithiated cathodes allowing for lower cost cathodes to be used. Everyday equipment such as hybrid cars are big beneficiaries of this product due to the increase in energy capability which would allow for electric vehicles travel further with more power.

2.2 Need Statement

Group 16 is sponsored by General Capacitors, which is located in Tallahassee, FL. The sponsor is Harry Chen, the chief technology officer at General Capacitor llc., However our main liaison and advisor is Dr. Zheng whom is their top research engineer and professor at FSU. The current project calls for group 16 to develop a coating machine. This machine will apply a uniform layer of stabilized lithium metal powder to the anode electrode of a Li-ion battery and to a Li-ion super-capacitor. This material and process application is newly developed. So group 16 is researching and developing a mechanism that can be scaled up to a production level. There are other coating machines on the marketplace, however none for this specific type of application. Due to the hazardous nature of the lithium metal powder, group 16 will develop a safe and productive way to meet our mechanisms requirements.

"A coating machine for this specific application is non existent"

2.3 Goal Statement & Objectives

Goal Statement:

"To develop an electrode with a uniform coating of stabilized lithium metal powder."

Objectives:

- Uniformity of roughly 20%
- Ability to apply a sufficient coat onto the electrode
- Ability to apply a coat in less than 10 minutes
- Coating must be applicable to electrodes of varying sizes.
- The process must be semi-automatic

Our goal is to develop an electrode that has a uniform coating of stabilized lithium metal powder. To execute this process, our intent is to design a prototype machine that will handle the lithium metal powder safely while applying a coat of specified thickness to the surface of a metal sheet that will later be cut to be made into an anode.

2.4 Constraints

- The budget given by General Capacitors is $2000
- The lithium powder is to cover the total surface area of the flat battery's anode
  - The area will be varied from 5-12 cm (width) and 5-250 cm (length)
- Lithium coat must have a uniform layer of 10m with 20% fluctuation in thickness
- One coating process under 10 minutes
- The metallic lithium content of the powder needs to be at least 98%
- Working with the lithium powder must be done in a dry environment
  - AME dry room is 0.5% humidity
  - Lithium reacts explosively to H2O

A prototype machine for coating copper anodes with stabilized lithium metal powder (SLMP) will be made by May 2015. General Capacitors LLC along with AME/FSU will be providing the Senior Design group 16 with a budget of $2000. There are a couple of possible prototypes in mind, every tentative prototype, however, will must meet these constraints.

Thorough research on powder metallurgy will be done to be able to understand and reproduce experimentation on the SLMP.

2.5 Methodology

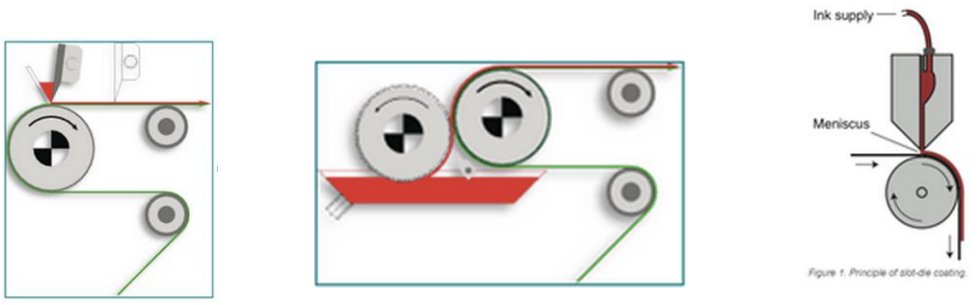
Slurry Coating Design:

The basic process will be to disperse the Stabilized Lithium Metal Powder in a solvent to form a slurry of a homogenous solution. This slurry is then coated on the electrodes and then dried leaving only a coating of Lithium on the electrode.

Hydrocarbons are a potential solvent that SLMP can be added to and then can be readily evaporated from the slurry to promote drying. Since there are many different Hydrocarbons available we will need to determine which would be the best fit since each have their own advantages and disadvantages. Each solvent will produce different electrode thickness, durability, and porosity of the electrode layers resulting in different performances for each solution.

Some components that will be needed for a slurry coating machine are a simple controller turning the machine on and off as well as allowing the user to vary the area size that is being coated and the thickness, a device to dispense the SMLP into the solvent, a device keep the solution mixed well by either stirring the solution at a high RPM or by agitating it, and rollers to smooth and press the materials

There are a few different techniques to apply the solvent to the electrodes such as a knife coating technique, Engraved Roller, Slot-die coating, tape casting, double sided horizontal coating and intermitting coatings techniques.



(a) *(b)* *(c)*

Figure 3. Illustrates the Slurry Coating Process: (a) Knife Coating, (b) Engraved roller, (c) Slot die

2.6 Schedule

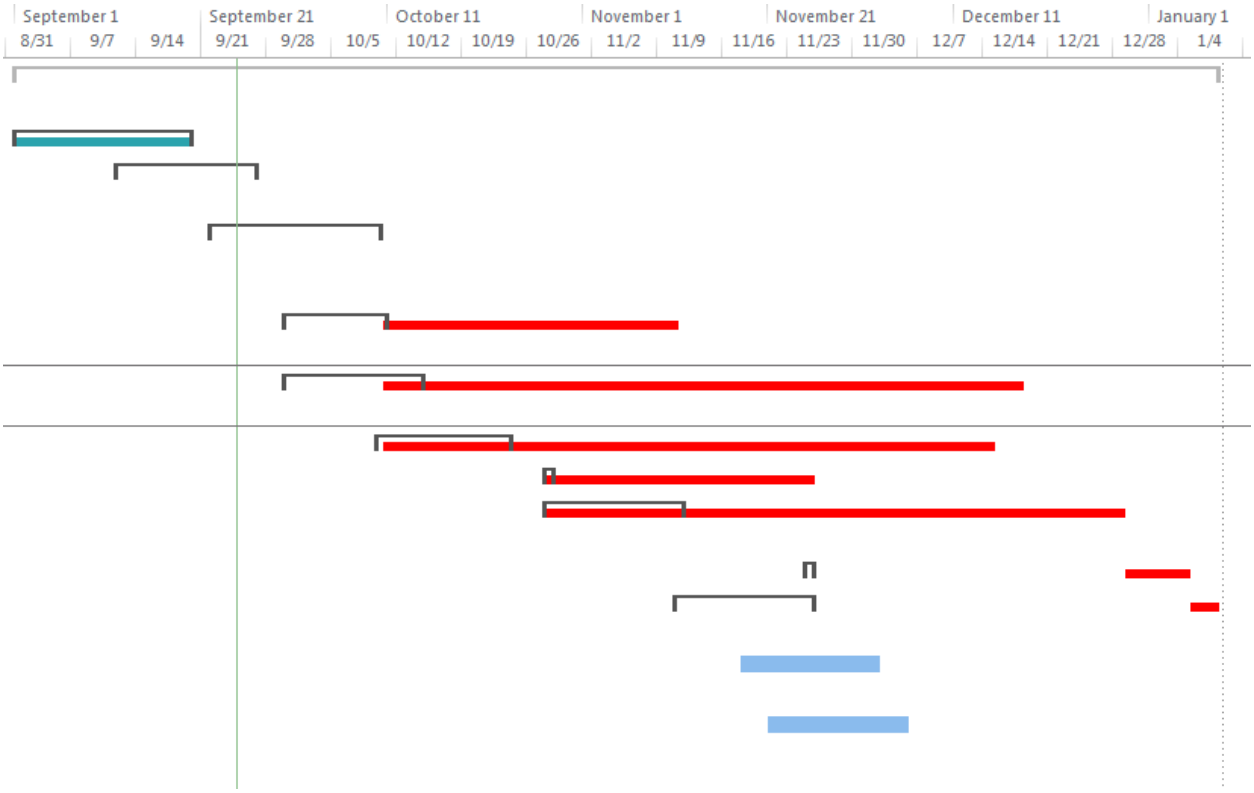


Figure 4. Gannt chart for the SLMP project.

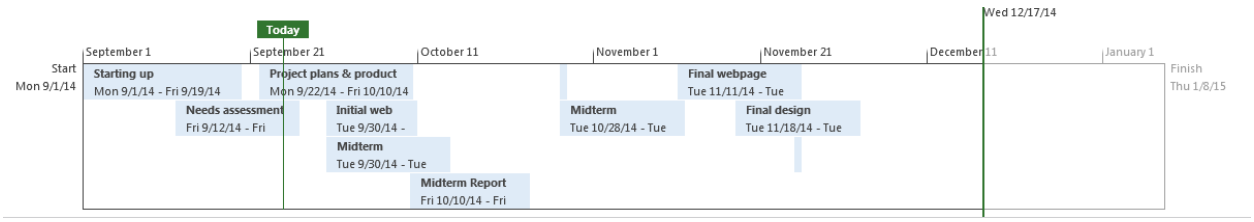


Figure 5. Timeline with names of events.

3 Conclusion

Lithium ion batteries and super-capacitors are the newest frontier of modern day technology. The company FMC Lithium, has developed a new stabilized lithium powder that has been tested and proven to improve battery capacity and energy density. Our sponsor, General Capacitors is currently working on implementing this new development on pre-existing lithium-ions batteries and super-capacitors. Our goal is to create a prototype machine that will uniformly coat a layer of stabilized lithium metal powder onto an electrode. Our mechanism must have the ability to coat an electrode within 10 minutes while achieving a uniformity of roughly 20%. Our future plans are to finalize a design of a mechanism that can produce a quality layer of stabilized lithium and begin research on material choices for that proposal.

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