Restated Project Definition and Scope/Project Plan
Prototype Machine for Coating Stabilized Lithium Metal Powder

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Abstract

A formal structured plan to build a Stabilized Lithium Metal Powder (SLMP) coating machine is presented in this report. Using the dry method, a surface application design will be utilized. SLMP particles will be loaded on top of a copper sheet (electrode), with a loading range of ~0.5-3 mg/cm^2. Leaving a uniform coating of SLMP on the copper anode. This paper is used to restate and iterate the goal of this project over the next few months. These goals include the completion of the coating machine prototype and testing to optimize the efficiency of the process. This document also contains an overview of our coating machine, which is in the construction process. As well as updated research on techniques of SLMP applications that were developed in 2014. The dates and stages of completion estimates of the project are included in the Gantt chart attached in this report.

1 Introduction

1.1 Objective

The objective of this project is to develop a Stabilized Lithium Metal Powder (SLMP) coated anode electrode. 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 [1]. A prototype machine that can uniformly coat SLMP on a flat battery electrode is to be developed. The stabilized lithium metal powder (Li/Li_2CO_3) is a relatively new product created by FMC Lithium Corporation. The SLMP particles are a form of lithium metal based on a core/shell concept [11]. The CO_3 reacts with the lithium metal and forms a shell layer on the surface of the unexposed lithium metal [11]. According to the Safety Data Sheet for SLMP, exposure to elevated temperatures above the melting point (180.5°C/357°F) [2] can result in spontaneous ignition when it comes in contact with humid air. The main application of this metal powder is to be used in existing lithium ion batteries. This methodology improves the capacity of the Li-ion battery by 5 to 15% [2]. Another application of the SLMP is in Li-ion super-capacitor to improve the energy density by 2-4 times [2].

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 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.

1.2 Background

Stabilized Lithium Metal Powder (SLMP), Li/Li_2CO_3, is a newly developed material for the application in Li-ion batteries. As seen in figure 1, this type of lithium material comes in the elemental dry form, which enhances the energy carrying properties. In combination, the Li-ion anode yields the most efficient utilization and the fastest diffusion [1]. The SLMP particles are a form of lithium metal based on a core/shell concept [3]. The CO_3 reacts with the lithium metal and forms a shell layer on the surface of unexposed lithium metal [3]. According to the Safety Data Sheet for SLMP, exposure to elevated temperatures above the melting point (180.5°C/357°F) [4] can result in spontaneous ignition when it comes in contact with humid air. The chemistry that governs SLMP provides the best opportunity to increase energy density in Li-ion batteries. The methodology improves the capacity of the Li-ion battery by 5 to 15% [4]. Another application of the SLMP is in Li-ion super-capacitor to improve the energy density by 2-4 times [4]. By introducing SLMP into Li-ion batteries it creates the opportunity for variation in anode/cathode material, such as Si, Sn based and manganese, vanadium respectively. These variations can lead to double the energy density, more overage tolerant systems, and potentially lower costs in new generation Li-ion batteries using SLMP [6].

Figure 1.Optical microscope image of SLMP taken from FMC

There are two main types of dispersion methods possible with SLMP, dry dispersion or wet dispersion. Previous research describes a slurry procedure to lithiate electrodes with Stabilized Lithium Metal Power. For example, in the journal of power sources, it covers a process of adding the SLMP slurry by film casting using a doctor blade [5]. The slurry production process involves the mixing of the SLMP and a solvent to make a homogenous mixture. Then the slurry material is pumped into a slurry container and enters the film casting procedure. A doctor blade, which is the edge of a smooth knife, spreads the slurry onto the anode film. The slurry making process, along with an added drying time, makes the whole method long and costly. Another type of application that has been developed within the last few months of 2014 was a slurry procedure that used an isobaric pressing method. In this particular design rare gases were used to apply the homogeneous mixture to an anode sheet. This was applied by spraying the mixture along with rare gases. This anode sheet is on a roll which allows for more material to be coated quicker and more efficiently. However these gases also make for a more toxic working environment, which needs to be taken into account for future production applications.

The process undertaken for this project will consist of surface application using the dry method, which would not require any drying time and no use of slurry tactics. The SLMP would be solely loaded onto a copper sheet to form the required electrode and later pressed so as to stick the SLMP to the anode. The lithiated electrode could easily be activated by pressing the SLMP and breaking the particle shell [3].

2 Project Definition

2.1 Design Specifications

2.1.1 Expectation

The sponsor of group 16, Harry Chen, expects a functioning machine that forms a uniform layer of stabilized lithium metal powder onto a copper sheet. This machine should be able to operate semi-automatically. The sponsor's expectations have stayed consistent since the commencement of the project.

2.1.2 Design Constraints

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

- 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 5-25 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 H_2O

The project's design constraints have not changed since the commencement of the project. The $2000 budget has projected to be sufficient money to complete the SLMP coating machine.

2.1.3 Motivation

With this projected product, General Capacitors will be able to couple the SLMP to the electrodes of batteries and super capacitors. Battery's capacity increases 5-15% and the super capacitor's energy density 2-4 times. The SLMP coat will also help with battery deterioration experienced during use. FMC develops the SLMP and General Capacitors produces the improved batteries and super capacitors, which are sold for profit. The original incentives for the development of the SLMP coating machine remain intact. Research facilities in China have also been developing machines for the same purpose. The race for a place in the SLMP coated fuel cells market provides a new incentive for General Capacitors and Group 16 to produce a finished product.

2.1.4 Component Breakdown

The main components of the coating machine are listed below.

Funnel

- The funnel directs the pouring of stabilized lithium metal powder. The funnel flows into a mesh system.

Mesh System

- High grade meshes are coupled with vibration dampeners and actuators. The actuators directly vibrate the meshes allowing the powder to sift through. The vibration frequency will determine the flow pattern on the copper sheet running on the conveyer belt. The meshes are positioned by vibration dampeners attached from the frame to the mesh. This will lessen the impact of the vibration running through the whole machine.

Conveyer Belt

- The conveyer belt is used to move the copper sheet back and forth, underneath the funnel's opening. After the copper sheet is fully covered with SLMP it is fed into a press machine.

Press Machine

- The MR-100A rolling press presses the lithium powder onto the copper sheet. This press will provide the appropriate uniformity and thickness of SLMP.

Frame

- The frame of the coating machine will house all of the components. The frame is being built with steel square tubing to keep the machine as stiff as possible. Filler will also be used inside of the hollow square tubing to help dampen the system from the vibrations while running.

Arduino Uno R3 – MCU

- The electrical components of the coating machine are controlled by the microcontroller Arduino Uno R3. The Arduino will allow the adjustments of the conveyer's speed and direction, actuator's frequencies and power functions.

1000 W Power Supply

- With all the electrical components a power supply is needed to regulate the voltage drawn and directed to the electrical components.

2.2 Performance Specifications

2.2.1 Expectations

Our machine is expected to read the length and width inputs (between 5cm – 10cm wide and 5cm – 25cm long) which a user inputs and then automatically coat a uniform layer of SLMP on an electrode with a uniform thickness that is greater than 20%. To do so the electrode will be moved under the dispersion system 10 times by a conveyor belt to ensure uniformity and will then be shut down when the coating is complete. Furthermore, if there is any malfunctions or emergencies the machine must be able to be powered down at any time.

2.2.2 Needs

Due to the dangerous nature of the SLMP many safety precautions are necessary to ensure the safety of the operator. The coating machine must be operated in a dry room with <2% humidity, since SLMP is pyrophoric material. A pyrophoric material is a substance that can ignite when coming into contact with water or humidity. All electrical components of the machine must be grounded before use, as static electricity may also cause the combustion of SLMP. The coating machine must also be operated on a completely level surface; otherwise the coating uniformity may be compromised due to the round nature of the SLMP. Full laboratory attire is also required (apron, safety goggles, and face mask), and should be worn at all times throughout operation. Inhalation and ingestion of SLMP are extremely harmful.

2.3 Plan for Manufacturing

Most of the components for the SLMP coating machine are off-the-shelf standard parts that will be ordered through an online distributor or purchased in-store. This will save time and energy in the design process. The hopper will be bought itself, but an adjustable plate will be custom built to adjust and close the opening of the hopper. The plate will be made from aluminum sheet, but a power screw will extend and retract the plate itself. The frame of the coating machine will be made from aluminum square tubing. This aluminum square tubing will be cut and welded to the open rectangular box shape desired. A flap also made from aluminum sheet will be made for the purpose of feeding the anodes into the press machine. All the cutting and welding of the aluminum sheets and tubing will be handled by the machine shop at FAMU-FSU College of Engineering. Holes will be drilled in the frame to be able to attach major components of the coating machine such as: the hopper, springs of the meshes, plexiglass, hinges, and adjustable plate.

2.4 Procurement

Since December of 2014, procurement of all necessary components has begun. Distributors and companies have been contacted throughout the weeks for quotes, purchases, and shipments of parts. Six components of the coating machine had been ordered as of the first week of December 2014. The square aluminum tubing of the custom frame has been ordered. A kilogram of micro-carbon beads, which have similar surface properties of the stabilized lithium metal powder, were ordered and are expected to arrive within the next two-weeks. The conveyor belt that was originally to be purchased from Dorner is now going to have to be constructed by the team. The quote given to our representative exceeded the allotted budget given to the project. The micromeshes have been ordered from Grainger Industrial supplier. A total of 3 varying mesh sizes have been ordered. The microcontroller that will communicate with the electrical components of the coating machine is in possession of the group as of current. Dr. Zheng has provided the group with a press machine with sufficient accuracy and power to coat the anodes with SLMP. The only components that are still in the process of the ordering are electrical components, which are scheduled to be completed by January 19th, as seen in the Gantt chart found below in figure 2.

3 Methodology

The design process and construction of the prototype machine requires a vast amount of research, manufacturing, construction, testing, and analysis. This overall process with take a significant amount of time and as such will need to broken down into tasks and mile stones. Our schedule breakdown can be found below in section 3.1 along with figures and tables with further explanation.

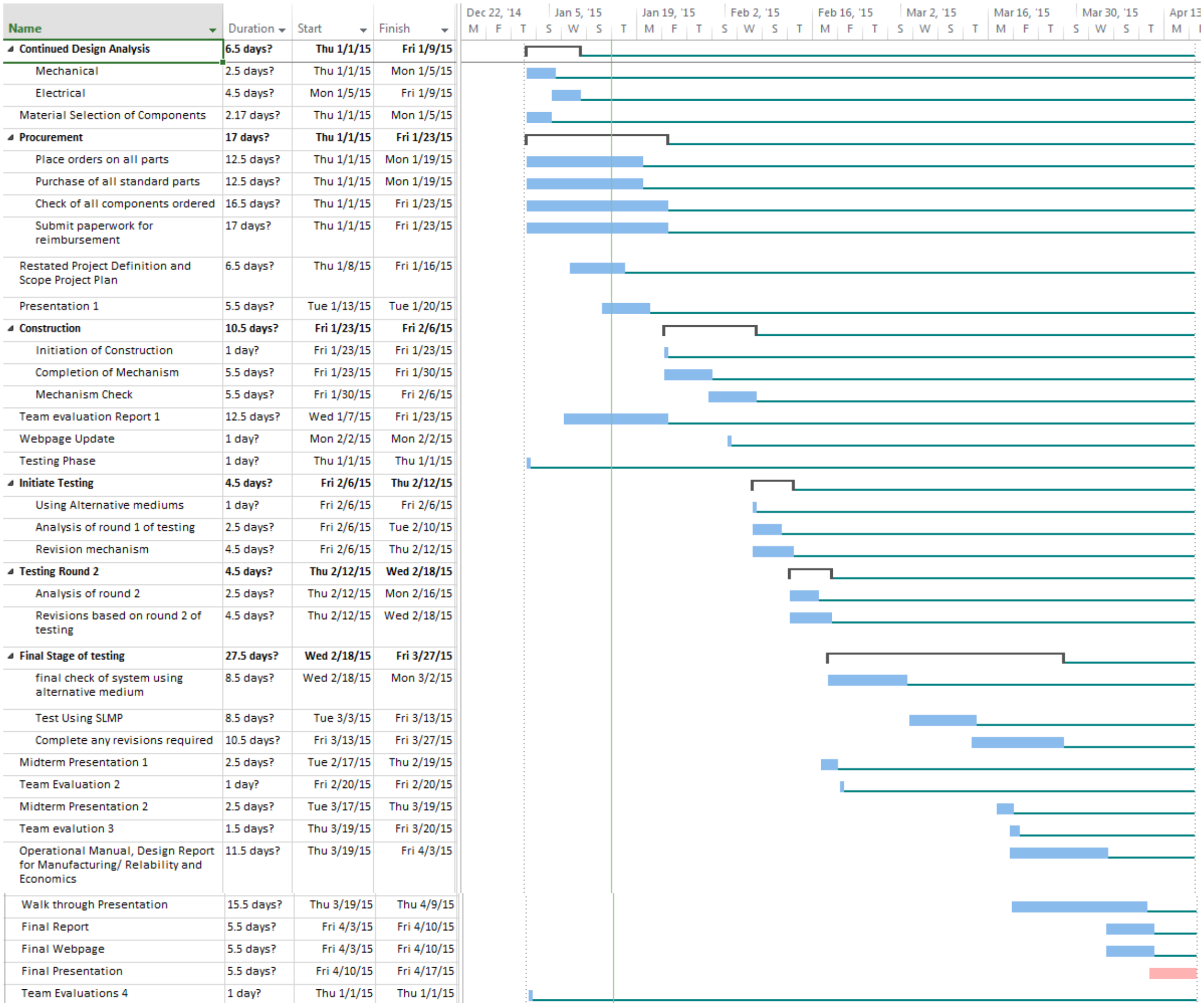
Another portion of our project that will need to planned out and scheduled will be programming of certain components and user interfaces. Our prototype machine will have a programmable logic controller that will be utilized to allow a user to input the desired values.

3.1 Schedule

To continue the progress of the prototype machine that will uniformly coat an electrode with stabilized lithium metal powder a strict schedule must be adhered to. Below in figure 2 is a Gantt chart breakdown of all of the tasks and milestones required to fulfil our goal. Many of the tasks will be dependent on precedent work, while others will grow upon one another from this point forward. Typically major tasks will be given a 7-day period for completion. For Milestones the time period can range from a 1-day to 17-day period. The time limit assigned is based on the amount of research, analysis, and labor that we as a team have deemed necessary for each task.

3.2 Resource Allocation

Resource Allocation has been divided amongst the team equally. Each member will be required to put in a minimum of 1,100 hours of work into this project. These hours are divided throughout the spring semester as to minimize the burden on the team. Each team member will have time to rest in between assigned tasks to be fair and to ensure efficiency and productivity. The detailed division of labor can be found below in table 1.



Name	Duration	Start	Finish
Continued Design Analysis	**6.5 days?**	**Thu 1/1/15**	**Fri 1/9/15**
Mechanical	2.5 days?	Thu 1/1/15	Mon 1/5/15
Electrical	4.5 days?	Mon 1/5/15	Fri 1/9/15
Material Selection of Components	2.17 days?	Thu 1/1/15	Mon 1/5/15
Procurement	**17 days?**	**Thu 1/1/15**	**Fri 1/23/15**
Place orders on all parts	12.5 days?	Thu 1/1/15	Mon 1/19/15
Purchase of all standard parts	12.5 days?	Thu 1/1/15	Mon 1/19/15
Check of all components ordered	16.5 days?	Thu 1/1/15	Fri 1/23/15
Submit paperwork for reimbursement	17 days?	Thu 1/1/15	Fri 1/23/15
Restated Project Definition and Scope Project Plan	6.5 days?	Thu 1/8/15	Fri 1/16/15
Presentation 1	5.5 days?	Tue 1/13/15	Tue 1/20/15
Construction	**10.5 days?**	**Fri 1/23/15**	**Fri 2/6/15**
Initiation of Construction	1 day?	Fri 1/23/15	Fri 1/23/15
Completion of Mechanism	5.5 days?	Fri 1/23/15	Fri 1/30/15
Mechanism Check	5.5 days?	Fri 1/30/15	Fri 2/6/15
Team evaluation Report 1	12.5 days?	Wed 1/7/15	Fri 1/23/15
Webpage Update	1 day?	Mon 2/2/15	Mon 2/2/15
Testing Phase	1 day?	Thu 1/1/15	Thu 1/1/15
Initiate Testing	**4.5 days?**	**Fri 2/6/15**	**Thu 2/12/15**
Using Alternative mediums	1 day?	Fri 2/6/15	Fri 2/6/15
Analysis of round 1 of testing	2.5 days?	Fri 2/6/15	Tue 2/10/15
Revision mechanism	4.5 days?	Fri 2/6/15	Thu 2/12/15
Testing Round 2	**4.5 days?**	**Thu 2/12/15**	**Wed 2/18/15**
Analysis of round 2	2.5 days?	Thu 2/12/15	Mon 2/16/15
Revisions based on round 2 of testing	4.5 days?	Thu 2/12/15	Wed 2/18/15
Final Stage of testing	**27.5 days?**	**Wed 2/18/15**	**Fri 3/27/15**
final check of system using alternative medium	8.5 days?	Wed 2/18/15	Mon 3/2/15
Test Using SLMP	8.5 days?	Tue 3/3/15	Fri 3/13/15
Complete any revisions required	10.5 days?	Fri 3/13/15	Fri 3/27/15
Midterm Presentation 1	2.5 days?	Tue 2/17/15	Thu 2/19/15
Team Evaluation 2	1 day?	Fri 2/20/15	Fri 2/20/15
Midterm Presentation 2	2.5 days?	Tue 3/17/15	Thu 3/19/15
Team evalution 3	1.5 days?	Thu 3/19/15	Fri 3/20/15
Operational Manual, Design Report for Manufacturing/ Relability and Economics	11.5 days?	Thu 3/19/15	Fri 4/3/15
Walk through Presentation	15.5 days?	Thu 3/19/15	Thu 4/9/15
Final Report	5.5 days?	Fri 4/3/15	Fri 4/10/15
Final Webpage	5.5 days?	Fri 4/3/15	Fri 4/10/15
Final Presentation	5.5 days?	Fri 4/10/15	Fri 4/17/15
Team Evaluations 4	1 day?	Thu 1/1/15	Thu 1/1/15

Figure 2. Detailed Gantt Chart depicting the spring semester schedule

Table 1. Resource Allocation Table which details the schedule breakdown into what team members are responsible such as milestones as well as the total hours spent on the project this spring semester.

Task/ Milestone	Hours/Days Need to Complete	Team Members					
		Marcos Leon	John Magner	Vannesa Palomo	Maria Sanchez	John Shaw	Benjamin Tinsley
Continued Design Analysis	6.5 days	X	X	X	X	X	X
Mechanical	2.5 days			X		X	
Electrical	4.5 days		X		X		
Material Selection of Components	6.5 days	X		X			
Procurement	17 days	X		X		X	
Place orders on all parts	12.5 days	X		X			
Purchase of all standard parts	12.5 days	X	X	X		X	
Check of all components ordered	16.5 days			X		X	
Submit paperwork for reimbursement	17 days	X	X				
Restated Project Definition and Scope Project Plan	6.5 days	X	X	X	X	X	X
Presentation 1	5.5 days		X		X		
Construction	10.5 days	X	X	X	X	X	X
Initiation of Construction	1 day				X		X
Completion of Mechanism	5.5 days	X	X	X	X	X	X
Mechanism Check	5.5 days	X	X	X	X	X	X
Team evaluation Report 1	12.5 days	X	X	X	X	X	X
Webpage Update	1 day						X
Testing Phase	1 day				X	X	
Initiate Testing	4.5 days	X	X	X	X	X	X
Analysis of round 1 of testing	2.5 days	X	X				
Revision mechanism	4.5 days			X	X		
Testing Round 2	4.5 days		X				X
Analysis of round 2	2.5 days	X			X		
Revisions based on round 2 of testing	4.5 days					X	X
Final Stage of testing	1 day	X	X	X	X	X	X
Final check of system using alternative medium	8.5 days	X	X	X	X	X	X
Test Using SLMP	8.5 days	X	X	X	X	X	X
Complete any revisions required	10.5 days	X	X	X	X	X	X
Midterm Presentation 1	2.5 days	X	X	X	X	X	X
Team Evaluation 2	1 day	X	X	X	X	X	X
Midterm Presentation 2	2.5 days	X	X	X	X	X	X
Team evaluation 3	1.5 days	X	X	X	X	X	X
Operational Manual, Design Report for Manufacturing/ Reliability and Economics	11.5 days	X	X	X	X	X	X
Walk through Presentation	15.5 days	X	X	X	X	X	X
Final Report	5.5 days	X	X	X	X	X	X
Final Webpage	5.5 days	X	X	X	X	X	X
Final Presentation	5.5 days	X	X	X	X	X	X
Team Evaluations 4	1 day	X	X	X	X	X	X
Number of tasks to Complete		28	27	27	27	27	24
Total Amount of Time Spent on Task/Milestone		1,600 Hours	1,428 Hours	5,304 Hours	1,768 Hours	1,488 Hours	1,144 Hours

4 Lessons/Challenges

During this project we have faced much adversity and are continuing to learn more about the project, each other, and how to work as a team. This project is very different from any other group project the team has worked on before. Since we are trying to construct a machine that has never been manufactured before there is no way of knowing the resulting outcome. The fact that this is an original concept created a challenge as to whether or not the best design for our objective was chosen. Through this process we have learned how to work as a team, coming up with many different design ideas.

A challenge that we have been facing is our budget, finding the appropriate equipment, and whether that equipment is within our allotted budget. For example, when selecting the correct type of conveyor belt our budget was a major deciding factor. We had been looking into buying a Dorner conveyor belt instead of building one for it would have given us more time for the testing phase, but when the quote was received it was determined that it exceeded our budgetary limits. Also many other components that we thought could help automate the machine were left out due to budget constrictions. We have learned that when planning a design we need to think more in depth about how we are going to allocate our money to make sure that we can make the best possible design without exceeding our budget. Also since we are making a custom machine ordering parts has been very difficult, such as finding properly sized meshes and funnels.

One of the most important lessons the group has learned was time management. This project requires a significant amount of time to be dedicated and with every member having a full schedule in addition to this project it has become hard to find period of time that coincide to meet and work together. However as time has progressed, we have learnt to manage our time much better and have improved communications by delegating jobs to distribute the work load. By trusting our team we learned that we don’t all have to be present for one of us to work the project and to be there for each other if one of us needs additional help.

5 Conclusions

The final design of our SLMP Coating Machine will essentially include a conveyor belt which moves an electrode under a SLMP dispersion system 10 times to evenly coat it’s surface. Actuators will be connected to a series of meshes which will vibrate them at different frequencies controlled by input voltages. When these meshes are being vibrated SLMP will then begin flowing at a steady rate. Once the coating process is complete the actuators will turn off stopping the flow of SLMP and the electrode will be ready to have the SLMP pressed onto it. Since this machine uses a dry method of coating there will be no drying time allowing for the SLMP to be immediately pressed.

The reason we decided to choose this design as our final design is because it is satisfies all of our requirements being safe, affordable, easy to use, and will satisfy the dispersion constraints of coating a uniform layer of SLMP of varying size in a time efficient manner. Also this is one of the simpler designs generated which allows for the machine to be built and programmed quicker, resulting in possible testing sooner. The testing process is now one of the most important aspects of this project since this is a prototype machine. Testing will require a large amount of time because, even with advanced flow rate calculations it is very hard to predict exactly what the flow rate until testing is done and time will be needed to allow for adjustments to be made if necessary. Another advantage of our design is that it allows for adjustments to be made and for additional components to be added if necessary to make the machine more efficient or automated. Our future work will include assembling our design and then beginning to testing of flow rates, mesh sizes, funnels sizes, motor speeds, power distribution, actuator frequencies, and program debugging.

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