Dipping Coating Machine

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STATEMENT OF CANDIDATE

I, William Bailes, declare that this report, submitted as part of the requirement for the award of Bachelor of Engineering (Honours) in the Department of Electronic Engineering, Macquarie University, is entirely my own work unless otherwise referenced or acknowledged. This document has not been submitted for qualification or assessment at any other Academic Institution.

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ABSTRACT

Conventional dipping techniques for components are based around submerging and removal from the liquor solely in the vertical plane. The project sought to confirm if improvement in film thickness and quality could be achieved through adoption of alternative dipping strategies including involving changes in speed, angularity and rotation to improve film thickness and uniformity.

Two new designs of dipping machines were developed, one around a robotic arm submersion technique and the other around vertical linear travel submersion system and comparison made against convention dipping machines available in the University Laboratory.

The prototype machines showed promise over the current dipping machine technology available in the lab at University.

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1. Introduction

Dipping and spin coating are used for coating Semiconductors for manufacturing and/or development. The Dipping Machine that this project outlines changes how the object gets dipped into the solutions. By utilising other forms of robotics, it gives greater freedom for moving the Semiconductor in different ways from the conventional down and up machines. The main objective, for this project, is to develop a method that can simply change the thickness of the coat on the surface through a simple user interface. The main function is to establish if rotations can influence film thickness and uniformity on the Semiconductor or object. Along with the rotation of the object, other functions of dipping will also be tried to establish the differences in the coating.

To check the machine is unique and different from the machines currently available on the market, experiments will be performed to find whether the coating on the object can be changed. Many of the machines, on the market, are the simple down and up dipping coaters, others are spin coaters which spin off the liquid. The spin coater machines waste large amounts of the coating liquor during spinning. Whilst there is some potential to capture the material spun off, there is highly likelihood that it will be contaminated. Thus, a dip coater was chosen over a spin coater for this experiment.

The desire outcome is to create a machine who's capability can be altered to enable performance to be assessed against changing factors with respect to coat thickness and the even spread of the material over the surface. The resultant capability to change the film thickness coverage may not be achievable solely through utilizing this technique and consideration may need to be given to an alternative strategy for covering toward the finish of the undertaking. On the off-chance that the machine can or cannot change the thickness to the clients' needs, then the result has been met ie; Can a turn coater machine be developed which can control the thickness of covering through controlling of speed and time?

The expectations would be a machine that could perform investigations into the thickness of coat, evenness of coat together with the after-effects of the analyses. In the event that it is conceivable to have a machine to change the thickness, the machine is a model unit characterised to discover the variances associated with changes in the thickness of the coat and uniformity of coating. This machine may prove less reliable to guarantee that all conceivable outcomes can be trialled with the trials primarily focused to confirm the strategies which will best change the film thickness.

Project Scope and Specification

After developing some ideas with my Manager, it was decided that the dip technique was the best option to explore with changing the thickness of the coat. The project adopted usage of dipping machine techniques to submerge the object to be coated into a beaker of coating fluid. For this, it is proposed the use of a six (6) axis robotic arm to undertake this test. This approach was selected over a five (5) axis robotic arm or others because it enabled descent and ascent at specific angles, as well as vertically. This can permit the dipping at any trajectory and path desired whilst carrying out the test.

There are two (2) parts of this undertaking; first is the layout and creation of a machine which can embrace such a combinations of dipping philosophies with the second part of this assignment, dedicated coating quality and texture to selected components. The subsequent is a listing of processes that be can be executed under this project.

- Machine/Robotic arm
    - Design of the machine:

      It was envisaged that the design of the machine would take the longest time to complete with design embracing the engineering of all the parts of the arm, control system and ancillaries needed to complete this project. Many of the parts may need to be custom-made for this project, which increases the time needed to complete the build. It was of concern that many of the parts may not be readily available locally and thus sourcing times traveling from overseas suppliers needed to be factored in..

    - Construct of the machine:

      This included construction/assembly together with programming of the machine to carry out the experiment. Construction would become one of the more important parts of the project because without the machine being both suitably robust and offering high degree of flexibility in operation, the experiment cannot be performed. Machine integrity and operability proved to be important considerations to ensure functionality of design was achieved.

    - Testing machine:

      Functional testing of the machine was needed during construction to confirm the design concepts together with functional operation. Once assembly was completed, software debugging was undertaken to ensure all bugs were fixed before the experiment.

- Experiment
    - Determine coating methods using machine:

      This is to determine the types of functions and dipping technique to be used to see if the coat would change and how. Each function would be slightly different to see how the changes are caused.

    - Test using these methods

      By using the test functions determined above, the machine performs prescribed tests with output data further analysed to determine how coating had been achieved. These will be the samples.

- Measure the thickness and analyse coat

  The machine functioned samples will be analysed for slight differences to see how the coat changes with the different functions. The samples will be analysed against other samples with each different dipping function.

Outcomes and Impact

There are many different milestones and goals which will make this project achievable, but the overall goal will be to have a machine that can reset the thickness of the coat on the surface of a material or component. The following is a list of milestones that which are envisaged to achieve successful completion of this project.

1. ***determine the settings***

The goal here will be to determine how the machine will be set and how the machine will move. This may have an impact on the next milestones. Settings may include angle of entry, angle of exit, speed of rotation and other functions. The setting will aim to provide thickness of coat as well as speed of dip and other settings

2. ***determine the movement of the machine***

A six (6) axis robotic arm can move in multiple ways but the movement of the machine is a function of its settings. The machine actual movement is determined by these settings and the interaction of software with arm design.

3. ***Design the prototype of the machine***

The design of the machine may not depend solely on the settings of the machine, consideration needs to be given to component size to be coated. This milestone will need to be understood before construction or any testing can begin. This will determine the construction of the machine and how it is assembled. Some modifications may need to be made during the construction and the testing to ensure that the machine can perform the determined settings.

4. ***Construct the prototype***

Constructions will commence once the design has been finished. Some of the design may have a problem which are unforeseen at the outset and will need to be addressed through redesign. The construction will need to be completed before any testing begins. Some modifications may need to be made during the construction and the testing to ensure that the machine can perform the determined settings.

5. ***Testing the prototype***

After the robotic arm is finished it will go through some testing to ensure that the machine can achieve the determined settings. This testing will also determine how control of the arm is going.

6. ***Conduct experiments for changing thicknesses***

Set experiments using the settings to try and determine the change in thicknesses of the coat.

After the milestones, there are some secondary level milestones that will improve the operation of the machine but have no connection to the project or the experiment. The following are the secondary milestones.

1. ***Wirelessly controlled***

By adding a Bluetooth or Wi-Fi module, the machine can be wireless controlled by an App or other interface. This milestone is not essential to conduct the experiment but will help the machine operation in the future.

2. ***Web access controlled***

With the addition of web access, the machine can be controlled from any computer connected to the same local network. The machine would need to use Wi-fi or Ethernet modules to connect the machine to the local network. The machine with these modules within it, will allow it to host a server that hosts a web interface for the machine. There are positives and negatives with connecting the machine to a network like this. A positive would be that it can be access from any machine and a negative would be that it would be unsecure for the amount of time that would be developing for it.

2. Personal interest

Researched that had been done before the project was offed was with a spin controller. I knew what was involved and the struggles that will need to be overcome for this project. This previous researched allow me want to do this project over all others.

Using parts from HDD, I have created a spinner that spins a disk, coating PCBs or other flat things in a somewhat even coat of liquid. It is also can be used as a magnetic stirrer by using the magnet from the HDD. The unit uses the brushless motor from HDD to spin the disk. Since the unit does not need to have a lot of torque, this motor is perfect as it can spin at high speeds (depends on motor driver and HDD type).

For more information, see: http://tinkersprojects.com/project/2-1-spinner-hdd/

Figure 2.1 spin coater

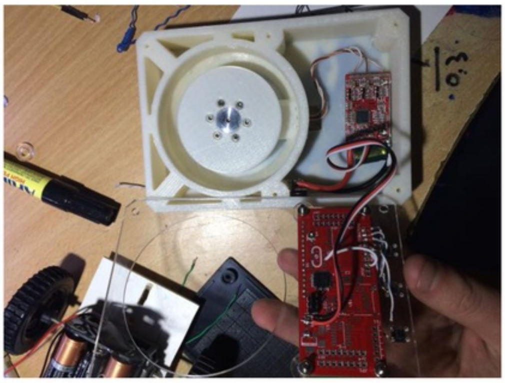

Figure 2.2 spin coater controller

3. Background

Can a spin coater machine be designed that can manage the thickness of coating by controlling the velocity and time? A spin and dip coaters are used in integrated circuit development and manufacturing to coat the wafers with a substance which could be for doping or etching. There are many unique forms of substance that can be used to coat the material for various processes and there are many machines already available that do the same thing. All the machine simply performs the down, dip and up. Other are spin coaters that spin the wafer at high speeds and the substance is dripped into the middle. By using centrifugal forces, the substance is forced outwards across the wafer, coating it in the process.

All the machine on the marked used this dipping or spinning but each machine is different in either the size or user interface. Some of the interface work well and are easy to use but others are not.

Figure 3.1

Displacement: 150 mm

Speed: 0.01-150 mm/min

Figure 3.2

Stroke length: Maximum 457mm

Delay Time: 1-60 seconds

Figure 3.3

Speed: 1-12,000 rpm

Substrate diameter: 260mm round

Acceleration: 30,000 rpm/sec

Figure 3.4

Speed: 0.1-1000 mm/minute

All the current products on the market that were found, all do the same in-terms of movement and settings. There may be some differences between them such as how the object attaches or how the coat is applied. The settings throughout these machines only really changes the speed and time of coating.

The current machine being used at Macquarie University is one of these simple machines with a simple but annoying user interface. This machine uses a geared stepper motor with metal wire to pull a block of brass up or down. This can also be over-ridden with a hand crank on the side connected to the stepper motor's axle. The user interface is simple but not user friendly, if we were computers it would be great. The problem comes when you dip the object then forget to set the up mode before running the machine again, this with cause the machine to continue going down and could damage the object if it hits the bottom.

Figure 3.5 Front panel of current machine

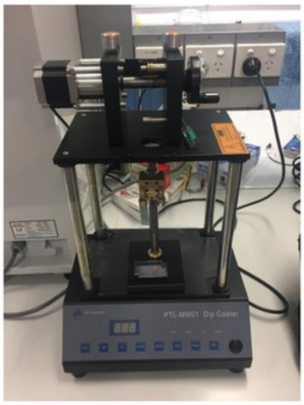

Figure 3.6 Current machine

This project will determine if a machine can be developed where parameters such as thickness of the substance on the material can be inputted as a variable whilst maintaining uniformity of coat thickness across the surface. If there no correlation between how the object gets dipped, then a simple user interface would be better than the current machine.

Literature Review

Over the years there has been many articles about adopting the dipping and spin coaters to gain improvements from them. Here are a few that was found relating to this project:

Physics and Applications of DIP Coating and Spin Coating

The two different ways for coating a "slab and cylinders" [6] are spin coating and dip coating. This journal explains how these coating techniques can be used to uniformly coat a thin film on the surface with liquid. The different techniques of applying the coat in different ways, different techniques need to be adopted to control both uniformity of thin film and thickness of the film.

Dip coating is the older technique of the two because it is far less complicated and simpler to understand the workings. This method of coating is often less used in precision coating circumstances than other methods. This journal describes techniques to improve the evenness of the thin film together with thickness of the coat. It explained that the faster the object was withdrawn from the liquid bath, the thicker the coat is deposited on the surface. The drying of the film is the second most important issues which is a function of liquid flow on the surface on the object. This insures the combination of liquid flow across the object and subsequent rapidness of drying.

Spin coating is the more recent development to maintain uniformity of the thin coating film across the surface. This is a coater that spins the surface where the liquid is applied in the middle. From the source, the liquid starts spreading to the edge of the slab using viscous and centrifugal forces, coating it with a uniform thin film. The extra gets spun off the and captured in a container

Crack-Free, Thick Ceramic Coating Films via Non-Repetitive Dip-Coating Using Polyvinylpyrrolidone as Stress-Relaxing Agent

This journal make greater reference to the films themselves and how they react under different conditions than the techniques of applying them to the surface. Throughout the journal, they referenced using the dipping technique to coat the film across the surface. Alkoxide-acetate solution containing PolyVinylpyrrolidone, was used to prepare PZT and $BaTiO_3$ by using the dip coating technique. It was noted that PolyVinylPyrrolidone increased the thickness and suppressed crack during heating. With some films, it was seen that there was a decrease in tensile stress when heat treated. Within this demonstration, the dipping method used to coat

How to exploit the full potential of the dip-coating process to better control film formation

Dip Coating is a low-cost method of coating thin layers from a bath of chemical solution. This process is waste free and much easier to scale up for manufacturing. The dipping method "offers good control on thickness" [5] due to the accurate control of the speed, withdrawal from the liquid and much simpler than other control method. The accurate withdrawing speed helps to control the final thickness. Thickness from 1nm to 1μm coated across the surface of the object can be achieved.

"The full potential of Dip-Coating has not yet been fully been explored or exploited." This method has many different capabilities including nano-casting, nano-composites, nano-fluidics and optics.

4. Approach and Methodology

After reviewing a lot of machines on the market and seeing that they can only dip down and up, it was decided to create a free moving dipping machine. This created the idea of making a robotic arm to dip samples into a solution. A six (6) axis robotic arm can emulate the current machines to create a standard of testing then can change the movements to rotate and move the sample if different ways compared to the current machine. If there are issues with this the machine will change to a simple dipping machine with added features.

The first and main motion/function that is going to be tested is the rotation of the sample as it is dipped. It is hoped that the solution will mix as the sample rotates and spread the coat evenly across the surface. A robotic arm would work to allow for this movement and a simple modulating machine could also achieve this as well.

Other motion/function are secondary from the rotation. These motion/function that is going to be tested are different motions for entering and exiting the solutions as the sample is dipped. This can include different angles together with different acceleration functions as its exits the solutions. The robotic arm will be able to perform most of these functions while a simple machine is much more limited to the dipping functions that it can perform.

Project costs

It is undetermined if this project will achieve the goal of been able to input a thickness into a machine and for it to product that within limits. There have been studies that have done similar with good results but with a different aim. Other studies have proved that the faster that the machine pulls away from the liquid the thicker the coat on the surface of the object.

All the item needed are outlined in the table below with cost and description. The budget for the project will be $400 and cost controls will be maintained to ensure cost come in within those nominated.

QUANTITY	DESCRIPTION OF GOODS	$	TOTAL $
1	C-EUC0603K 0.1uF	0.05 USD	0.05 USD
3	R-EU_R0805 1.8k	0.04 USD	0.12 USD
3	R-EU_R0805 10K	0.04 USD	0.12 USD
1	R-TRIMMCVR42A	0.04 USD	0.04 USD
1	RESONATOR16MHZ	0.11 USD	0.11 USD
4	R-EU_R0805 1k	0.04 USD	0.16 USD
1	V_REG_LM1117SOT223	0.17 USD	0.17 USD
3	R-EU_R0805 3.3k	0.04 USD	0.12 USD
4	4051D	0.06 USD	0.24 USD
2	CAP_POLD	0.1 USD	0.20 USD
1	V_REG_LM1117SOT223	0.18 USD	0.18 USD
1	ATMEGA328P_TQFP	0.98 USD	0.98 USD
1	CH340G	0.29 USD	0.29 USD
1	MICROSD holder	0.15 USD	0.15 USD
1	SWITCH-MOMENTARY-2SMD	0.03 USD	0.03 USD
1	16x2 LCD	0.82 USD	0.82 USD
2	male pin header	0.03 USD	0.06 USD
2	female pin header	0.05 USD	0.10 USD

4	female pin header stackable	0.41 USD	1.64 USD
7	28byj-48	0.52 USD	3.12 USD
6	a4988	0.67 USD	4.02 USD
1.5KG	filament	7.45 USD	11.18 USD
20	M3 screws	0.03 USD	0.60 USD
40	M3 screws	0.02 USD	0.60 USD
30	M3 screws	0.02 USD	0.45 USD
50	M3 washers	0.02 USD	0.75 USD
50	M3 nuts	0.02 USD	0.75 USD
50	M3 inserts	0.02 USD	0.65 USD
2	200mm 10mm hardened round shaft	1.59 USD	3.18 USD
2	10mm linear bearing	5.67 USD	11.34 USD
1	8 mm lead screw	5.67 USD	5.67 USD
1	8 mm lead screw nut	1.34 USD	1.34 USD
1	5mm to 8mm coupler	3.2 USD	3.20 USD
2	608 bearing	1.5 USD	3.00 USD
2	limit switches	1 USD	2.00 USD
1	encoder	1.11 USD	1.11 USD
1	Micro SD card	14.95 AUD	14.95AUD
1	300x600x6mm acrylic sheet	32.00 AUD	32.00 AUD
20	PCB	0.5 USD	10 USD
	UPS shipping cost		45.00 USD
	PayPal charge		7.60 USD

TOTAL USD :	121.14
TOTAL AUD :	46.95
TOTAL :	204.66

Table 4.1 Project costs

Project Costs Evaluation

The cost of the project is below the total budget for the project of $400. Since the parts were supplied by mostly one supplier, the cost got lower towards the end of the project, it required more parts which need to be purchased from a different supplier. This raised the cost of the project a bit but still below the max budgeted amount of $400.

Project Timeline

Below is a Gantt Chart with the estimated times for starting and completing each task with more details/description under the table. All tasks are split into 2 groups; Designing and Construction of the dipping machine and Perform/undertake experiment.

Num.	Tasks	Weeks												
	Designing and construction of the dipping machine arm	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Designing of the machine	■ ×	■ ×	■ ×	■ ×	×	×	×	×					
2	Making of the machine		■	■ ×	■ ×	■ ×	■ ×	×	×					
3	Programming of the machine				■	■ ×	■	■	■ ×	×	×			
4	Debugging and testing of the machine				■	■	■	■	■ ×	×	×			
	Preform/undertake experiment	1	2	3	4	5	6	7	8	9	10	11	12	13
1	Set up experiment								■	■	×			
2	Preform/undertake experiment									■	■ **x**	■ ×	×	
3	Analyse results of experiment										■	■ ×	■ ×	
4	Write report	■	■		×	×	■	■	■		×	■ ×	■ ×	■ ×
5	Write in log book	■ ×	■ ×	■ ×	■ ×	■ ×	■ ×	■ ×	■ ×	■ ×	■ ×	■ ×	■ ×	■ ×

Table 4.2 Gantt chart

Note: Blue = proposed planned time to complete tasks, × = actual time spent

Designing and construction of machine

Designing of the machine

The design of the machine may not depend on the setting of the machine besides from the size. This milestone will need to be achieved before construction or any testing can begin. This will determine the construction of the machine and how it is assembled. Some modifications may need to be made during the construction and the testing to ensure that the machine can perform the determined settings.

Making of the machine

Constructions will commence when the design has been finished for that part. Some of the design may have a problem which were unseen and will need to be addressed during initial testing phase, the construction will need to be finalised before any full operational testing can begin. Some modifications may need to be made during the construction phase with further testing to ensure that the machine meets design targets.

Programming of the machine

Programming may take a while to achieve 100% operation with full method checking to validate operation. After completion of the machine, the full program will be uploaded ahead of testing. A series of programme tests will be developed to ratify the operation of the units and catalogue test curves and settings.

Debugging and testing of the machine

Debugging all the errors within the design of the machine will ensure that the arm performs to it intended level. After the machine is finished, its operation will be validated to ensure that it achieves the determined design settings. Where changes are found necessary as part of the functional testing, documentation needs to be upgraded accordingly.

Preform/undertake experiment

Set up experiment

From the capabilities from the arm's movement will determine how the experiment will be carried out. The movement of the arm will allow the object to move differently through the coating substance. From the movements, arm characteristics can then be determined against how the arm will move to achieve the determined path.

Perform/undertake experiment

After determining and calculating the paths of movement, the machine can perform it multiple times gather the relative data that can determine if it is possible to achieve changing the thickness of coats on an object.

Analysing results of experiment

This will be the part where it is determined if it is possible to change the thickness of the coat with a determined path. If it is possible then it will be determining how the machine will need to move to achieve this, although all six (6) axis may not be need.

Write report

Write a report to show the findings and confirm if it is possible to change the thickness of coat on an object. Also write about the construction of the machine.

Project Timeline Evaluation

The project was on track up until the parts need to be ordered. It took more time than anticipated for proccessing and shipping the parts, this put the whole project back about 2 weeks. One of the parts was either the wrong part or incorrectly described, this caused problems with other parts and needed to get remade. This problem put the project back another 1-2 weeks and had a ripple effect on the future of the project. This reduded the amount of time for programming, debugging and experimenting. When the time schedule was being developed, more time should have been alotted to shipping and parts sourcing. The impact was that the backend of the project was severely compressed as seen on the above time schedules.

Risk Assessment

Within this experiment, there with be lots of different risks involved with it. Each risk will need to be individually assessed for its safety and impact. A risk that is deemed excessive and thus unsafe will need a Safety Plan to manage that risk to bring it within acceptable risk levels. Each risk has been given a Risk Score from 1, being Low, to 10, being Extreme, any risk with a score above 3 will need a management/control plan to reduce that risk to 3 or below. This are the risk that are proposed but there will be more when the project/experiment is being carried out, the risk table will be consistory updated to manage unseen and new risks.

RISK IDENTIFICATION		RISK ASSESSMENT		RISK CONTROL
NO.	What harm can happen to people or equipment	Risk Score (1-10)	List any Control Measures already implemented	Describe what can be done to reduce the harm
1	machine spilling beaker	5	None	Have the machine sense if it hits the beaker and have an anti-spill for the beaker
2	Electricity	2	none	Insure that the machine can comply with the standard
3	Use of lab	2	University already have in place safety measures to ensure safe operation and lowing risks	Use PPE at all time when using Wear shoes always
4	Harmful substances	2	University already have in place regulations for handling such substances and lowing risks	Use PPE at all time when using Follow instructions to safely handle Read MSDS attached to all substances

Table 4.3 Risk Assessment

5. Robotic arm dipping machine

The idea of making a robotic arm came to try different dipping methods besides from the down and up motion. Different dipping approaches such as head rotation, angled object and post dipping functions are to be considered. This is to discover the impact of these on the coat and the surface.

Ideas and Brainstorming

That machine is coming together in parts. There was a few different designs that were thought of. The designs below were the two that were chosen to further the design to see which would be the best to construct the arm.

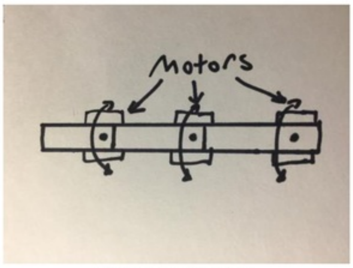

Figure 5.1 Design 1

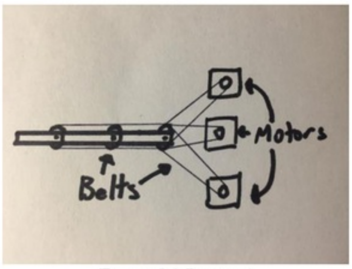

Figure 5.2 Design 2

Design 1

This design, shown in Figure 5.1, requires the motors to be integral parts of the arm which will increase the size and over-turning moments throughout each joint. This will require high torque motors that can integrated into the arm. A lot of robotic arms use this method to move the arm. This design will not allow the arm to move fast but will increase the smoothness of the arm operation, whilst reducing the clunky nature of the stepper motors.

Design 2

This design, shown in Figure 5.2, uses belts throughout the robotic arm to control each of the joints. This will make the arm smaller and with less weight. The base of the arm would be much bigger then Design 1 because of all the motors will be in the base and not in the arm itself. There will need to be a motor located on the end of the arm to provide for the rotation of the object.

Design 1 and Design 2

Both designs are just ideas and there may be a 3rd or 4th design to improve the working operations of the robotic arm. Each design has similarities between them, both designs use stepper motors to move each joint of the arm and angle sensor that will check the angle of the joint on start-up and during operation. The stepper motor drivers and most of the electronics will be the same because only the position of the motors and the overall design of the robotic arm will change but the robotic arm functionality will remain the same way.

The robotic arm will be placed on an Acrylic Base with levelling feet to ensure that the liquid is level, the robot will then know the angle on which to enter it. The user interface will be simple and will use buttons and a LCD as a readout to tell the user what to do.

The chosen design

Design 1 was the concept adopted with several material variations needed to attain the final arrangement to be used for the experiment. The arm will use a 5:1 gear ratio from the geared stepper motor. There will be an encoder within the larger gear for finding the position of the arm on start-up and checking where it has moved to. If there are problems with the encoder, a potentiometer will have adopted instead.

Before testing the arm, a smaller motor will replace the current holder on the slider on the current machine. This will show how the machine works and how the current machine can be improved. This test will give an insight into how the solutions liquid will attach on the sample. It will also show what controls will be needed to be created for the experiment.

If there any problems with the robotic arm and running out of time, the quickest solutions will be to create a machine like the current machine. This new machine can do many more functions including rotating downwards but less than the robotic arm. This will be enough to test some sample to discover if it is possible to change the coat. This machine will use a lead screw instead of a wire with linear bearings gliding along precision bar to complete the operation. The user interface will be simple with more functions and control than the current machine. It would also use the same base as the robotic arm and probably the same controller. At one or each end there will be limit switches for location of end travel points.

Robotic arm design

Base design

The base design is working well as is the base. It will need to be changed slightly to attain different functionality such as dipping in multiple different solutions. The design allows this to be changed to perform different experiments in the future. The anti-spill has not been 100% tested but can see it having problems if spilt as it has the potential to leak onto the electronics and damage the acrylic base. This will need to be addressed in the future. The vibrations from the motors, vibrate the solutions, this may be fixed with an anti-vibration mount for the beaker.

Arm design

The construction of the arm took a while to start due to organising the parts sourcing from overseas. The arm is constructed from 3D printed parts and works well as a prototype. The joins are a bit lose due the space between the teeth on the gears which makes the arm jolt a somewhat resulting in a less then smooth option. This will need to the addressed on the next generation of machine.

There were 3 prototypes for the arm, the first used a 5:1 gear ratio at each joint and an encoder within each gear for positioning. The sprung brush contactor for the encoders were problematic. To overcome this, the second design had the 5:1 gears negated with the steppers on a direct drive to the joint with a potentiometer. This did work but the steppers were skipping steps because it needed more torque and need the 5:1 reduction ratio. The potentiometer worked well so it was elected to mesh the two designs together to have the 5:1gear meshing and the potentiometers. This arm design proved successful and performs the best. The wires were going to be on the encoder as sliprings but since the its not getting used, the wires are going down the arm attached using cable ties and cable ties mounts.

Electronics

The same with the arms, the constructions of the electronics were delayed by the ordering and shipping of the parts. The PCBs were given to me for this project to try. The PLEX board give more flexibility than other Arduino development boards. The board has a LCD, SD and up to 32 inputs and outputs that will be required for this project. PLEX uses a ATMEGA328 which is the same as the Arduino UNO uses. The arm uses stepper motor to move the joints around and requires drivers to control them. These drivers are a HR4988 which requires 2 control pins to make the stepper step in either forwards or backwards. One pin is the directional and the other is the step, a pulse to the step pin will make the motor step in a direction dependent on the directional pin. If the directional pin is HIGH the motor will spin one way and if the directional pin is LOW then the motor will spin the other way.

Kinematics

The kinematics is one of the important parts of the program to get correct. The Equation 5.1 are the causations that need to be done to for the 2 main joints.

$$\mathrm{c} = \frac{\mathrm{x}^2 + \mathrm{y}^2 - \mathrm{DistancesA}^2 - \mathrm{DistancesB}^2}{2 * \mathrm{DistancesA} * \mathrm{DistancesB}}$$

$$\mathrm{s} = \sqrt{1 - \mathrm{c}^2}$$

$$JointB = \mathrm{atan2(s, c)}$$

$$\mathrm{k1} = \mathrm{DistancesA} + \mathrm{DistancesB} * \cos(JointB)$$

$$\mathrm{k2} = \mathrm{DistancesB} * \sin(JointB)$$

$$JointA = \mathrm{atan2(y, x)} - \mathrm{atan2(k2, k1)};$$

Equation 5.1 Kinematics

Program

Since the arm now uses potentiometer instead of the encoder, it has open other pins on the board that need to be used for the SD card. This allows the SD card to be used to program the arm to preform functions for the experiment. It has also simplified the program removing the calculations for each encoder of the arm and removing the function for rest to precisely know where each joint is angled.

The program for the electronics is almost finished because there are some positioning errors with the arm that need to be. The arm can work without this but it cannot travel to the correct position because of this error. The SD card hold all the programs and functions for the and is to easily program the arm to do anything that is need from the arm. The program could be programmed directly into main program on the ATMEGA328P but is not practical because then the program will need to be debugged.

Online programming tool

This online tool can be found (temporary) at http://test.bailes.com.au/uni-arm/.

This tool was made to assist in the programming of the robotic arm as seen in Figure 5.3. This tool is easy and simple to use to program the robot but will need to predetermine all the locations that the arm will been to be located after/before each command. Each command starts with a letter and ends before the next letter. Start by putting in the first locations and the setting for that location then click the "Add to program" button to add those commands to the right-side box. The left will then be clear to add the next set of commands. After each set of command line there will be placed a "G" to indicate to the robot to run the current settings. When all commands have been programmed in, then click the "Download Program" button to download and upload to SD card. The SD card will then be inserted into the robot to be run. All the commands are listed in the table below.

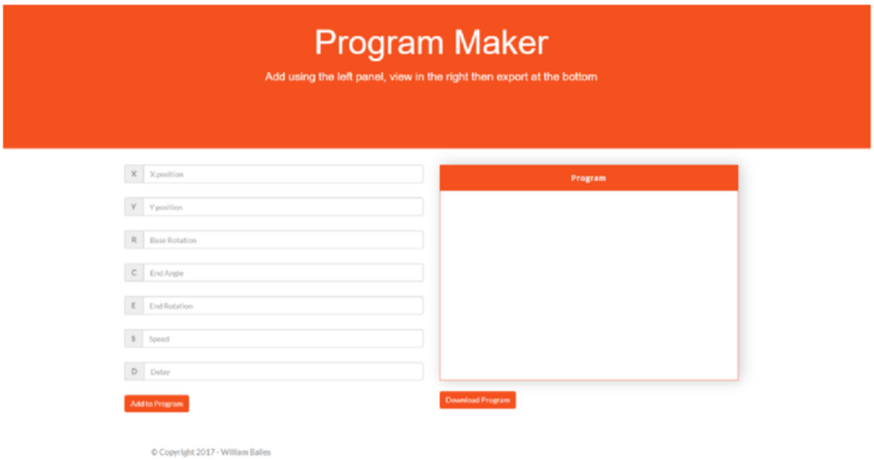

Figure 5.3 Online programming tool interface

Command	Settings
X	Set X position
Y	Set Y position
R	Set Base Rotation Positions
C	Set the robotic arms head at angle
E	Set the robotic arms head rotations speed
S	Set the speed of the robotic arm
D	Delay program without stopping the robotic arms head rotation
G	Run the current settings until robotic arm is at the set location

Table 5.1Programing commands

6. Other dipping machine designs

The concept is similar to the robotic arm unit and will provide different dipping methods besides from the traditional down and up motion but is limited to a few different motions such as head rotation and angled object. This is to discover the impact of these on the coat and the surface coverage. This dipping machine cannot move like a robotic arm but is much simpler and easier to control and program for the dipping tasks.

The base

The base design is done and is working well as the base. It will need to be changed a little for different functions, functions like dipping in multiple different solutions. The design allows this to be changed to preform different experiments in the future. The anti-spill has not been 100% tested but can see it having problems if spilt, leaking into the machine where the electronics is. This will need to be addressed in the future. The vibrations from the motors, vibrate the solutions, this may be fixed with an anti-vibration mount for the beaker.

The dipping arm

The construction of the arm took a while to start due to organising the part and them travelling to get here. The arm is constructed from 3D printed parts and works well as a prototype. The machine uses linear bearing to slide the overhanging up and down into the beaker which holds the liquid. On the arm where is another stepper motor to allow the sample to rotate around. A screw thread is used to pull and push the arm up and down allowing the arm to preform different functions. This dipping arm will not be able to perform as many different functions as the robotic arm but enough to find if there is a different in coats surface.

Electronics

The same with the arms, the constructions of the electronics were delayed by the late shipping of the parts. The PCBs were provided for this project to try. The PLEX board provide greater flexibility than other Arduino development boards. The board has a LCD, SD and up to 32 inputs and outputs that will be required for this project. PLEX uses a ATMEGA328 which is the same as the Arduino UNO uses. Stepper motors move the joints in the Arm require drivers to control them. The drivers selected were HR4988 which require 2 control pins to make the stepper step in either clockwise (forwards) or anti-clockwise (backwards) direction. One pin is the directional and the other is the step, a pulse to the step pin will make the motor step in a direction dependent on the directional pin. If the directional pin is HIGH, the motor will spin one direction and if the directional pin is LOW then the motor will spin the other direction.

The program

Everything function that the machine can do is programmed in. There are 2 main control functions, auto and manual. The auto function is to make using the machine easier, after entering all the settings that are required and selecting run, the machine will run using those settings. The auto function will dip down to a specified height then return to the starting point. The machine will restart itself every time to a limit switch. The manual function allows more control over the height because it does not get set. Selecting up or down allows the machine to move in that direction and does not need to be set back to a set point every time.

7. Experiment Procedure

To check the machine is unique and different from the machines on the market, it will perform some experiment to find out whether the coating on the object can be changed. Many of the machines on the market are the simple down and up dipping coaters, others are spin coaters which spin off the liquid. The spin coater machines waste lots of the coating liquid when it is spun off, some may be recoverable but would be contaminated. Therefore, a dip coater was chosen over a spin coater for this experiment.

The current machine

The current dip coater is a PTL-MM01 Dip Coater from MTI Corporation which coats a large amount by dipping the object into a beaker or some other liquid holding vessel. This machine will be used to create a standard which the experiment can conform to. While using the machine, it can be examined how it works and how that machine can be improved. A simple up and down will be performed to create this standard. Other students have been doing experiments with this machine and questions will/have been asked about the machine operation ability and functionality. They have also demonstrated how to use the machine and how they use it in their own research.

The sensors

There are two main different objects/semiconductors that will be dipped into the liquid and then tested. Both are sensors that are in a form of a capacitor and by connecting the two big pads connect to LCR meter, the sensor can determine the amount of nitrogen in water. This can also be reversed by knowing the environment where the sensor is, it can be determining different properties of the coats that visual inspection cannot be seen.

First of the two sensors is a PCB (printed circuit board) shown in Figure 7.1with tracks that create the capacitor. This PCB sensor has different sizes of tracks to create different values of capacitance or different amount of surface area with the coat can be on. The size of the tracks and the different spacing between them changes dependent of the sensor which will change the value of the capacitance on the sensor. This capacitance PCB, since it has been processed as a PCB by etching and coated with a tin coating to protect the copper tracks. The tin coat may have a slight difference with the coat because of how the copper is etched and the tin is applied. This means that the capacitance will be slightly different for every sensor. This may not matter depended of the application of the sensors but will need to be considered for this project. Because of this, this will not be the primary testing sensor for this project.

The second sensor is the same as the first but much smaller and using different materials and is shown in Figure 7.2. Unlike the PCB sensors using fiberglass as the base and copper as the tracks, this sensor uses semiconductor material/silicon as a base and gold as the tracks. This allows the sensor to be much smaller. The 2 gold pads are the connections point and the discoloured pad is the capacitor sensor area, this is similar to the PCB but much smaller. The discolouration comes from it being very small, the camera and the human eye see it as this way but closer examination, it is gold and black (silicon). The sensor has been etched simular to the PCB but much more accurately and unlike the PCB, there is no coating over the tracks to protect them. This sensor will be the one that will be mostly used for the experiment of this project.

Figure 7.1 PCB capacitor sensor

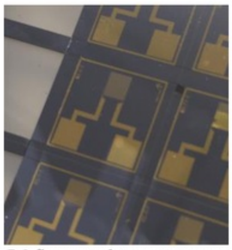

Figure 7.2 Semiconductor capacitor sensor

The sensor will be dipped into a solution that contacts a powder non-soluble polymer with Acrylic and Acetone. The Acrylic is used as a sticky substance and will aid the sticking of the polymer to the surface of the semiconductor or PC. This is a viscose fluid, so Acetone is added to the mix to lessen its viscosity. Over time, the Acetone will evaporate off from the mix resulting in it returning to the high viscosity liquid again and semiconductor after it has been dipped, to create the coat. This will require more Acetone to re-thin the liquid to allow the samples to be dipped. This will be hard to control due to the mount of evaporation from the liquid. To prevent this, the experiment will need to be performed quickly but safely. The safety part of the experiment cannot be avoided or minimalized. The sample will also be ordered and numbered in the order that they are dipped in to the solution.

Samples A – First samples

There are 2 main functions that going to be performed to seek whether these factions can improve the coat on the sensor. The first is the simple down, dip and up, the next is the head rotating while going down, dip and up. The others are different functions to see the impact on the of coatings against the different functions. The table below shows the different samples that will be done, after the tables is a description of each sample. The dipping speed and rotations speed is a function of steps per second, the motor has a 64:1 gear box inside and a step angle of 5.625°. This makes the rotational speed per rotation: dipping speed *5.625°/64/360. This set of samples is more a test to proof it working and to test the best way to test for other samples.

SAMPLE NO.	MATERIAL	DIPPING SPEED	HEAD ROTATIONS SPEED	TIMES DIPPED	DIPPED ORDER	NOTES
1	Silicon	700	1000	1	1	
2	Silicon	700	2000	1	4	
3	Silicon	350	1000	1	2	
4	Silicon	350	2000	1	5	
5	Silicon	700	1000	1	3	45° angle dip
6	Silicon	0	0	0	-	Not dipped
7	Silicon	700	0	1	6	
8	PCB	700	2000	10	7	
9	PCB	700	0	10	8	

Table 7.1 samples A

Sample 1

This is a silicon semiconductor sensor that will be dipped once in to the solutions with a dipping speed of 700 and a head rotation of 1,000 steps per second. The sensor will be dipped rotating down until just past the sensor then rotating up in the same rotating direction.

Sample 2

This is a silicon semiconductor sensor that will be dipped once in to the solutions with a dipping speed of 700 and a head rotation of 2,000 steps per second. The sensor will be dipped rotating down until just past the sensor then rotating up in the same rotating direction.

Sample 3

This is a silicon semiconductor sensor that will be dipped once in to the solutions with a dipping speed of 350 and a head rotation of 1,000 steps per second. The sensor will be dipped rotating down until just past the sensor then rotating up in the same rotating direction.

Sample 4

This is a silicon semiconductor sensor that will be dipped once in to the solutions with a dipping speed of 350 and a head rotation of 2,000 steps per second. The sensor will be dipped rotating down until just past the sensor then rotating up in the same rotating direction.

Sample 5

This Sample is like Sample 1 but instead of the sensor being level with the fluid, it has been angled at 45°. The sensor is a silicon semiconductor sensor that will be dipped once in to the solutions with a dipping speed of 700 and a head rotation of 1,000 steps per second. The sensor will be dipped rotating down until just past the sensor then rotating up in the same rotating direction. This sensor will coat some of the testing connection points which may influence it

Sample 6

This is a silicon semiconductor sensor that will not be dipped in to the solutions. It will become one of the standards to confirm change to the sensor in the other Samples.

Sample 7

This is a silicon semiconductor sensor that will be dipped once in to the solutions with a dipping speed of 700 steps per second. The machine will not be rotating its head to create another standard. The sensor will be dipped down until just past the sensor then up.

Sample 8

This is a PCB sensor that will be dipped ten times in to the solutions with a dipping speed of 700 and a head rotation of 2,000 steps per second. The sensor will be dipped rotating down until just past the sensor then rotating up in the same rotating direction with every dip.

Sample 9

This is a PCB sensor that will be dipped ten times in to the solutions with a dipping speed of 700 steps per second. The sensor will be dipped down until just past the sensor then up with every dip.

Samples B – Dipping and rotations samples

All these samples will be using one semiconductor sensors to see the effects of the dipping speed compered to rotational speed. The sensor will be dipped, analysed, cleaned then repeated for the next settings. The setting of dipping speed is 1-3mm/sec and the rotation speed is 0-6. There will be a sample taken for every variation of these settings as seen in table below.

SAMPLE NO.	MATERIAL	DIPPING SPEED mm/sec	HEAD ROTATIONS SPEED	TIMES DIPPED	NOTES
1	Silicon	0	0	0	
2	Silicon	1	0	1	
3	Silicon	2	0	1	
4	Silicon	3	0	1	
5	Silicon	1	1	1	
6	Silicon	2	1	1	
7	Silicon	3	1	1	
8	Silicon	1	2	1	
9	Silicon	2	2	1	
10	Silicon	3	2	1	
11	Silicon	1	3	1	
12	Silicon	2	3	1	
13	Silicon	3	3	1	
14	Silicon	1	4	1	
15	Silicon	2	4	1	
16	Silicon	3	4	1	
17	Silicon	1	5	1	
18	Silicon	2	5	1	

19	Silicon	3	5	1
20	Silicon	1	6	1
21	Silicon	2	6	1
22	Silicon	3	6	1

Table 7.2 samples B

Sample 1

This is a silicon semiconductor sensor that will not be dipped in to the solutions. It will become one of the standards to confirm change to the sensor in the other Samples.

Sample 2-4

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution. Sample 2 will be dipped with a dipping speed of 1 mm/second. Sample 3 will be dipped with a dipping speed of 2 mm/second. Sample 4 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 5-7

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 1 quarter rotation/second. During the delay, the head will still rotate. Sample 5 will be dipped with a dipping speed of 1 mm/second. Sample 6 will be dipped with a dipping speed of 2 mm/second. Sample 7 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 8-10

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 2 quarter rotation/second. During the delay, the head will still rotate. Sample 8 will be dipped with a dipping speed of 1 mm/second. Sample 9 will be dipped with a dipping speed of 2 mm/second. Sample 10 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 11-13

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 3 quarter rotation/second. During the delay, the head will still rotate. Sample 11 will be dipped with a dipping speed of 1 mm/second. Sample 12 will be dipped with a dipping speed of 2 mm/second. Sample 13 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 14-16

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 4 quarter rotation/second. During the delay, the head will still rotate. Sample 14 will be dipped with a dipping speed of 1 mm/second. Sample 15 will be dipped with a dipping speed of 2 mm/second. Sample 16 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 17-19

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 5 quarter rotation/second. During the delay, the head will still rotate. Sample 17 will be dipped with a dipping speed of 1 mm/second. Sample 18 will be dipped with a dipping speed of 2 mm/second. Sample 19 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 20-22

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 6 quarter rotation/second. During the delay, the head will still rotate. Sample 20 will be dipped with a dipping speed of 1 mm/second. Sample 21 will be dipped with a dipping speed of 2 mm/second. Sample 22 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Samples C – Samples for scanning electron microscope

All these samples will be using eight semiconductor sensors to see the effects of the dipping on the machine designed and compere them to the current machine. The setting of dipping speed is 1,3mm/sec and the rotation speed is 0,3 and 6. The mix that the samples with be dipped in will not contain the polymer but just the acrylic. This is because these samples will be placed under an electron microscope for analysed to see the difference between the machines.

SAMPLE NO.	MATERIAL	DIPPING SPEED mm/sec	HEAD ROTATIONS SPEED	TIMES DIPPED	NOTES
1	Silicon	1	0	1	This will be done with the current machine
2	Silicon	3	0	1	This will be done with the current machine
3	Silicon	1	0	1	
4	Silicon	3	0	1	
5	Silicon	1	3	1	
6	Silicon	3	3	1	
7	Silicon	1	6	1	
8	Silicon	3	6	1	

Table 7.3 samples C

Sample 1-2

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution with using the current machine for comparison against the new machine. Sample 1 will be dipped with a dipping speed of 1 mm/second. Sample 2 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 3-4

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution. Sample 3 will be dipped with a dipping speed of 1 mm/second. Sample 4 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 5-6

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 3 quarter rotation/second. During the delay, the head will still rotate. Sample 5 will be dipped with a dipping speed of 1 mm/second Sample 6 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Sample 7-8

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 6 quarter rotation/second. During the delay, the head will still rotate. Sample 7 will be dipped with a dipping speed of 1 mm/second Sample 8 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up.

Samples D – Current dipping machine

All these samples will be using one semiconductor sensors to see the effects of the dipping speed compered to rotational speed. The sensor will be dipped, analysed, cleaned then repeated for the next settings. The setting of dipping speed is 0-180mm/min. There will be a sample taken for every variation of these settings as seen in table below.

SAMPLE NO.	MATERIAL	DIPPING SPEED mm/min	HEAD ROTATIONS SPEED	TIMES DIPPED	NOTES
1	Silicon	0	0	1	
2	Silicon	30	0	1	
3	Silicon	60	0	1	
4	Silicon	90	0	1	
5	Silicon	120	0	1	
6	Silicon	150	0	1	
7	Silicon	180	0	1	

Table 7.4 samples D

Sample 1

This is a silicon semiconductor sensor that will not be dipped in to the solutions. It will become one of the standards to confirm change to the sensor in the other Samples.

Sample 2-7

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution with using the current machine for comparison against the new machine. Sample 2 will be dipped with a dipping speed of 30 mm/minute. Sample 3 will be dipped with a dipping speed of 60 mm/minute. Sample 4 will be dipped with a dipping speed of 90 mm/minute. Sample 5 will be dipped with a dipping speed of 120 mm/minute. Sample 6 will be dipped with a dipping speed of 150 mm/minute. Sample 7 will be dipped with a dipping speed of 180 mm/minute.

Samples E – dipping at 45 degrees

All these samples will be using one semiconductor sensors to see the effects of the dipping speed compered to rotational speed. The sensor will be dipped, analysed, cleaned then repeated for the next settings. The setting of dipping speed is 1, 3mm/sec and the rotation speed is 0, 3 and 6. There will be a sample taken for every variation of these settings as seen in table below.

SAMPLE NO.	MATERIAL	DIPPING SPEED	HEAD ROTATIONS SPEED	TIMES DIPPED	NOTES
1	Silicon	1	0	1	Places it 45 degrees
2	Silicon	3	0	1	Places it 45 degrees
3	Silicon	1	3	1	Places it 45 degrees
4	Silicon	3	3	1	Places it 45 degrees
5	Silicon	1	6	1	Places it 45 degrees
6	Silicon	3	6	1	Places it 45 degrees

Table 7.5 samples E

Sample 1-2

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution. Sample 1 will be dipped with a dipping speed of 1 mm/second. Sample 2 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up. Each sample will be place at a 45 degrees angle from the normal pointing, allowing a corner to be pointing downwards.

Sample 3-4

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 3 quarter rotation/second. During the delay, the head will still rotate. Sample 3 will be dipped with a dipping speed of 1 mm/second Sample 4 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up. Each sample will be place at a 45 degrees angle from the normal pointing, allowing a corner to be pointing downwards.

Sample 5-6

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 3 quarter rotation/second. During the delay, the head will still rotate. Sample 5 will be dipped with a dipping speed of 1 mm/second Sample 6 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up. Each sample will be place at a 45 degrees angle from the normal pointing, allowing a corner to be pointing downwards.

Sample 7-8

Theses is a silicon semiconductor sensor that will be dipped once in to the solutions with a delay of 3 seconds in the solution and a rotational speed of 3 quarter rotation/second. During the delay, the head will still rotate. Sample 7 will be dipped with a dipping speed of 1 mm/second Sample 8 will be dipped with a dipping speed of 3 mm/second. These sensors will be dipped down until just past the sensor then up. Each sample will be place at a 45 degrees angle from the normal pointing, allowing a corner to be pointing downwards.

Method

The method is split into 2 different methods, the overall method and the sample method. The overall method is the overall method for the experiment including setup, dipping of samples and packing up. The sample method is the

Overall method

1. ***Prepping machine for dipping***

The machine will need to be assemble if not already and booting to rest to the starting point. The starting point varies from the different machines that were made, the robotic arm will go to a set X/Y position and the other will increase in height until the arm hits the limit switch.

2. ***Gathering dipping solutions and samples***

The solution will need to be mixed and prepped. Dependent on the construction, the mix will need to be mixed with the correct ratio. The mix will include the coating Polymer, Acrylic and Acetone. Gather the samples ready for one to be selected for dipping.

3. ***Perform method for signal sample (see below)***

For each sample selected for dipping, select one at a time for testing and follow the “Each Sample method” to dip and test each of them. Each sample will have independent dipping functions allocated to it then analysed.

4. ***Take down the results***

In sure the results have been correctly logged and each sample can correspond to those results. Insure pictures have been take of the samples and the coats on their surfaces for analysing.

5. Clean up dipping solutions

Clean up the dipping solutions and all the other materials that was used to create the dipping solution. This will be done by putting the materials in the correct storing areas and either storing the mixed dipping solutions in the correct area for later use or disposed of in the correct way. When storing the mixed dipping solutions be aware that the Acetone will evaporate and more will need to be added when next used.

6. Disassemble and pack away machine

Dependent on how the machine is stored will be dependent if the machine will need to be disassembled for storage. The robotic arm can be separated into 2 parts for easy storage but the other machine will need to be taken apart. This is done but removing the top plate and undoing the screws holding the rods in place as well as decoupling the lead screw from the stepper motor. After that has been disconnected the plate can be reattached and the machine can be stored.

7. Clean up working area

Clean working area to how it was found with no spilt chemicals or dipping mix over the working area and a cleared desk.

8. Final checks

Insure and check all the samples, results, machine/materials and working for any problems that will need to be addressed before finishing.

Each Sample method using robotic arm

1. Prepare ready for sample

Before the samples is selected insure that machine and work space is ready for dipping. This includes resetting the machines setting and the mixed dipping solution is correctly mixed before starting the next dip.

2. Choose the sample

Select the next sample to be dipped into the dipping solution from the non-used samples. This sample with have the machine setting then will need to be set. Prepare these settings for the machine and record the setting to be used for reference.

3. Set machine

If not done so already, create a program using the online programming tool and upload into the machine. Scroll to the file that was made and get ready to run the program. While the programming is running watch the machine to insure there are no problem with the machine.

4. Attach sample to the machine ready for dipping

By using the sample attachment for the machine, attach the sample to the holder and then to the machine, ready to be dipped into the solutions. The holder uses one screw to clap down onto the sample and 2 more screws to hold the holder onto the motor.

5. ***Perform the dipping of the sample***

Select the program when the sample is ready to be dipped and wait until finished. Watch the machine to insure there are no problem with the machine while running.

6. ***Wait until coat is dry***

Wait until the Acetone has evaporated off leaving the Polymer and Acrylic behind.

7. ***Disconnect the sample from machine***

Disconnect the sample from the machine and holder while being careful not to disturb the coat on the sample. The holder uses one screw to clap down onto the sample and 2 more screws to hold the holder onto the motor.

8. ***Store sample***

Carefully store the sample and label it to identify which sample it is to match the correct machine settings to this sample. If this is not done properly, will create incorrect results.

9. ***Prepare for the next sample***

Clean up any mess that may be called by the current progress or anything that may affect the samples or solution.

Each Sample method using dipping machine

1. ***Prep ready for sample***

Before the samples is selected insure that machine and work space is ready for dipping. This includes resetting the machines setting and the mixed dipping solution is correctly mixed before starting the next dip.

2. ***Choose the sample***

Select the next sample to be dipped into the dipping solution from the non-used samples. This sample with have the machine setting then will need to be set. Prepare these settings for the machine and record the setting to be used for reference.

3. ***Set machine***

Set the all the setting in the machine for the sample to be dipped. It is recommended to use the auto dipping mode in that machine and set the speeds, height and delay so that the machine does all the work automatedly. The manual mode allows more control over the height without putting it directly into the setting. By setting the speeds, the height can be controlled with a simple button press. While the programming is running watch the machine to insure there are no problem with the machine.

4. ***Attach sample to the machine ready for dipping***

By using the sample attachment for the machine, attach the sample to the holder and then to the machine, ready to be dipped into the solutions. The holder uses one screw to clap down onto the sample and 2 more screws to hold the holder onto the motor.

5. Perform the dipping of the sample

In auto mode, select run to run the dip/dips. In the manual mode select either up or down to control the height of the arm. Watch the machine to insure there are no problem with the machine while running.

6. Wait until coat is dry

Wait until the Acetone has evaporated off leaving the Polymer and Acrylic behind.

7. Disconnect the sample from machine

Disconnect the sample from the machine and holder while being careful not to disturb the coat on the sample. The holder uses one screw to clap down onto the sample and 2 more screws to hold the holder onto the motor.

8. Store sample

Carefully store the sample and label it to identify which sample it is to match the correct machine settings to this sample. If this is not done properly, will create incorrect results.

9. Prepare for the next sample

Clean up any mess that may be called by the current progress or anything that may affect the samples or solution.

8. Results

There were 5 sets of samples done with different controls, Samples A was the first set of samples to be dipped and analysed. Theses samples were 9 different sensors. Samples B were one sensor which after dipped and analysed, it was cleaned and repeated. Samples C was for 8 sensors dipped in just Acrylic and analysed under a Scanning Electron Microscope. Samples D were from the current dipping machine at Macquarie University and compared with other data taken from samples A-E. Samples E was taking from one sensor positions at a 45-degree angle while dipped.

Samples A – first samples

On getting these results, it was noted that the 7th, a semiconductor, could not be read because it was damaged before being dipped, this sensor being one of the sensor that all the other sensors was going to be compared against which was annoying but the data from the other sensors did show interesting data. The sensors can be separated into 2 different categories, semiconductors and printed circuit boards which are the materials/name used to describe them.

Semiconductor

For the semiconductor, it can be seen in Figure 8.1 and Figure 8.2that there are 2 different groups. The Sensor 2 (orange line) and Sensor 4 (yellow line) samples are much less than the other semiconductor sensors. Theses 2 sensors were rotated at double the speed of the other sensors and their data produced a nice curve while the other sensors all change their values by large amounts. This could be an error in reading or dipping.

After dipping more sensors in samples B-E, it was shown that all that data in the other samples groups is like the sensor 2 (orange line) and sensor 4 (yellow line) samples. This means that the data for the other samples could be wrong because of many different variables. One of the contributors could have been the constrains of the Polymer solutions was weak compared with later sample tests. This can be seen but the images of the coat and the evenest of them. Sample 1 (shown in Figure 8.3) is splotchy and clumpy while Sample 2 (shown in Figure 8.2) has more of an even coat across the surface. Another factor that could have contributed to this, this was the first samples that was dipped and methodology was still in the learning phase. Since Samples 1, 3 and 5 (in that order) were dipped first, this can confirm it could be a factor to making the data jump values.

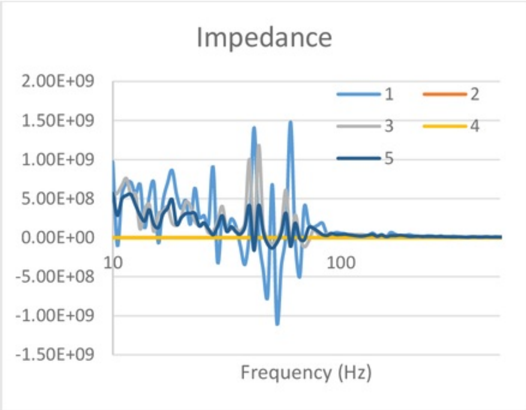

Figure 8.1 impedance results from sensors 1-5

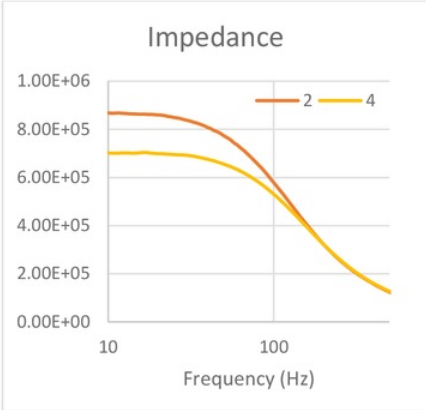

Figure 8.2impedance results from sensors 2 and 4

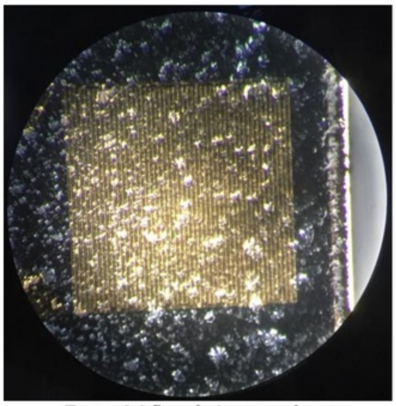

Figure 8.3 Sample 1 image of coat

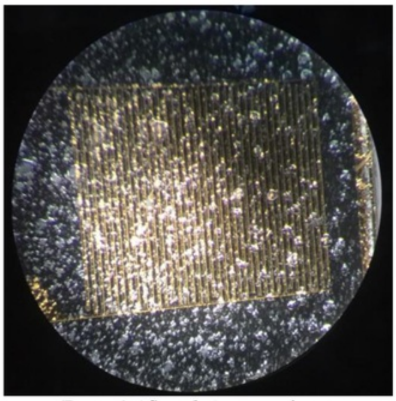

Figure 8.4 Sample 2 image of coat

printed circuit board

For the PCB sensors, it can be seen that it is similar to the semiconductor sensors where the value jumps increase rapidly. The coating on the PCB sensors seems to be not as thick as the coats on the semiconductor and can be shown in Figure 8.6 and Figure 8.7. This sensor was dipped many times and the coat does not seem to have differed from the first. This could because the Polymer solution was a low constriction and did not stick too well to the surface of the PCB.

The data in Figure 8.5 from the PCB samples shows the 2 samples more followed each other which could many the coat had no effect on the surface. It was though that since the sensor tacks are larger than the semiconductor samples, it will need a thicker coat. The coating mix that was being used would not be the correct solution to be dipping theses sensors in. Theses PCB will not be used to take samples with again with in this project.

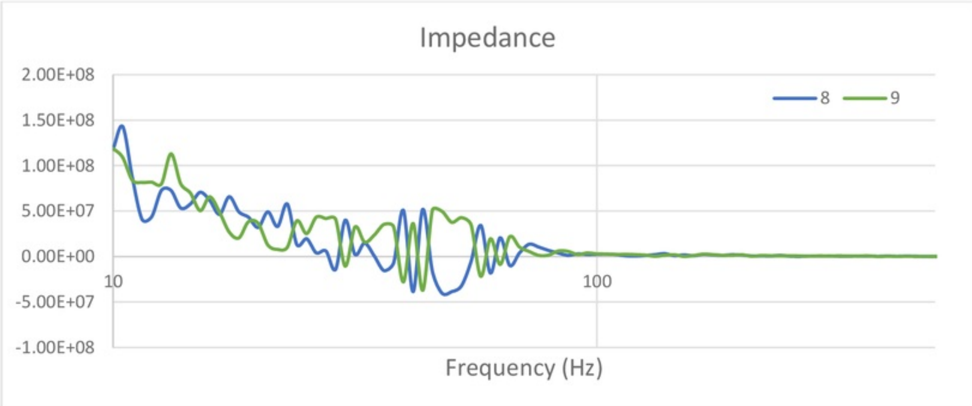

Figure 8.5 impedance results from sensors 1-5

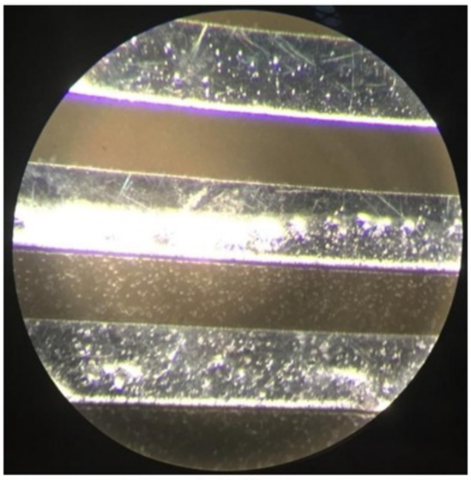

Figure 8.6 PCB polymer coating

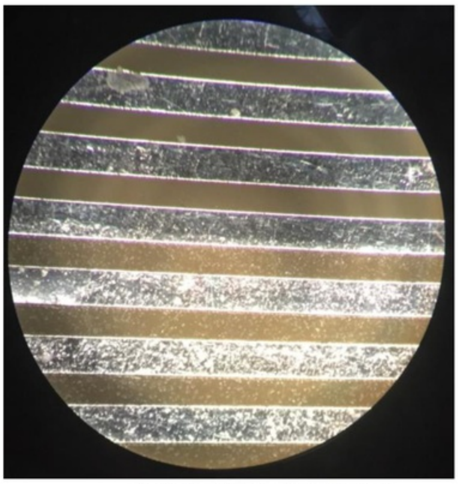

Figure 8.7 PCB polymer coating

Samples B – Dipping and rotations samples

All these samples will be using one semiconductor sensors to see the effects of the dipping speed compered to rotational speed. The sensor will be dipped, analysed, cleaned then repeated for the next settings. The setting of dipping speed is 1-3mm/sec and the rotation speed is 0-6.

The results are split into 2 different groups, dipping speed and rotation speed. Out of all 22 samples are split into groups to be averaged and displayed on charts. One of the sample's data can greatly change the results, this could because that sample when dipped was not constants with the other dips with in this sample set. There are 2 set of averages, one is with all samples and the other is with sample 19 removed. This is to show the effect of this one sample to the reset of the data set.

Dipping speed

Figure 8.8 and Figure 8.10 shows the impedances of the 3 different speeds used to dip the sensor into the solution. Each speed shown is the average of the samples at that speed. Figure 8.8 is with sample 19 included and Figure 8.10 is without sample 19. Figure 8.9 is the rate of change of order which is the analysation of the order of the speed at each frequency. Figure 8.9 shows the rate of change of the trending line of the order at each frequency. This can identify which frequency different speed cross when there a bit close on Figure 8.8.

The effect of sample 19 can be seen in the averaging of speed 3 in Figure 8.8 and Figure 8.10. Figure 8.8 shows speed 3 having the highest impedance most of the time but there is not consistently between the speed and the change of impedances. Figure 8.10 is different from Figure 8.8 because there is a distinctive link between the speed of dipping and the impedance. Sample 19 will be a problem because it cannot be ignored but it needs to be included, this sample could show unforeseen differences from other samples.

Distinctive relationship in Figure 8.10 shows that as the speed of dipping increases, the impedance decreases. This is based on the surface tension on the dipping solutions. The slower the dipping speed, the more the surface tension drags on the coating the surface of the semiconductor resulting in a thinner coat. The faster the dipping speed, the more the surface tension fails to drag the coating off thus leaving a thicker coat. It was noted on the faster speed, there was notably more coat on the surface then lower speeds.

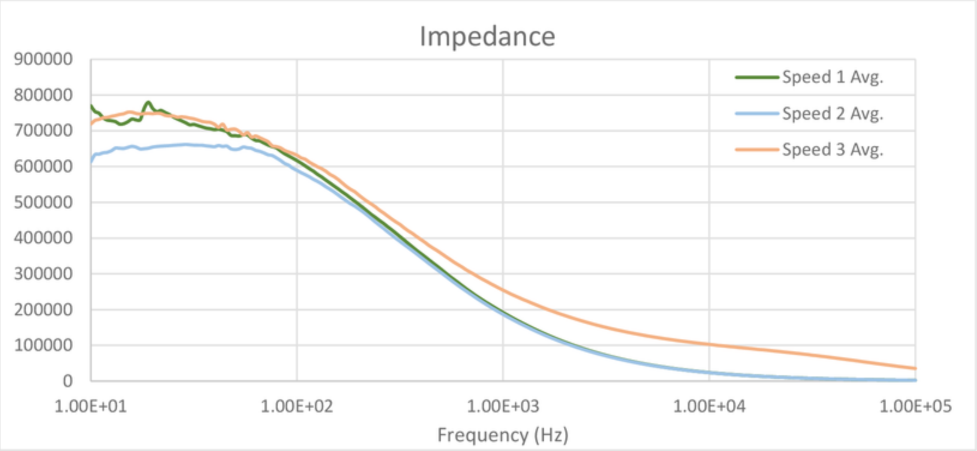

Figure 8.8 Impedance for dipping speed with sample 19

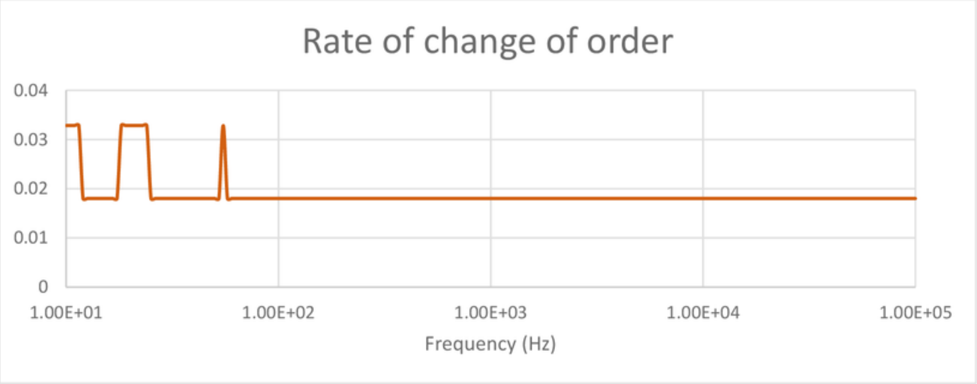

Figure 8.9 Rate of change of order

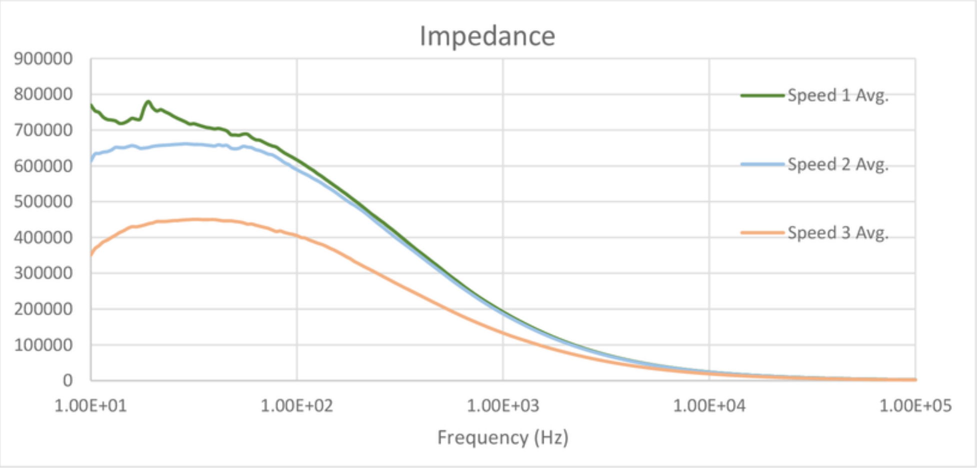

Figure 8.10 Impedance for dipping speed without sample 19

Rotation dipping speed

Figure 8.11 and Figure 8.13 shows the impedances of the 7 different speeds of rotation while dip the sensor into the solution. Each speed shown is the average of the samples at that speed. Figure 8.11 is with sample 19 included and Figure 8.13 is without sample 19 included. Figure 8.12 is the rate of change of order which is the analysation of the order of the speed at each frequency. Figure 8.12 shows the rate of change of the trending line of the order at each frequency. This can identify which frequency different speed cross when there a bit close on Figure 8.12.

As with the speed of dipping, the effect of sample 19 can be seen in the averaging of speeds in Figure 8.11 and Figure 8.13. Figure 8.11 does consistently between the speed and the change of impedances but its not as clear as Figure 8.12 where sample 19 has been removed. Sample 19 will be a problem because it cannot be ignored but it needs to be included, this sample could show unforeseen differences form other samples.

Figure 8.13 is like Figure 8.11 but without sample 19, it's order is closer to what was expected. It can be seen in this chart that as the sample rotates faster, the impedance decreases. This could because of the surface tension of the dipping solutions. The slower the sample rotates the more the surface tension holds together coating the surface of the semiconductor with a thinner coat. The faster the rotation speed, the more the surface tension fails to hold it together creating a thicker coat.

Figure 8.12 is the rate of change of order which is the analysation of the order of the speed at each frequency. It shows the rate of change of the trending line of the order at each frequency. This can identify which frequency different speed cross when there a bit close on Figure 8.12 and it also show where the orders trend reverses. After 100 Hz the order starts changing more frequent, this could because of the ripples in the data. After 1000 Hz the orders trend enters into the negative. There could be no relationship between impedance and speed of rotation from this point or it the higher impedance could be decaying faster than the lower impedance.

This data in Figure 8.11 and Figure 8.13 shows that the rotation of the object while getting dipped it can affect the coat. This result has confirmed that the rotation of the sample can either increase the impedance by decreasing rotation or decreasing the impedance by increase rotation. This indicates the coat on the surface of the samples has been changed. This result cannot describe how thick or how even the coat on the surface of the sample. The polymer used is a thin power that does not devolve into the solutions and this creates a spottiness effect across the samples surface. From this, it can be said that the surface would not be evenly coated because of this power.

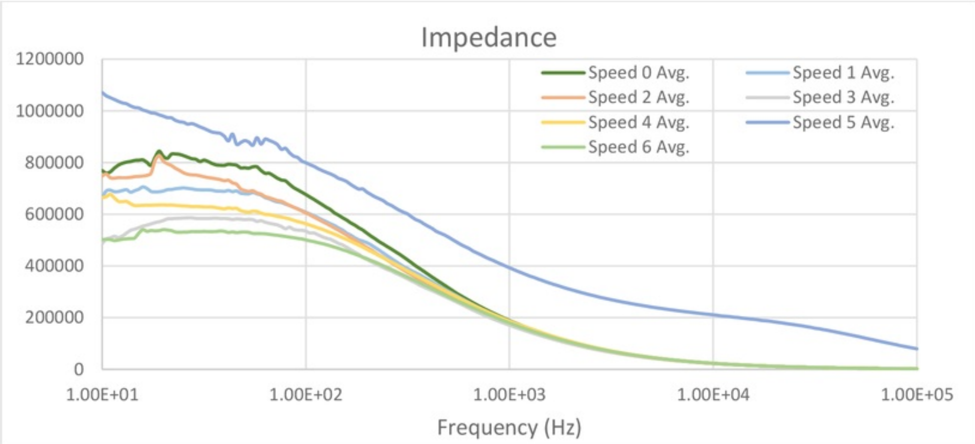

Figure 8.11 Impedance for rotation speed with sample 19

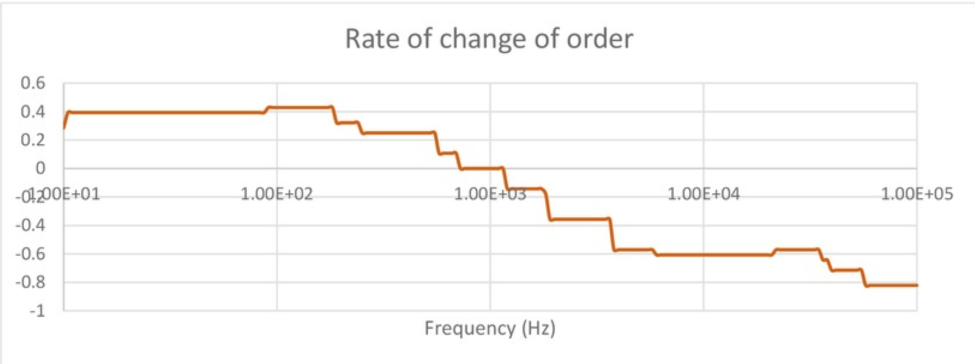

Figure 8.12 Rate of change of order

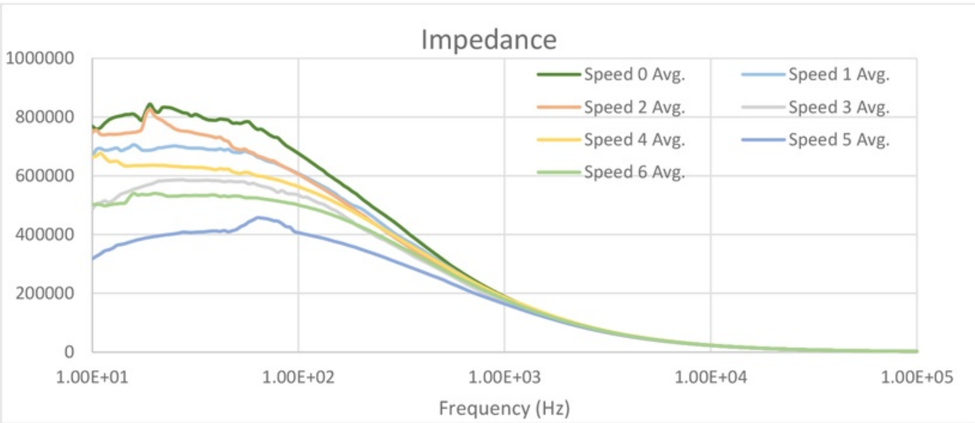

Figure 8.13 Impedance for rotation speed without sample 19

Samples C – Samples for scanning electron microscope

All these samples will be using eight semiconductor sensors to see the effects of the dipping on the machine designed and compere them to the current machine. The setting of dipping speed is 1,3mm/sec and the rotation speed is 0,3 and 6. The mix that the samples with be dipped in will not contain the polymer but just he acrylic. This is because these samples will be placed under an electron microscope for analysed to see the difference between the machines.

Figure 8.14 Impedance of uncoated sensors14 are all the starting values of all 8 sensors without any coating. This shows that the sensors are not all the same but different, this has an influence the results and the analysing of the coat with the LCR meter. This will need to be considered for every result and could be the reason for odd results and can be seen in Figure 8.15 where some values are higher than what there meant to be.

Sadly, there will not be any results from the electron microscope because there was nothing to see and could not detect the thickness of the coat. Some new samples have been dipped with a thicker coat in hopes to see the thickness, but this will be done after this document will be submitted.

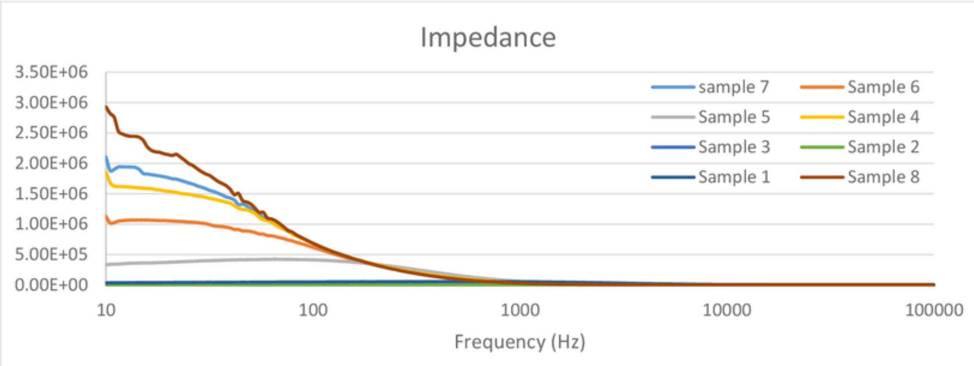

Figure 8.14 Impedance of uncoated sensors

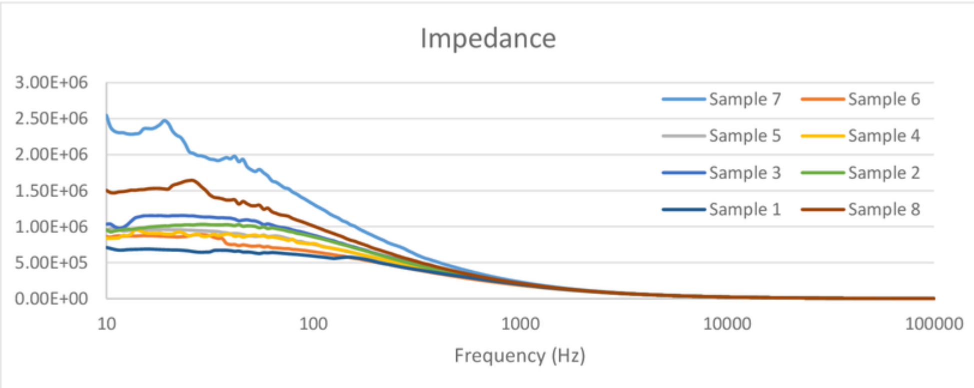

Figure 8.15 Impedance of samples

Current machine

Samples 1 and 2 are samples from the currently used machine at Macquarie University and Figure 8.16 show that the sample's average rotation speed's impedance is lower than the new machines and it falls away with about the same amount. The sample's average dipping speed in Figure 8.17 does not show the same. In Figure 8.17, as the current machine increases with dipping speed, the impedance also increases which is the reverse other all the samples that were dipped. This could be an incorrect sample but can't be discarded. If this is correct, it means that the new machine does not coat in the same way are the current dip coating machine but if the coat is constant and even with that new machine then it should be fine.

Dipping speed

The new and current dipping machine from this data seems to be consistent in Figure 8.19 except for speed 6 average. This average is high but with no other speed between 0-6 (beside from the samples) it is hard to tell if it is. For these samples, the polymer was not added to allow the electron microscope to scan it without the lumps and bumps that it leaves behind. By removing this, the coat seems to be smoother. The coating material could be one of the contributors for the high values. All samples before this have been coated with a polymer but no samples have been taken without it.

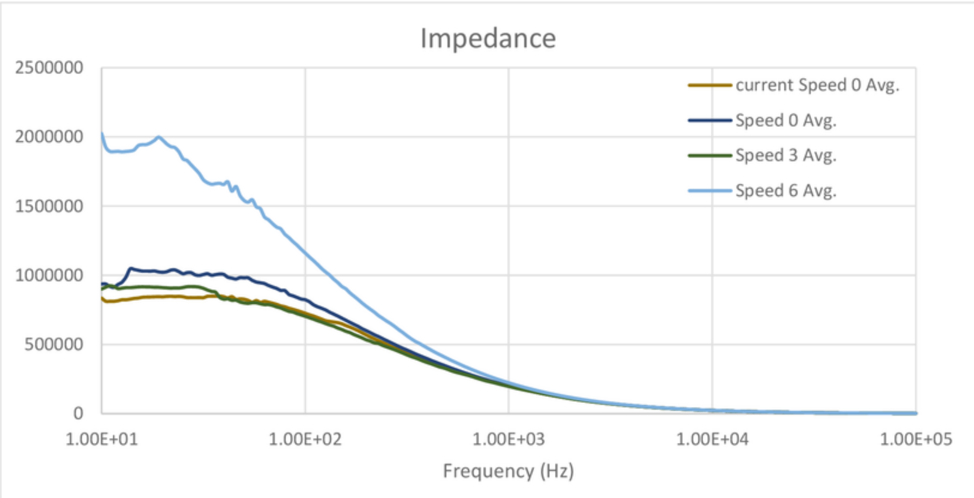

Figure 8.16 Impedance for dipping speed

Rotation dipping speed

Figure 8.17 seems to have more consistence than Figure 8.16 but the it is not consistent with the rest of the samples that are taken. In Figure 8.17, as the current machine increases with dipping speed, the impedance also increases which is the reverse other all the samples that were dipped. This could be an incorrect sample but can't be discarded. If this is correct, it means that the new machine does not coat in the same way are the current dip coating machine but if the coat is constant and even with that new machine then it should be fine.

Sadly, there will not be any results from the electron microscope because there was nothing to see and could not detect the thickness of the coat. Some new samples have been dipped with a thicker coat in hopes to see the thickness, but this will be done after this document will be submitted. This could have shown better results as the coat out be of different thickness or evenness. The coating material could be one of the contributors for this to happen. All samples before this have been coated with a polymer but no samples have been taken without it.

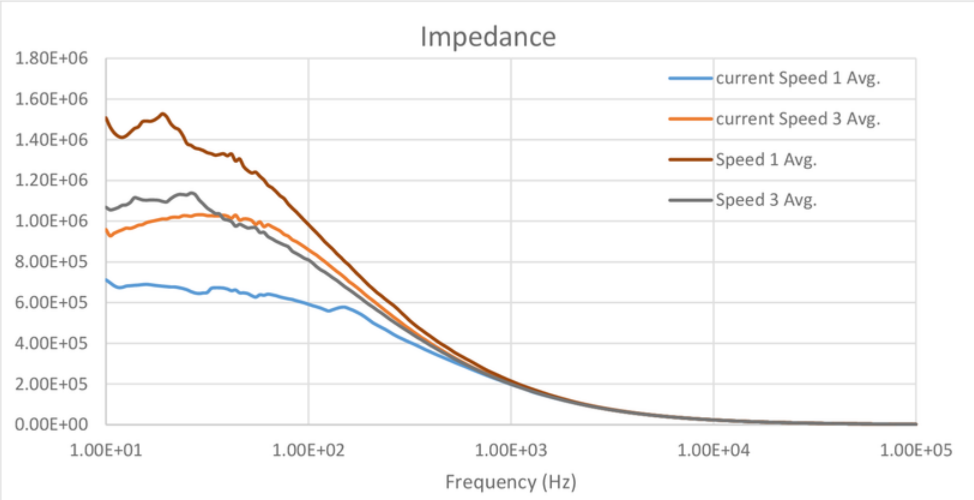

Figure 8.17Impedance for rotation speed

Samples D – Current dipping machine

This samples set describes the current machines dipping coats. Figure 8.18 compared to Figure 8.11 and Figure 8.12 is smoother but not as consistence. The samples order in Figure 8.18 jump many and seems to still have a strong positive trend as seen in Figure 8.19. This rate of change of order chart does show some interesting shifts it different frequencies. There is no consistence between the rate of increasing impedance over frequencies of the different speeds. Between samples 1, 2 and 5, the higher the impedance at low frequencies, the faster the impedance declines over the frequencies. This is the same as samples 6 and 7 but is not consistently across all samples. If the samples 4 and 3 were in a lower position and ack like the other samples, this samples set would be consistent and be a stronger set than the newer machines. The newer machine as more consistent throughout its samples but the impedance at each frequency is not smooth unlike the current machine. if this smoothness is fixed the new machine would be better than the current machine.

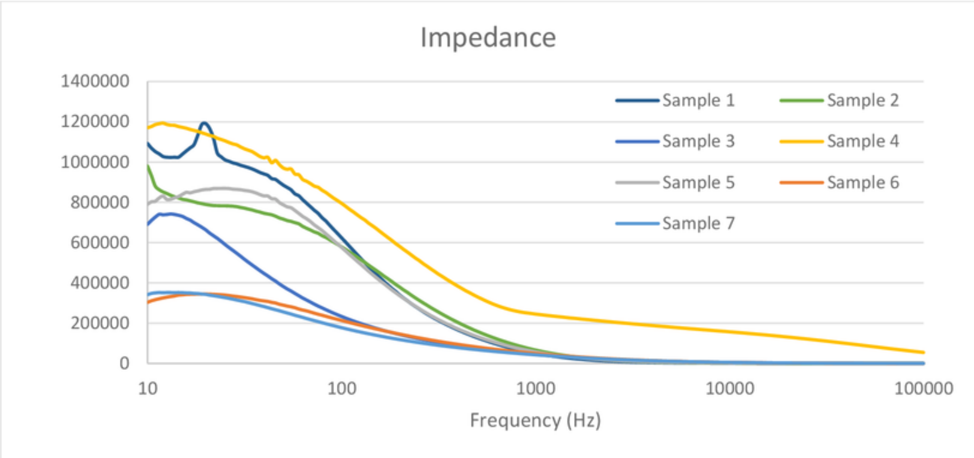

Figure 8.18 Impedance of dipping speed

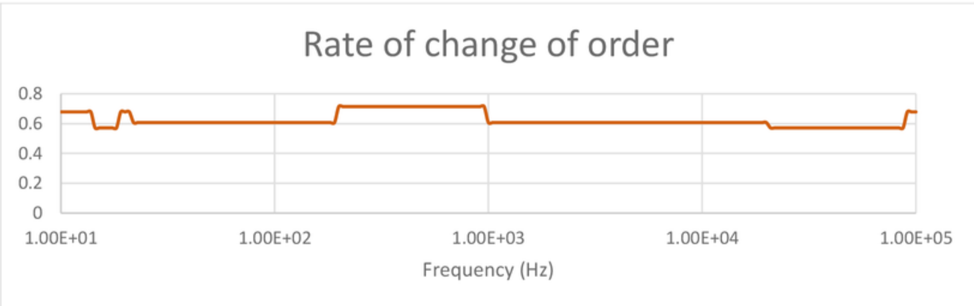

Figure 8.19 Rate of change of order

Samples E – dipping at 45 degrees

All these samples will be using one semiconductor sensors to see the effects of the dipping speed compered to rotational speed. The sensor will be dipped, analysed, cleaned then repeated for the next settings. The setting of dipping speed is 1, 3mm/sec and the rotation speed is 0, 3 and 6.

Unexpectedly, this sample set are complying different from other data sets that have been dipped and experimented with. Placing the sensor at 45 degrees has made the sensor drop faster than other dipped samples, limiting the band width to about 100Hz. This is thought to be surface tension acting differently on the pointed corner.

In Figure 8.20 and Figure 8.21 the 45 degrees angled can be seen to start about the same as all other dipped samples but drops off as a much faster rate than any other samples. There could be any different reasons for this including the contaminated or different constriction mix but thoughts are the surface tension. Both dipping speed and rotational speed had an effect like previous sample sets and can be seen with the different starting and continuing values but the rate on which it drops away is completely different. It was thought that it was surface tension because as the sample is coming out of the solution, the area of the sample in the water is becoming much less. The surface tension above is pushing down onto a point where it can't hold much of the solution. As the point comes out of the solution, it is a point and the solution can slide of the end when a normal dipped sample has a flat end on the bottom of the sample where the surface tension attaches too.

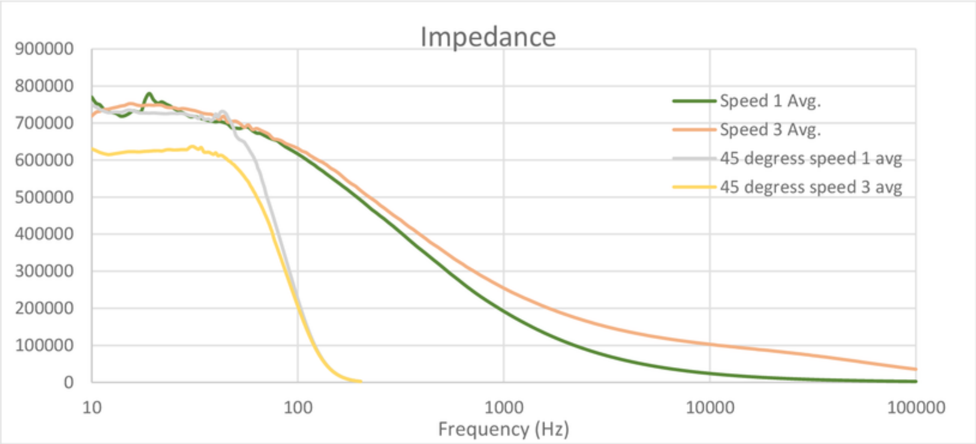

Figure 8.20 Impedance of dipping speed

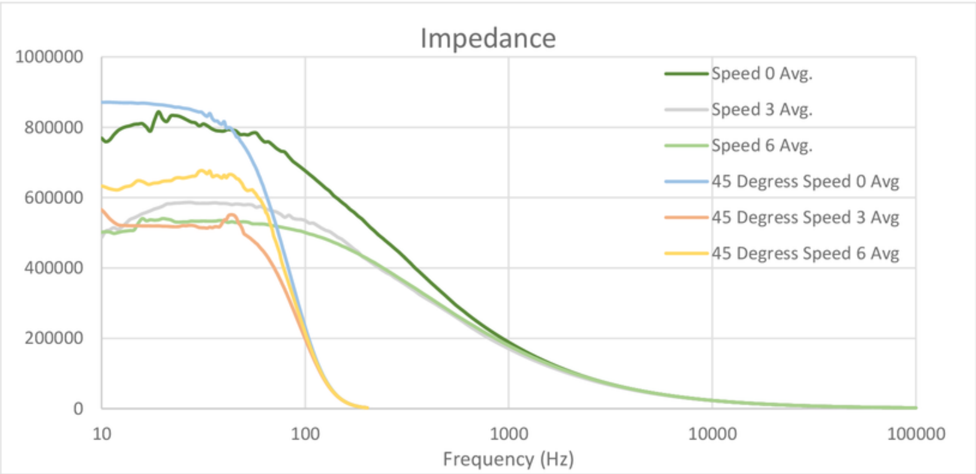

Figure 8.21Impedance of rotation speed

9. Machines evaluations

There was 2 machines and a test machine that were produced and they in different ways, the first was the robotic arm, the second was a simple test jig for the current machine and the last was a horizontal dipping machine. The construction of the machines and the testing of the functions that they can perform is important to the overall operation of the unit. This could confirm there are differences from these machines to others on the market and potentially be able to change the coat on the surface of the object. The two different types of samples that are getting coated are made from: 1) Silicon with Gold as tracks and 2) Fiberglass with Copper (with a Tin coating over the Copper) as tracks.

The most problematic issue was sourcing the parts for the machines, they took about 3 weeks to come from the supplier. This sourcing issue was further exacerbated by the components arriving being different from those expected. This put the project about 2 weeks behind, limiting the time available to finish the construction and testing of the machines.

The current machine

The current machine that is being used at Macquarie University to dip samples is a PTL-MM01 Dip Coater from MTI Corporation. This machine is simple to use with simple controls and manual control when the machine is not running. But there are areas that the machine can be improved to increases the performances and user experience with the machine. The machine uses a metal wire with a loop at the end to pull a holder up along a slide. This holder and slide can be switched out for a different one because it is not attached to the machine. This holder and slide is not screwed down or held in place on the machine and can be taken away from the working area. Over the working area is where the wire runs through pulleys and then spooled on to the axles which connects into the gearbox of the motor. The motor used is a stepper motor with what looks like a planetary gearbox. This machine is expensive and solid, it can be seen where the designers did not care much about cost.

Construction

The construction of the machine is solid and heavy. The machine is mostly made from heavy gauge steel to make it strong, but this make it very heavy and difficult to be moved. It would work well in a fixed location but since it needs to be relocated as needed, the weight issue if of concern. The benefit of its being so solid is there is little or no vibration created by the motor and is stable when operated. The slide is good because it can be changed to a different type of slide which can attach to the wire.

User interface

The user interface is simple but needs to be improved. While the machine is going down and the mode does not get changed to up, if it gets run the machine will continue down because the operator forgot to change it over. This happen many times while testing and using this machine. This could have overcome by adding a button to run up/down or have the ability to select and not be able to run without selecting a mode, this will only happen at run time.

The machine only has 2 setting and does not have any functions besides from the single down or up of the sample/object. The 2 setting are speed of the dipping and how far from the current position to travel. It would be great if there was a faction that return the sample to the starting position (up and down) this can be achieved with those 2 setting and possibly add a delay while the object/sample has been dipped.

Functions

This machine dose not perform any functions beside from the single up or down motion, created from the wire moving a block of metal alone a slide. This block and slider could be replaced with a different type of slide but would probably perform the same function.

Overall

Overall this machine is solidly designed and made, but expensive for what controls and user interactions are provided. Some of the design is an over-kill and could be produced more cost effectively or monies channelled into increased functionality or controls for the operator. Whilst limited, it does what it was bought for.

The robotic arm machine

Even though the robotic arm was a good idea and seemed practical, it was very hard to get perfect. Combining electronics, programming and parts, each having their own individual problems, led to further issues. If these issues could have been fixed in time, the resultant machine would have been the best options to try different functions of dipping. Sadly, the project was running out of time and had to resort to a different machine to complete the project. All the issues are listed below in respective categories.

Figure 9.1 Robotic arm machine

Base design

The base design worked well but would have been better if produced in steel. The case was made from Acrylic causing the pieces to be brittle and fragile individually but when screwed together, it was strong. When moving the case around, the Acrylic could move out of place which could result in breakages. The best solutions would to cast the hole case in one piece in Aluminium or make it out of steel.

Another problem with the case is the dipping solution used Acetone to thin the liquor ready for dipping. The case was made from Acrylic which Acetone can dissolve resulting in the case deforming. This is not the best for material for this machine because of the problem. A solution would be to produce the case out of metal coated in paint resistant to Acetone.

Arm design

The parts of the arms are made from PLA 3D printing filament and printed on a Flash Forge Dreamer but would be better if the parts were made from better materials such as Aluminium or Steel Alloy. This may increase the design and manufacturing cost but would make the parts more robust. Also, the dipping solutions uses Acetone in the mix and if it comes into contact with this plastic, it may deform it, contaminate the solution or damage the object being dipped. A metal would be the best for the arm elements even if the rest of the arm is made from PLA 3D printing filament.

The stepper motors used on the arm are geared 5V stepper motors but removing the centre tap makes two 5V coils totalling 10V. When the arm was left on, the motor would start to overheat with resultant melting of adjacent parts. This meant parts needed to be replaced after parts were melted or deformed through heating. Better stepper motors would be needing to fix this with a lower voltage to prevent this re-occurring.

The controller uses a 10-bit analogue to digital converter (ADC) to read the potentiometer but this was not high enough resolution to properly read them. This resulted in the arms joints being up to 25mm out of position with resultant incorrect functionality of the arm when the program is run. The program could be written to correct this error but will take time. Sadly, this would be one of the major problems that need to be fixed before testing could proceed and necessitated the development of the other machine to enable the experiments to be performed.

The speed of the arm was getting programmed but the rate of acceleration needed was causing the arm not to go down and up straight. This was a problem because it need to enter the liquor at 90°in similar manner to the existing dipping machines. This could be fixed programmatically but required more time to write and debug. Sadly, this is also one of the major problems that need to be fixed before testing could proceed.

Electronics

The electrotonic work well both inside the case and on the arm. The LCD interface works well and is simple to use even though the arm is hard to program. The programming and the insertion of the SD card can be accessed through the top of the case making it easy to program the processor and the arm itself.

The stackable boards are great to save room in the case of the machine. Without the stackable boards, much larger and cumbersome custom board would have been needed. These would have taken more time to design, construct and debug, time that the project did not have. The controller was powerful enough to perform all the tasks that the machine needed. These tasks included calculating angles and positions while reading the next data from the SD card.

The use of the encoder disallowed the use of the SD card read but since the potentiometer were used instead of the encoder, this open that sections for use. The SD card reading is an important part of the programming and running of the machine. Without this, it would be much hard to control the dipping functions unless there were pre-programmed in. This approach would have taken up too much space on the microprocessor.

Program

The program for the Robotic Arm had most of what the arm needed but needed more development for smoother operation. The selection of the program for the arm to run is simple but needs be improved. The program allows the user to select the program but does not allow the user to set settings like speed, liquid height and position of beaker but currently can be set on the SD in the arms functional program.

The controller uses a 10-bit analogue to digital converter (ADC) to read the potentiometer but was not of sufficiently high resolution to properly read them. This makes the arms joints up to 25mm out of position and when the program is run, the function of the arm is not correct. The program could be written to correct this error but will take time which there was none. Sadly, this would be one of the major problems that need to be fixed before testing and stop development for the arm to development the other machine to perform the experiment.

Online programming tool

The online programming tool did not have any problems but could be become easier to use and edit. Maybe the introduction of libraries of programs and predetermined programs ready to be run. It is annoying that the program needs to be downloaded then placed on a SD card which in turn had to be placed into the machine. This could be better with a direct link via USB to the machine to program it directly.

Functions

Due to the processor reading the position of the potentiometer incorrectly, resulted in the machine not positioning itself correctly. Adopting an encoder could correct this but would use up more resources on the boards. This will make the SD not functionable. A program could be made to read the correct position of the potentiometer but did not have time to write and debug it in time for testing.

The test jig for the existing machine

This is a simple attachment to the existing machine which allows the machine to rotate the sample while dipping to test how the system reacts before making the next machine.

Design

The design is simple that attaches to the existing machine shown in Figure 9.2 Rotation jig and contains one stepper motor to rotate the sample. It worked well but the sample was not getting coated because the consistency of the solutions was not high enough to maintain the Polymer in suspension resulting in it sinking to the bottom before it could have completed any coating. This is a problem for all the machines.

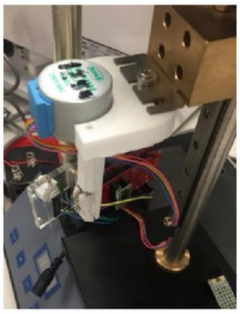

Figure 9.2 Rotation jig

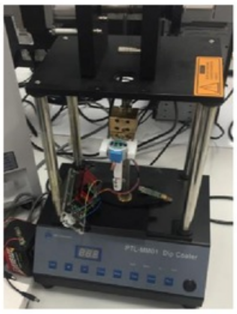

Figure 9.3 Rotation jig

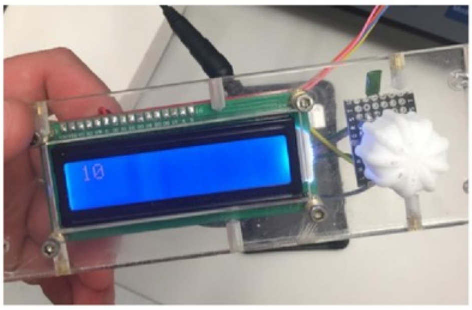

Figure 9.4 Rotation jig setting interface

The parts of the arms are made from PLA 3D printing filament and printed on a flash forge dreamer but would be better if the parts were made from better martials like aluminium and steel. This will increase the design and manufacturing cost but would make the parts stronger and last longer. Also the dipping solutions uses Acetone in the mix and if it comes into contact with this plastic, it may deform it, contaminate the solution or damage the object being dipped. A metal would be the best for the of the arm even if the rest of the arm is made from PLA 3D printing filament.

The stepper motors used on the arm are geared 5V centre taped motors but when not, centre tapped makes 10V stepper motor. When the arm was left on the motor would start to overheat and start melting some of the parts around them. This meant parts need to be reprinted to after a part got melted. Better stepper motors would be needing to fix this with a lower voltage to prevent this from happening.

Electronics

The electronics controller controlled the speed of the rotation by using a encoder and displaying it on the LCD screen. There were no problem or errors with this.

Program

The program was simple and easy to use There were no problem or errors with this.

Functions

This device connected to the current machines mount but using 1-3 screws but when it was printed there was a problem that the screws hold did not line up but about 0.3 mm. this made this device only use one screw to hold it in place which was not a big deal, it was only a test jig.

The other problem with this test jig was the device over hung onto a lip which meant the beaker was not stable. A fix for this would be to make a new work space, levelling stage to place the beaker on the make it stable or moving the motor further out beyond the lip.

Dipping (vertical travel) machine

This machine is like the other machine on the market but was made to make it easier to control. the robotic arm was made for it free moment but needed to be programmed by an external tool. This machine need to be simpler than the current machine with more setting and limits. Some of these settings are height, speed and delays of dip.

Base design

The base design worked well but would be better if it was mad from steel. The case was made from Acrylic coursing the pieces to be brittle and fragile but when screwed together was strong. When the case got taken about the Acrylic could move out of place and if moved too much would break. The best solutions would to case the hole case in one piece or make it out of steel.

Another problem with the case is the dipping solution used Acetone to thin the liquid ready for dipping. The case was made from Acrylic which Acetone can melt and deform the case. This is not the best for material for this machine because of the problem. A solution would be making the case out of steel with a coating of paint that does not deform when exposed to Acetone.

Arm design

The parts of the arms are made from PLA 3D printing filament and printed on a flash forge dreamer but would be better if the parts were made from better martials like aluminium and steel. This will increase the design and manufacturing cost but would make the parts stronger and last longer. Also the dipping solutions uses Acetone in the mix and if it comes into contact with this plastic, it may deform it, contaminate the solution or damage the object being dipped. A metal would be the best for the of the arm even if the rest of the arm is made from PLA 3D printing filament.

The stepper motors used on the arm are geared 5V centre taped motors but when not, centre tapped makes 10V stepper motor. When the arm was left on the motor would start to overheat and start melting some of the parts around them. This arm is much better at managing this than the robotic arm because this arm does turn itself off after a while but it’s something that need to be considered. This meant parts need to be reprinted to after a part got melted. Better stepper motors would be needing to fix this with a lower voltage to prevent this from happening.

Electronics

The stackable boards are great to save in the case of the machine. Without the stackable boards, there would have been a much larger custom board in the case that would have taken more time to design, construct and debug, time that the project did not have spare. The controller was powerful enough to perform all the tasks that the machine need. These tasks included calculating the height of the arm, but this is much simpler than the robotic arm.

Program

The program is much simpler than the robotic arm and faster to write because of how little calculations there are need to calculate the positions. Since this machine uses a lead screw the move the sample up, down and rotate, it can be all linear calculations while the robotic arm need more complex calculations. Those calculations could have many different variations of the position of the arm. This machine also has a limit switch which it much easier to find the positions of the arm.

This is a bug in the program that has not been able to be fixed yet. This bug does not allow the auto function to be run. The bug is thought to be skipping a command somewhere to make it not run. The auto faction is meant to reset before starting, dip at the set height and then reset. If the dipping count time is more than 1 it will repeat the dip and reset until it dips to that number. It is known that the reset function works but not the dipping function. This is where the bug will be located.

Sometime there will be random letter appear on the LCD screen on the right. This is from previous setting that has been left there and not be cleared. This will need to be addressed in the program.

User interface

The user interface is meant to be simple and easy to use unlike the robotic arm and the current machines. The current machine does have a simple interface but cannot control all the functions that should be required as part of the machine. this machine has both manual and auto functions to make it easy to control where the position of the arm is and how deep it dips and for how long.

This is a bug in the program that has not been able to be fixed yet. This bug does not allow the auto function to be run. The menu items setting and controls all work fine but it's this bug that does not. The bug is thought to be skipping a command somewhere to make it not run. The auto faction is meant to reset before starting, dip at the set height and then reset. If the dipping count time is more than 1 it will repeat the dip and reset until it dips to that number. It is known that the reset function works but not the dipping function. This is where the bug will be located.

Currently the speed and height setting are displayed as steps or steps per second. This will need to be changed to millimetres and millimetres per second. This is a calculation that will be done on the microprocessor ad displayed ion the LCD.

Functions

The arm has 2 functions, manual and auto. Both have settings that can be set without any external tools or devices. This means that the machine can be used by anyone that requires something to be dipped or simular functions. Under both manual and auto have speed setting and the auto has height and delay setting as well. The manual uses commands up and down to control the positions other arm. Setting the setting can be long because of how big the numbers are and the step of the encoder. This step need to be changed to represent millimetres

The menu items setting and controls all work fine but it’s this bug that does not. The bug is thought to be skipping a command somewhere to make it not run. The auto faction is meant to reset before starting, dip at the set height and then reset. If the dipping count time is more than 1 it will repeat the dip and reset until it dips to that number. It is known that the reset function works but not the dipping function. This is where the bug will be located.

The mechanical functions of this machine are that it can move up and down while rotating the head around. This is like the test jig device but as a machine with full control settings including dip speeds and rotation speed.

10. Discussion

There was 2 machine that were produced and they in different ways work well, some areas better than the current machine and in other not as much. Below are issues and how it could be fixed or add functionality to improve the machine. Part of the experiment could be improved to what it thought better and consistent results.

Robotic arm machine

3d printed parts

The parts of the arms are made from PLA 3D printing filament and printed on a Flash Forge Dreamer but would be better if the parts were made from better materials such as Aluminium or Steel Alloy. This may increase the design and manufacturing cost but would make the parts more robust. Also, the dipping solutions uses Acetone in the mix and if it comes into contact with this plastic, it may deform it, contaminate the solution or damage the object being dipped. A metal would be the best for the arm elements even if the rest of the arm is made from PLA 3D printing filament.

Overheating motors

The motors would over heat if left on for long periods of time. This can be overcome by changing the motors for stronger heavier motors but the arm may not be able to support it, this is why these motors where chosen.

Vibrations

The stepper motors when they move create vibrations that would affects the arm performance. The 3d printed parts and the connections between them are not solid enough to stops this vibrations from travelling throughout the machine. The machine vibrations are sent throughout the machines arms and base, this makes the sample and the solution vibrate. This could be one of the reasons why the samples results are very sharp and jagged compare to the smooth results from the current machine. Reducing the vibrations could make these results smoother, creating a better machine and test results

Better stepper motors or smaller steps could be used to reduce the vibrations created but them. Dampener could be introduced to reduce extra vibrations throughout the machine and constructing the machine out of a stronger and stable material.

Arms locations

The controller uses a 10-bit analogue to digital converter (ADC) to read the potentiometer, but this was not high enough resolution to properly read them. This resulted in the arms joints being up to 25mm out of position with resultant incorrect functionality of the arm when the program is run. This was one of the main problems with the robotic arm, therefore the robotic arm was stopped temporally until more time could be gained (if there was any lift).

A higher analogue to digital converter (ADC) could have been used to read the potentiometer to return the correct position but it would still have some small error. The ideas of using an encoder with 360 encoders was thought to be the best ideas but it was using to many resources on the controller. The machine would move the joins until each joint change the encoder value, this indication that that joint was at that position. It also need to be rest every time it need to find the position, it can't keep track of itself as frequently as the potentiometer. The potentiometer could incorporate this finding on it but the potentiometer my not be 100% even across the range.

Positions of the sample

The arm could have calculated the position of the sensor but could not sense if the sensor bumped into any object. This could damage the sample. A complete redesign and rethink will be needed to fix this. There are no thoughts about how to fix this currently.

Overall

Sadly, the new machine incorporating the robotic arm needs work so it can facilitate testing at 45° and other dipping functions.

Dipping (vertical travel) machine

Comparison to current machine

The current machine is smoother in how it runs but the new machine can be improved to run smoothly like the current machine. Whilst there are many problems with this new machine but it has been proven to work in essence and with work to eliminate the identified flaws, it is perceived that its additional features can help improve the coat technique. It is also perceived that ultimately, with work, the new machine can be superior and most cost effective than other dip coaters on the market.

3d printed parts

The parts of the arms are made from PLA 3D printing filament and printed on a Flash Forge Dreamer but would be better if the parts were made from better materials such as Aluminium or Steel Alloy. This may increase the design and manufacturing cost but would make the parts more robust. Also, the dipping solutions uses Acetone in the mix and if it comes into contact with this plastic, it may deform it, contaminate the solution or damage the object being dipped. A metal would be the best for the arm elements even if the rest of the arm is made from PLA 3D printing filament.

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The motors would over heat if left on for long periods of time. This can be overcome by changing the motors for stronger heavier motors but the arm may not be able to support it, this is why these motors where chosen.

Positions of the sensor

The arm could calculator the position of the sensor but could not sense if the sensor bumped into any object. This could damage the sample. A complete redesign and rethink will be needed to fix this. There are no thoughts about how to fix this currently

There could be a sprint sensor off the rotation stepper motor, but this could be problematic with the vibrations throughout the arm and sample holder

Bearing rotation holder

As the sample rotates it does not rotate directory on the spot as intended to. This is because the holding coming off the axle of the stepper motor is not straight. This could have made the results different to if it was straight. If it was straight, the results could be better or worse. It could be give better consistently with the different samples but the effect of it not being straight could have given this result and if it does not rotate like this, the surface tension could be different making different results.

This could be fixed and tested by adding a set of bearing to hold the holder in place with it rotates around. A off cantered holder could be made for more experimentation.

Vibration

The stepper motors when they move create vibrations that would affects the arm performance. The 3d printed parts and the connections between them are not solid enough to stops this vibrations from travelling throughout the machine. The machine vibrations are sent throughout the machines arms and base, this makes the sample and the solution vibrate. This could be one of the reasons why the samples results are very sharp and jagged compare to the smooth results from the current machine. Reducing the vibrations could make these results smoother, creating a better machine and test results

Better stepper motors or smaller steps could be used to reduce the vibrations created but them. Dampener could be introduced to reduce extra vibrations throughout the machine and constructing the machine out of a stronger and stable material.

The working area

The working and dipping area of this machine is limited to the size of the rods and screw thread. The current machine has a much larger working and dipping area but cannot be increased or decreased. The new machine is annoying to work with unless a smaller beaker is used, or the working/ dipping height is increased. Once the beaker is under the sample ready for dipping, then the machine works fine but it is the removing of the sample holder and the removing of the beaker that gets annoying.

Screw thread

The machine uses a screw thread to move the arm up and down to make the sample dip into the solution. The current machine uses a metal wire to pull a block of metal up and down. The wire is good because when the block hits something that in the way like the side of the beaker, it stops and does not continue. The screw thread would want to continue and could break the beaker if it was in the way. This can be overcome with sensors to indicates that there is something in the way of the arm and cannot continue. There is already a senor wire setup it just need a senor attach and placed somewhere on the arm.

Overall

This machine does works and almost equal to the current machine. There are some problems that will need to be fixed to make this machine perform better but there are other problem/upgrades that could make this machine much better than the current machine. This machine could be better than dipping machines on the market because of the features that it can perform.

Experiment

The silicon sensors

The silicon sensors are capacitors sensors which are very small and hard to handle without damaging or marking them after cleaning. Some of the sensors on the silicon wafer were not etched properly and therefore unable to be used. The sensors were getting dipped into an Acrylic mix which can be cleaned by Acetone. Cleaning the sensors is hard because it is difficult to gauge when it is 100% cleaned and how much this will affect it. Figure 10.1 silicon sensor is the sensor that has been dipped into the solutions and Figure 10.2 silicon sensor close-up is a close-up of a semi-cleaned sensor. The tracks can be seen to form the capacitor. The specks on the sensors is dust and other dirty, this sensor is not clean and is not ready for dipping

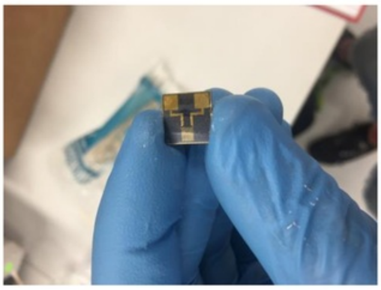


Figure 10.1 silicon sensor

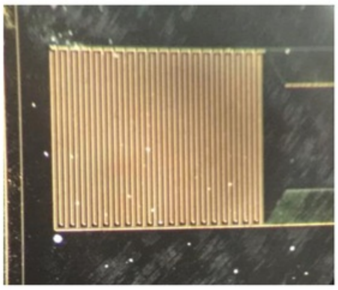


Figure 10.2 silicon sensor close-up

The Printed circuit board (PCB) Samples

The printed circuit board was not getting coated and when analysed showed about the same as if it was not coated. Figure 10.3 is the PCB sensors without the coating and Figure 10.4 is PCB with a coating. As it can be seen in Figure 10.4, the sensor was only lightly coated, not enough to make a difference.

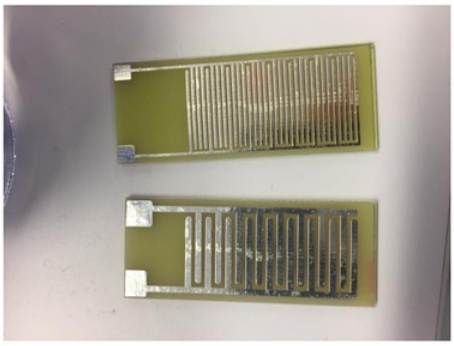


Figure 10.3 sensor without coating

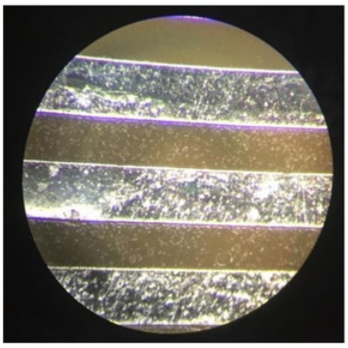


Figure 10.4 PCB sensor with coating

The rotation of the sample

The rotation of the samples can change the coat but it is unknow it if it thickness or how the coat is applied. The electron microscope could show if can determined the thickness of the coat. The analysing that was done in the results was from a LCR meter to determine the impedance and hoe it differs from the different settings. From the LCR meter is was determine that the coat was changing consistently. From the samples sets the speed of rotations and the speed of the dipping can control the same impedance over the frequency range when it dips. There is no distinctive difference from controlling the rotation from the dipping speed. Both reline on the speed to change the impedance. The decent of impedance over frequency is at the same rate (does float a bit), showing they can both be used to change the impedance. The benefit of the rotation could be the mixing of the solution when dipped.

The 45 degrees samples

The 45 degrees angled sample set had a surprising result with the decent of the impedance over frequency increasing. This samples set all had shaper decent than another sample set that where dipped and tested. Exploring this would be interesting to create a new method that can create this without placing the sample on its side. This may be able to be achieved with a point on the bottom of the sample.

Electron microscope

Sadly, there are no results from the electron microscope at this presently at this time of creating this document.

First dip not mixed properly

When testing the machine, as the sample was getting dipped, it was not getting coated. While the sample was getting dipped, all the polymer solution sank to the bottom of the beaker and did not attach to the sample. It was unknow why this it but when the solution was mixed then immediately dipped after mixing, the sample was coated. If it was mixed then the machine dipped the polymer would sick before the machine would dip the sample. It could have been the too much acetone in the solution making it too thin for the acrylic to stick and the polymer to get stuck in the acrylic.

By making the mix more concentrated, the polymer would stick and all samples were dipped using a high concentrated mixed. For the thinner mixes, there was a thought of adding a magnetic mixer to stir the mix up more but the high concentrated works and this was not needed.

clean room and contamination

The results of the samples were sometime a bit off and this could have been caused by contaminations like dust, dirty and leftover substance from other dips. This can be prevented with the use of a clean room with remove airborne contaminants like dust. Clean beakers and cleaned samples would help to stop contaminants on these surfaces.

evaporation

while dipping the samples, the acetone in the mix was evaporation changing the concentration of the mix. This would affect the results of the samples but it is unknow by how much it did. This is a variable that is hard to control unless all the samples could be dipped at the sample time. This could be overcome by mixing the solution every time before the dip but this would be a waste of the dipping solution materials.

EMF radiation and analysing jig

The analysing jig is mad of printed circuit board (PCB) Stripboard and some connectors to hold and connect to the sample. This can be seen in Figure 10.5 analysing jig and Figure 10.6 analysing jig. Theses connectors are then attached to the LCR meters clips. The position of the sensor on the contacts changes every time it is connect. It was hard to get the sample in the same position every time but will all ways be out but some amount. This may have made the results different from the value of the sensors. There is not shielding from any electric and magnetic fields radiation (EMF) this could have also changed the results from the value of the sensor.

A better jig including alinement tool with connectors that get place in the same spot would make it more consistent. Having a faraday cage around the test jig would help reduces electric and magnetic fields radiation (EMF) and get consistent results.

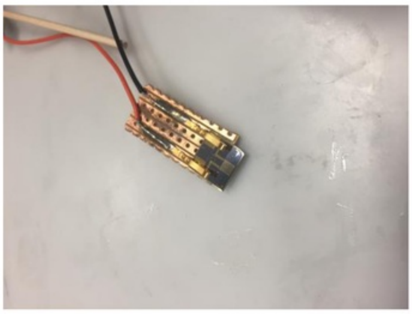


Figure 10.5 analysing jig

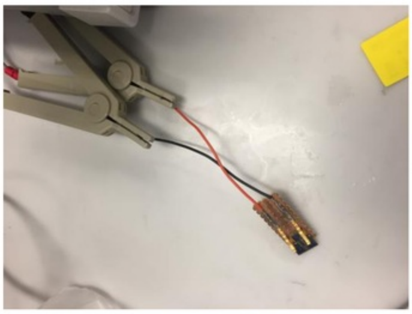


Figure 10.6 analysing jig

Sensors are different

Since the silicon sensors are so small, any slight difference between the sensors have a huge capacitive difference make the sensor unique and different. For some of the data set it was required to use difference sensors to, this would have made the results for that samples set not as defined as the other sets that used one sensor. This could be changed but that would require multiple trips to the electron microscope which is not easily done. It was better to dip multiple sensors and analyse it from before it was dipped.

Future machine upgrades

The following items could be future upgrades for the machines for control and ease of use.

SD program for vertical travel machine

Like the robotic arm, it would be good if there was a function to load a program or set dipping function from the SD to perform the dipping required. This will save time from setting all the setting required for the dips.

USB, Wi-Fi and ethernet connection

To make it easier for the user to use the machine, connection to a computer via USB or internet connection. This would be able to program the machine with better control and faster interface. Programming to the SD without removing would be a benefit.

11. Conclusions

Three different dipping devices were produced to explore the development of the dipping coat thickness and uniformity during the dipping process and understand the resultant outputs. The first based around Robotic Arm technology (Figure 11.1). The second was an attachment and modifications to the existing dipping machine to confirm the prototype design of Vertical Travel Machine to the University machine. the thirds is a vertical travel machine (Figure 11.2). The robotic arm machine aimed to offer even greater flexibility in dipping with more options could be trialled to attain the thickness and uniformity of the coat could be analysed.

There is a relationship between rotation/dipping speed and impedance. Not one as much to separate the different motions unless there is difference shown un the electron microscope. Rotation and dipping speed can be used together to change the impedance. Change the rotation speed it shown to change the impedance more reliably that dipping speed. There are good promises for the 45 degrees samples set with distinct difference of impedance over frequency than the other dipping sample sets.

Sadly, there are no results from the electron microscope in this document.

Figure 11.1 robotic arm machine

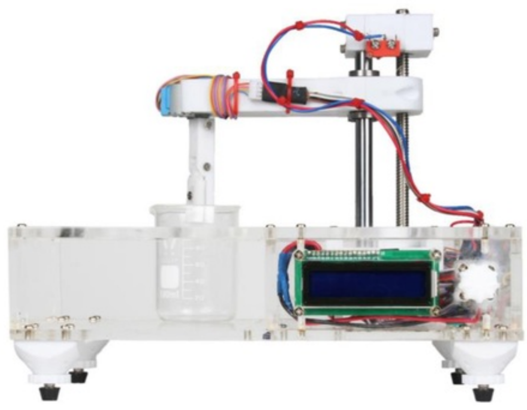
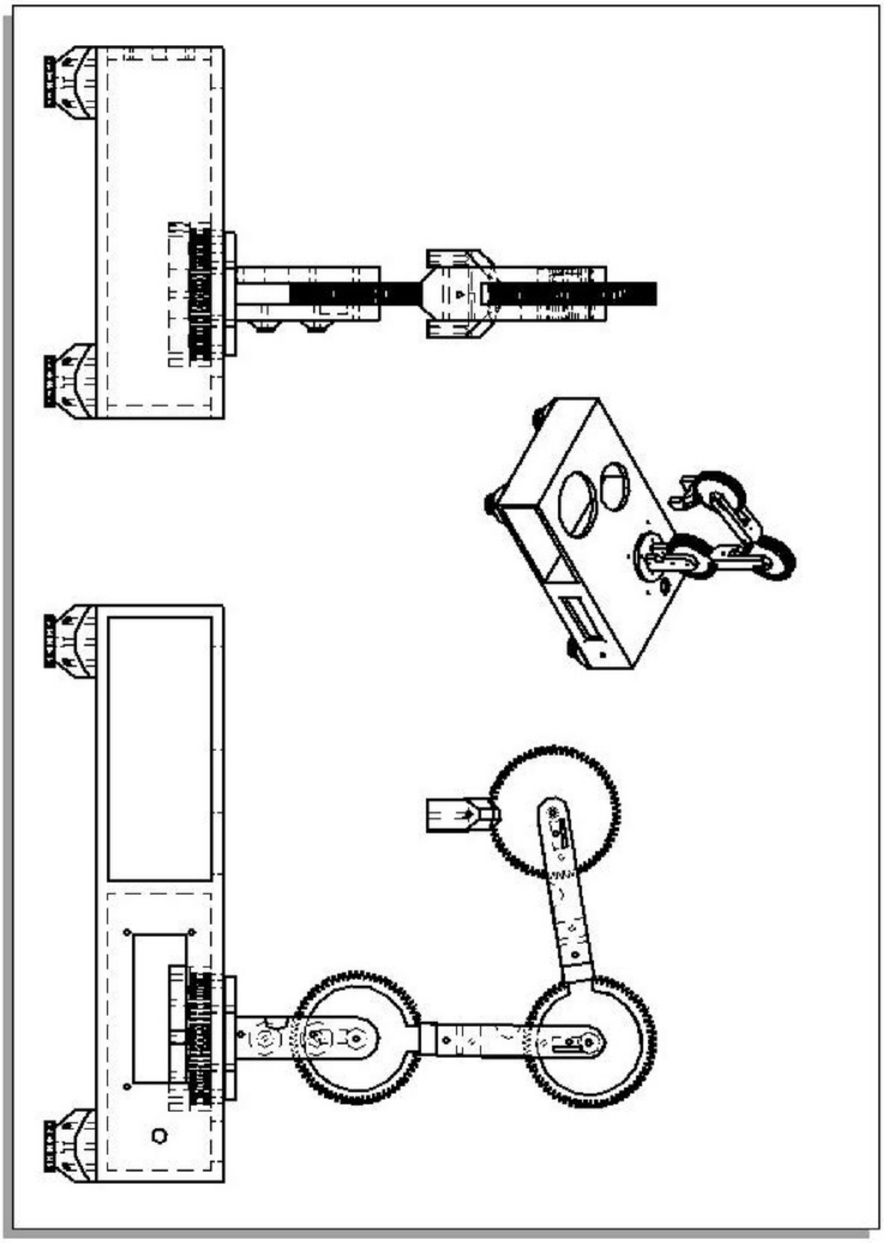


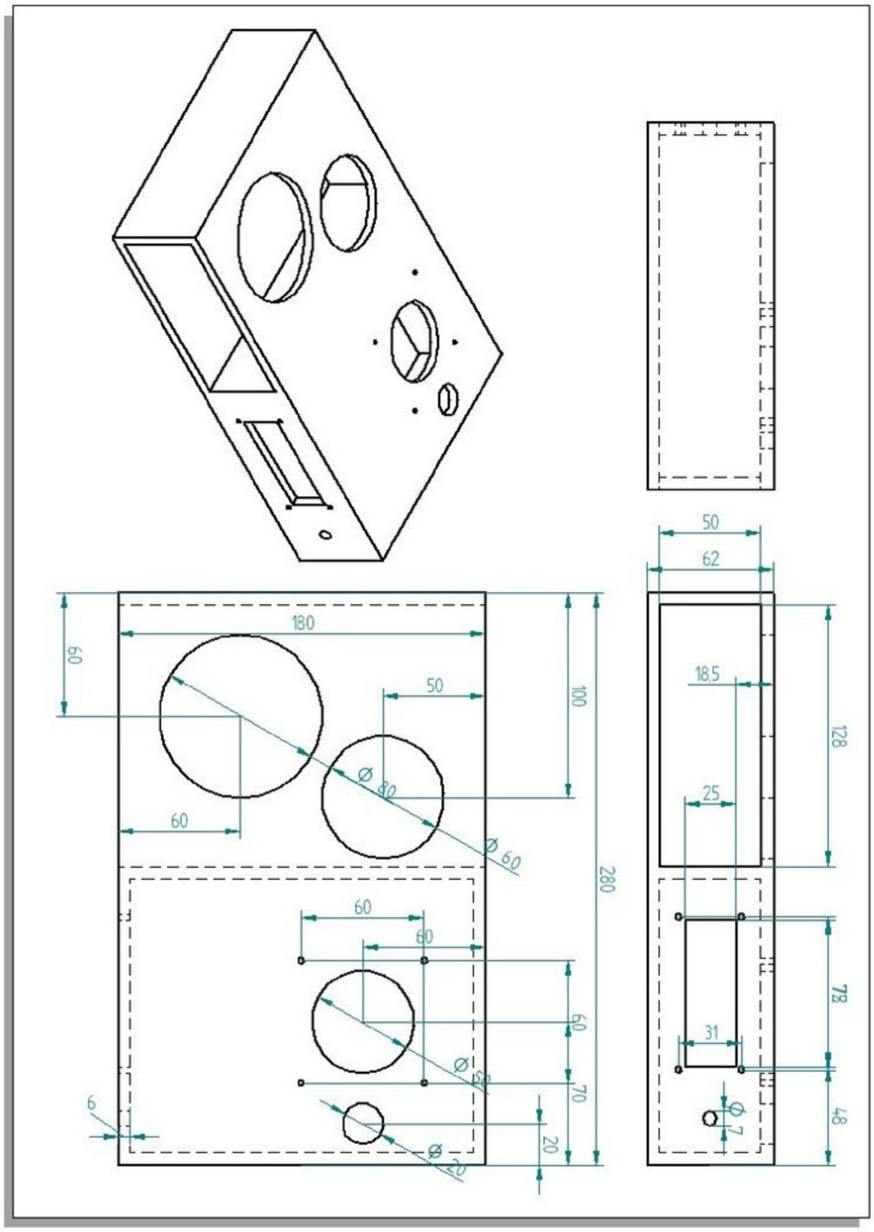
Figure 11.2 Dipping (vertical travel) machine and base

12. Appendix A – Robotic arm design

Assembly

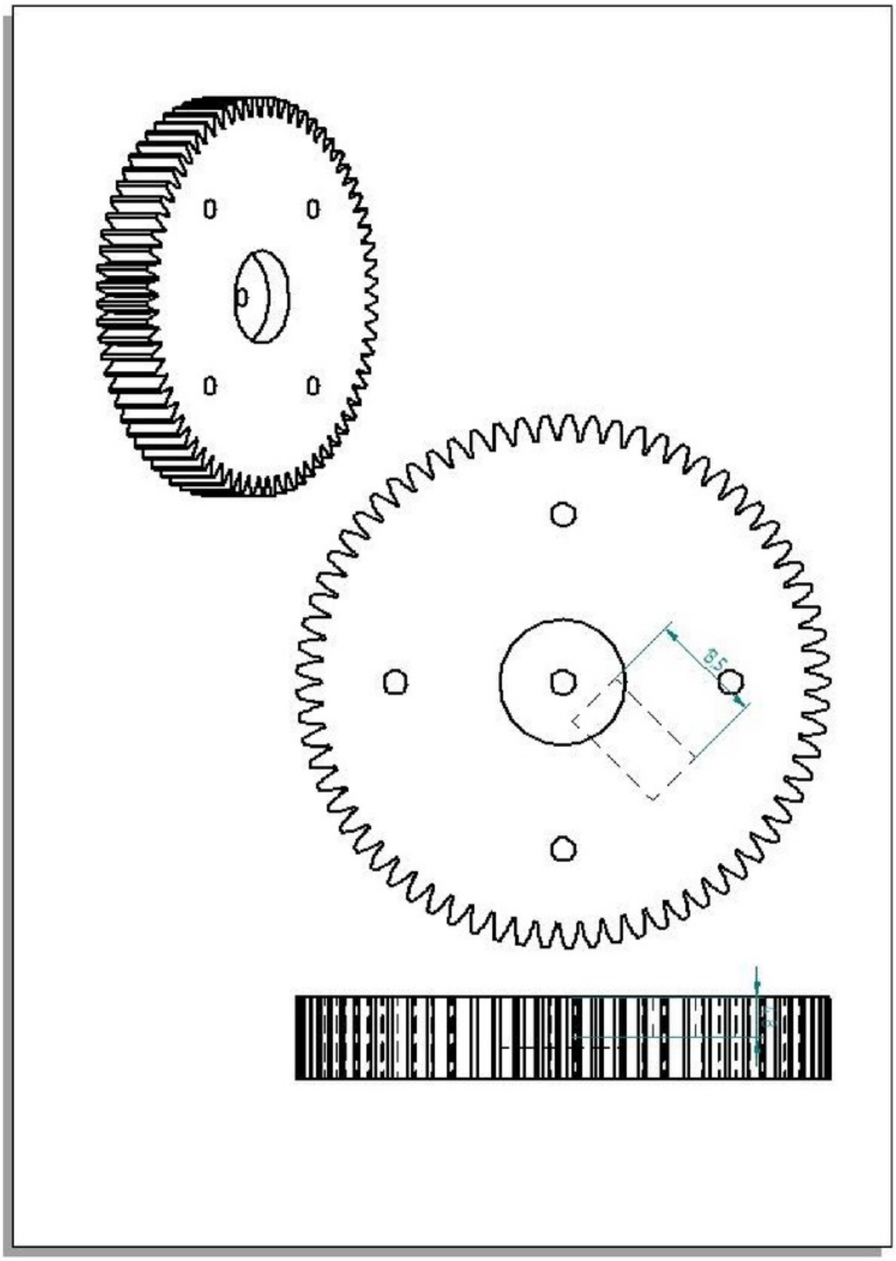


Base/case

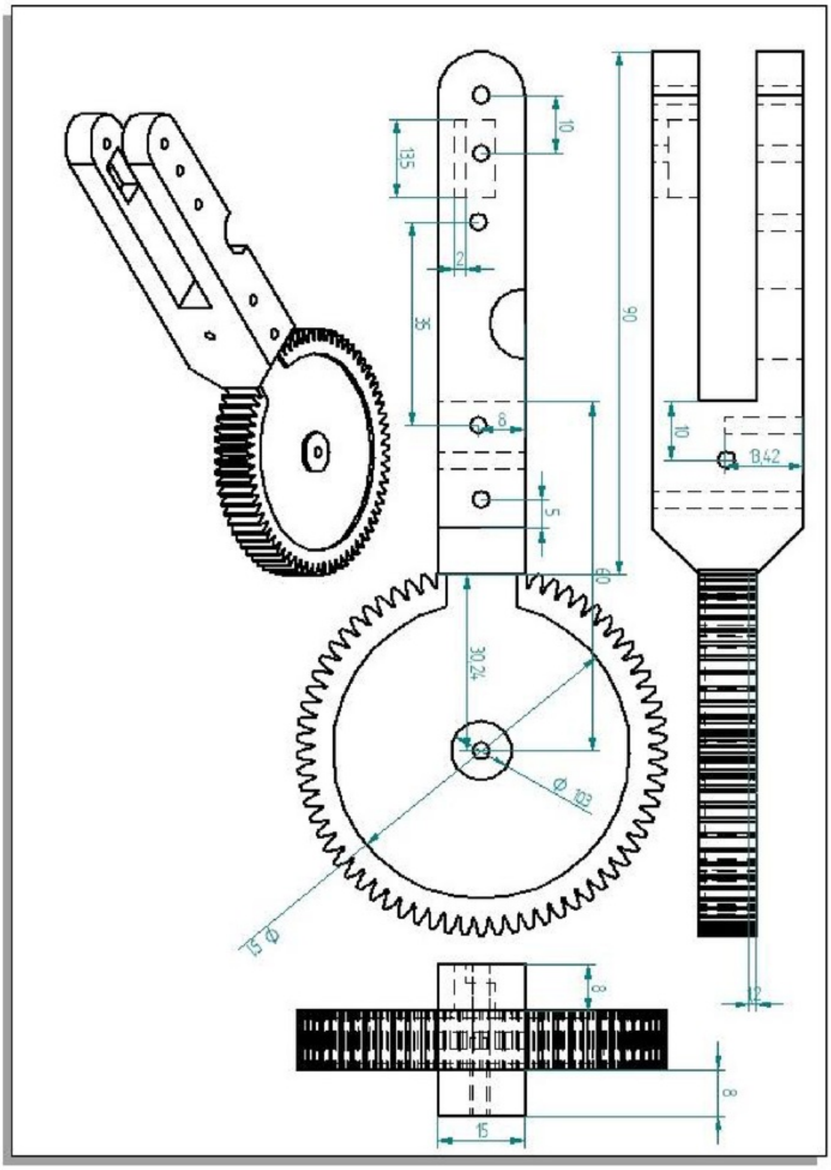


180
50
60
60
100
280
Ø 80
Ø 60
60
60
60
70
Ø 50
20
Ø 20
6
50
62
18.5
128
25
78
31
48
Ø 7

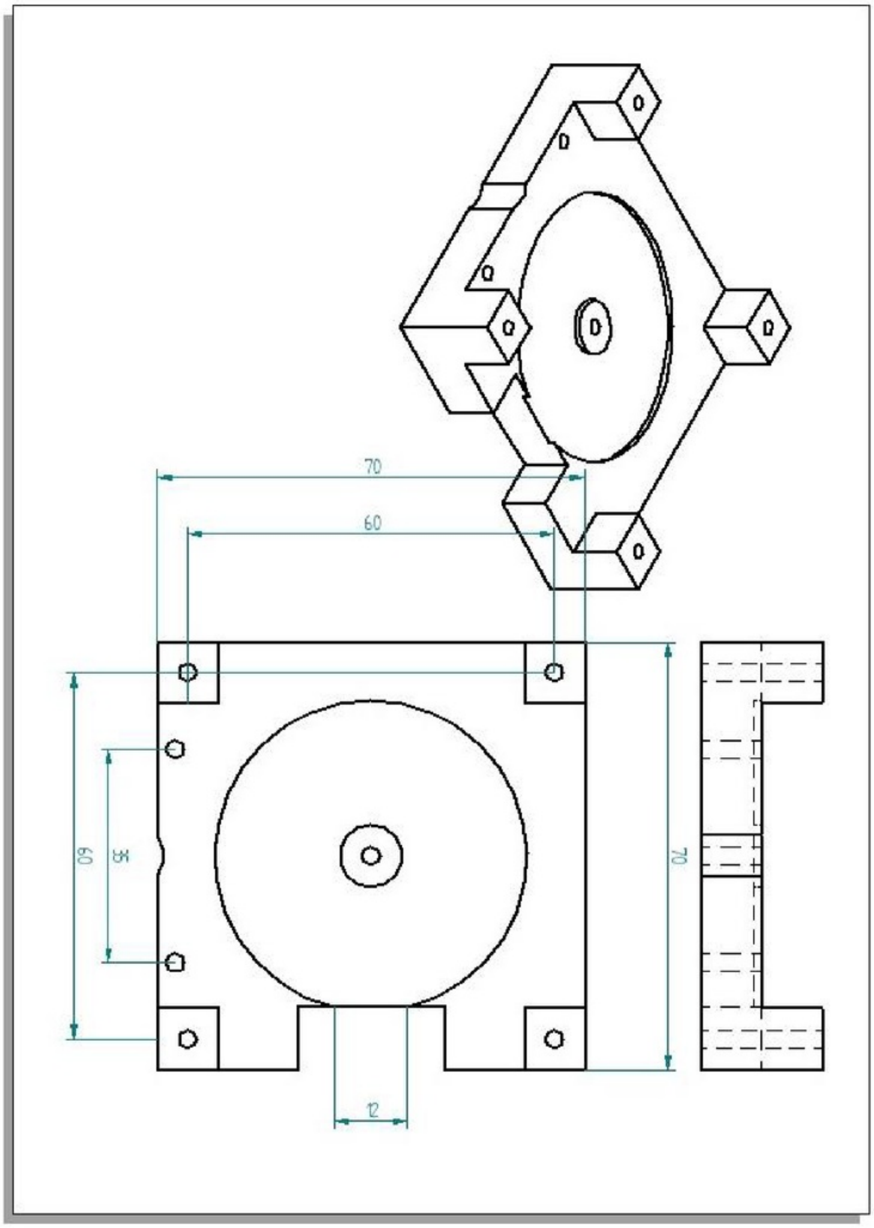
Base gear part



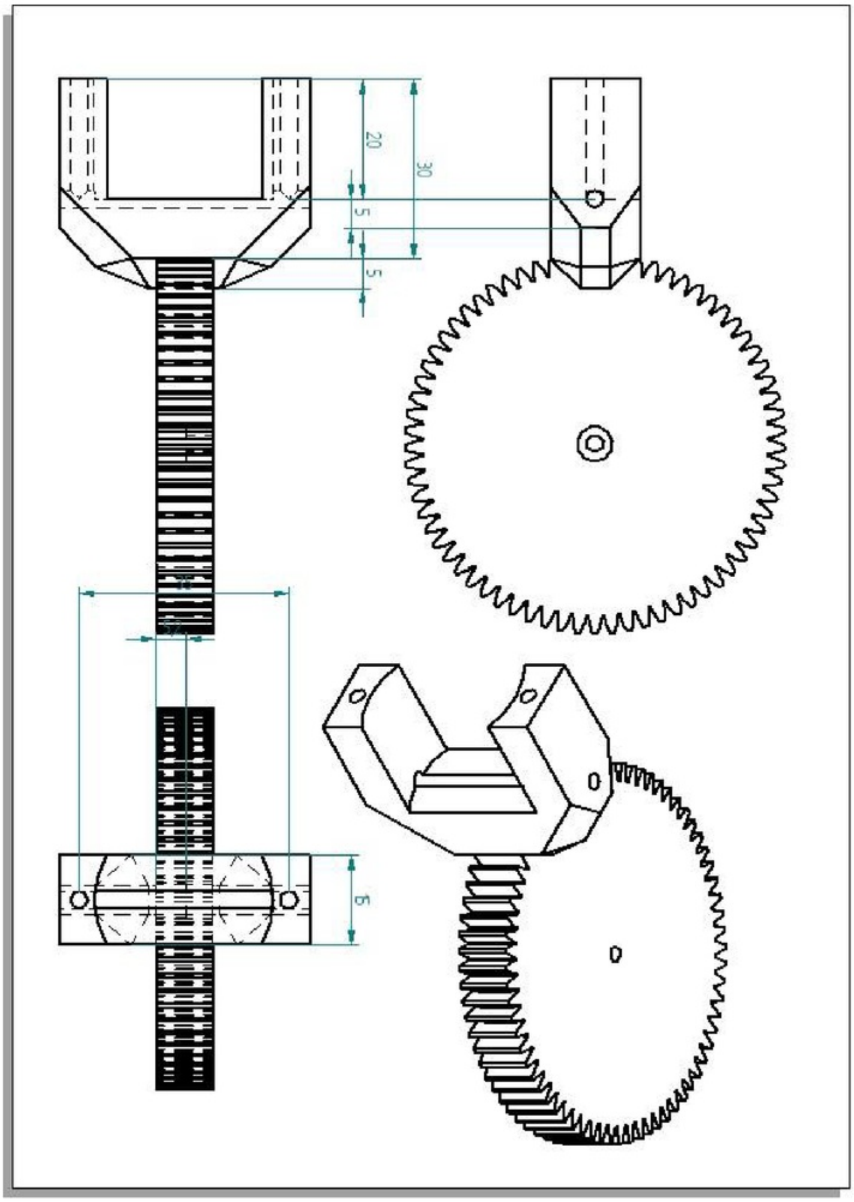
Middle arm part



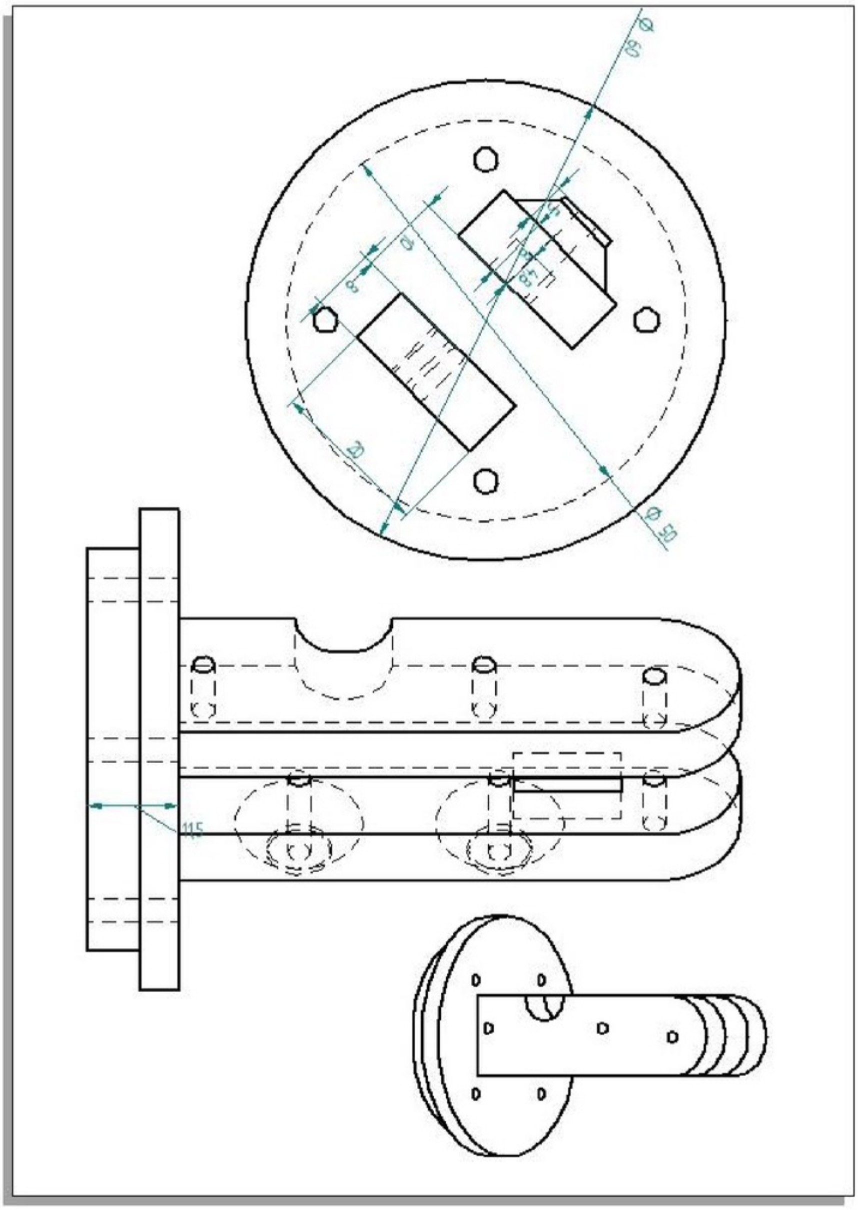
Base mount part



End arm part

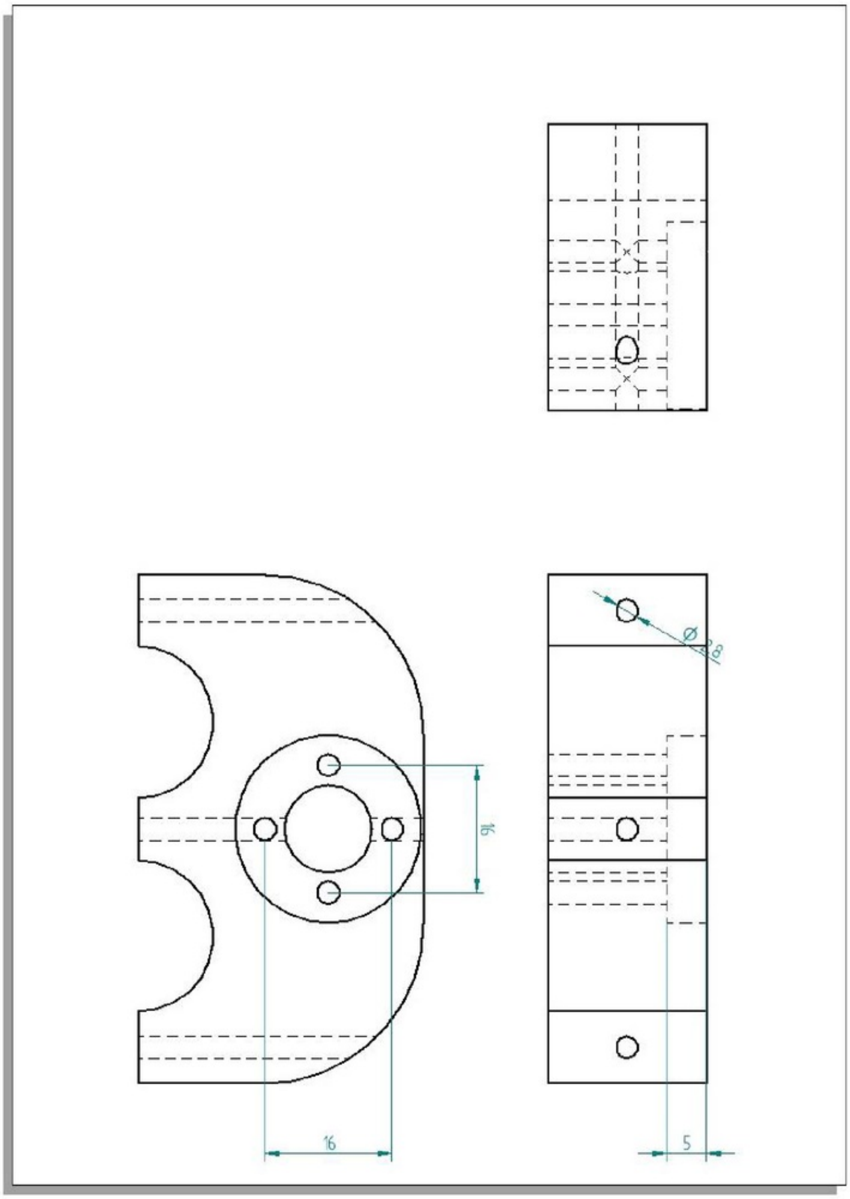


First arm part

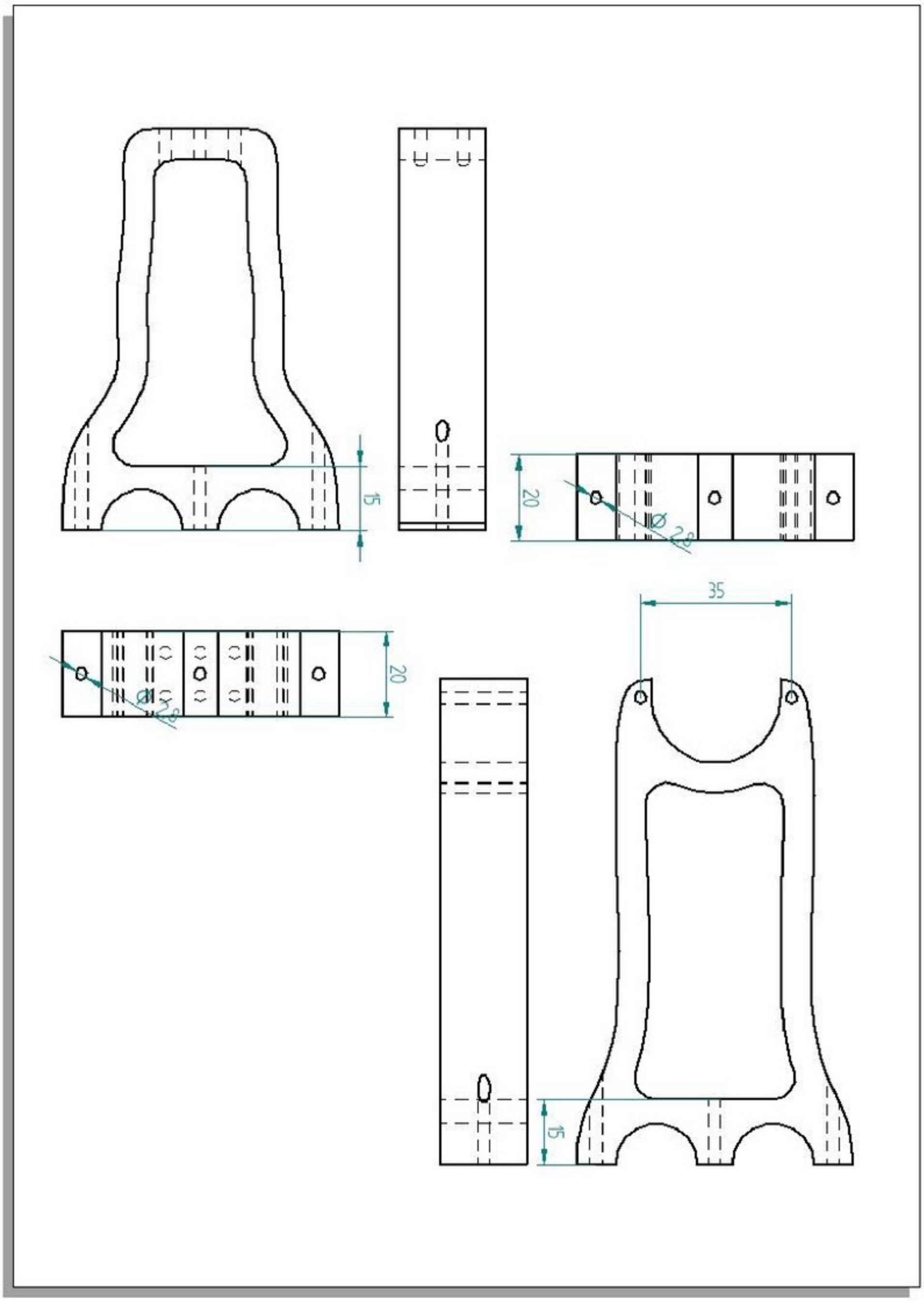


13. Appendix B – Dipping (vertical travel) machine design

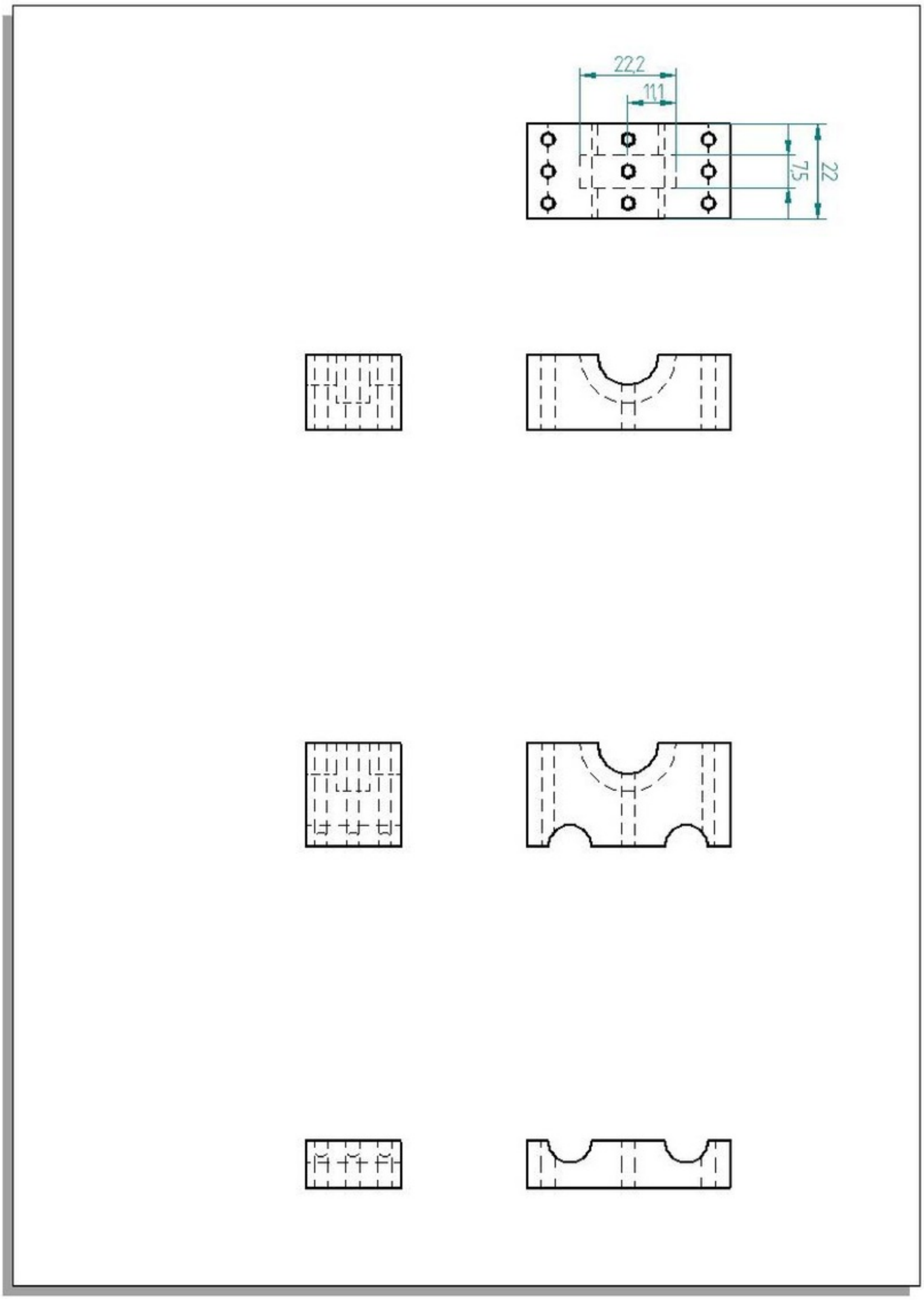
Sliding arm part 1



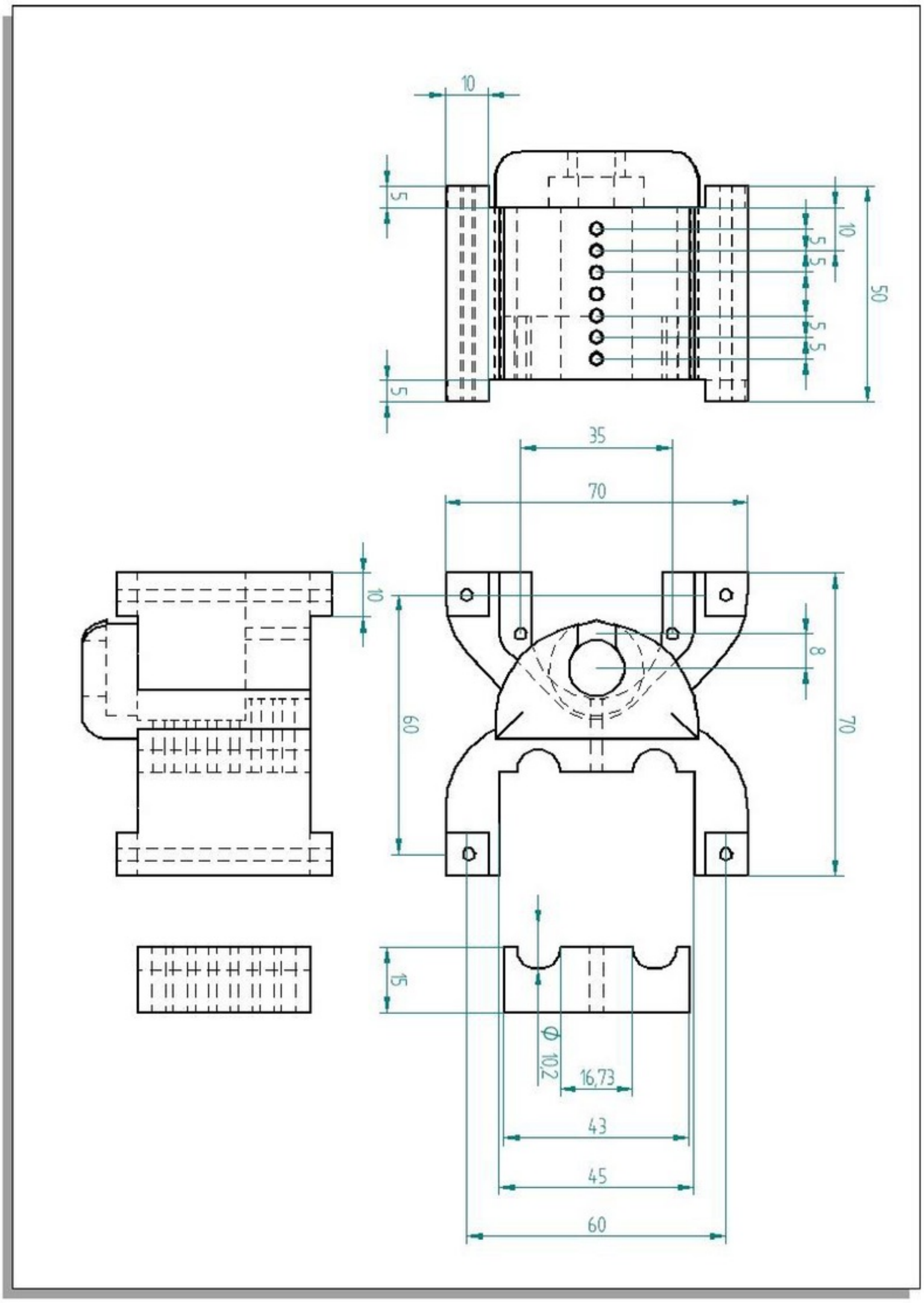
Sliding arm part 2



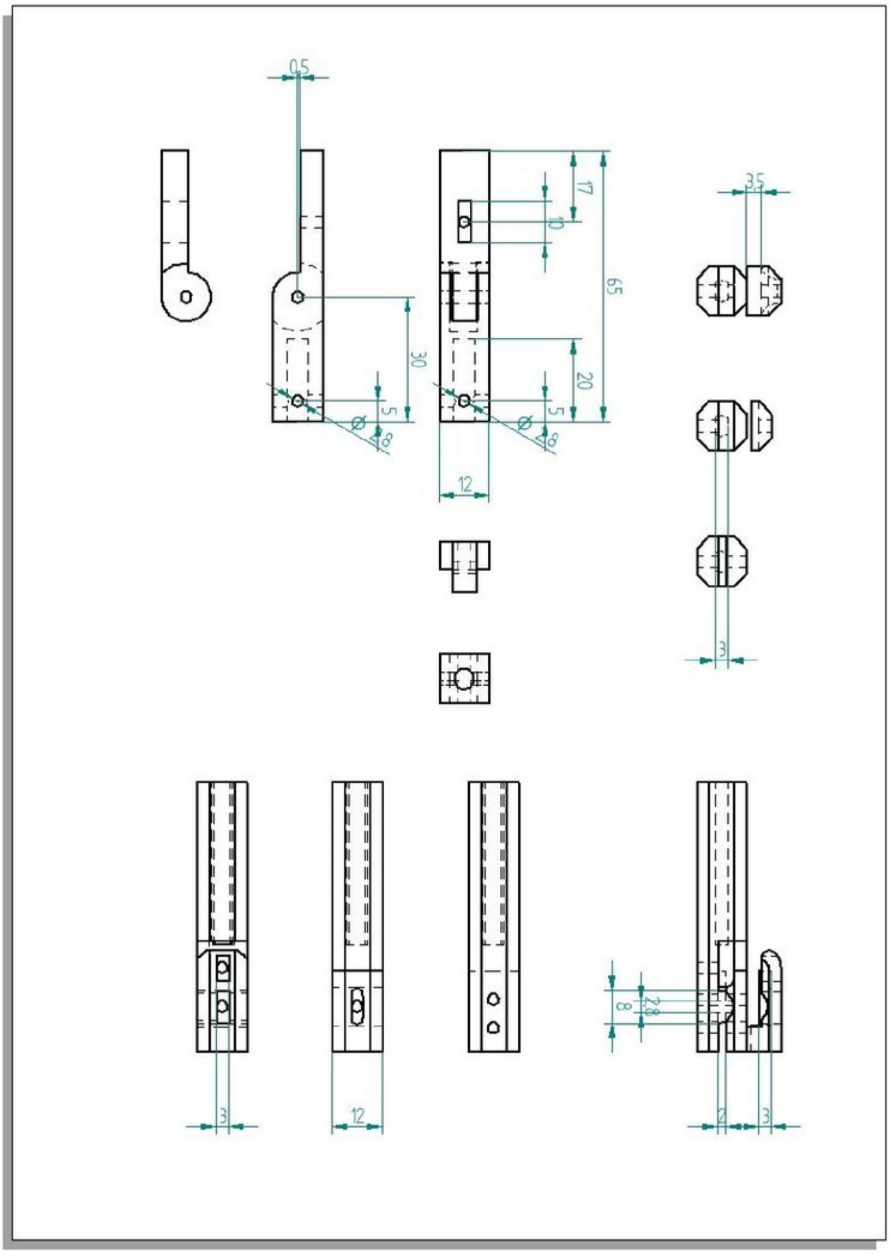
Top rod mounts



Bottom rod and motor mounts



14. Appendix C – Dipping holder design



15. Appendix D – Robotic arm program

```
#include <SPI.h>
#include <SD.h>
#include <LiquidCrystal.h>
#include <AccelStepper.h>
#include <Plex.h>
#include <math.h>

#define DistancesA 112.74
#define DistancesB 112.74
#define MaxAngleDegreesA 180
#define MaxAngleDegreesB 90
#define MaxAngleDegreesC 90
#define MinAngleDegreesA 0
#define MinAngleDegreesB -90
#define MinAngleDegreesC -90
#define MaxAngleValueA 907
#define MaxAngleValueB 867
#define MaxAngleValueC 914
#define MinAngleValueA 166
#define MinAngleValueB 156
#define MinAngleValueC 169
#define offsetValueA 225 //45
#define offsetValueB 127
#define offsetValueC 134
#define pi 3.14
#define steps 19
#define maxSpeed 100

#define JointR 6
#define JointA 0
#define JointB 3
#define JointC 4
#define JointE 1

#define encoderA 2
#define encoderB 5
#define encoderC 7 //button

double Xvalue = 100;
double Yvalue = 100;
double Rvalue = 0;
double Evalue = 0;
double Cvalue = 0;
double Svalue = 100;
double Dvalue = 0;

AccelStepper stepperR;
AccelStepper stepperA;
AccelStepper stepperB;
AccelStepper stepperC;
AccelStepper stepperE;

LiquidCrystal lcd(2, 4, 5, 6, 7, 8);

File dir;
File Files;
int encoder0Pos = 0;
int encoder0PinALast = LOW;

unsigned long currentPosInFile = 0;
bool Running = false;
int fileID = -1;
 long inPos = 0;

void setup()
{
 setupPlex();
 lcd.begin(16, 2);
 pinMode(A4, OUTPUT);
 digitalWrite(A4, HIGH);

 while (!SD.begin(10))
 {
  lcd.setCursor(0,0);
  lcd.print("Card failed");
  lcd.setCursor(0,1);
  lcd.print((int)positionX(angleA(),angleB()));
  lcd.print(" ");
  lcd.print((int)positionY(angleA(),angleB()));
  lcd.print("   ");
 }

 Xvalue = positionX(angleA(),angleB());
 Yvalue = positionY(angleA(),angleB());

 stepperR = AccelStepper(1,PinD,19);
 stepperR.setMaxSpeed(maxSpeed);
 stepperR.setAcceleration(1000000.0);
 stepperR.setCurrentPosition(angleR()*steps);

 stepperA = AccelStepper(1,PinD,19);
 stepperA.setMaxSpeed(maxSpeed);
 stepperA.setCurrentPosition(angleA()*steps);
 stepperA.setAcceleration(1000000.0);

 stepperB = AccelStepper(1,PinD,19);
 stepperB.setMaxSpeed(maxSpeed);
 stepperB.setCurrentPosition(angleB()*steps);
 stepperB.setAcceleration(1000000.0);

 stepperC = AccelStepper(1,PinD,19);
 stepperC.setMaxSpeed(maxSpeed);
 stepperC.setCurrentPosition(angleC()*steps);
 stepperC.setAcceleration(1000000.0);

 stepperE = AccelStepper(1,PinD,19);
 stepperE.setCurrentPosition(0);
 stepperE.setMaxSpeed(maxSpeed);
 stepperE.setAcceleration(1000000.0);
}

void loop()
{
 if(digitalReadC(encoderC))
 {
  while(digitalReadC(encoderC))
  {
   if(Running)
   {
    runsteps();
   }
  }
  Running = !Running;
  currentPosInFile = 0;
  delay(200);
  return;
 }

 if(Running)
 {
  digitalWrite(A4, LOW);
  runsteps();
  if(hasFinshedStepping() && hasFinshedRun())
  {
   PrintFileName(Files);
   NextData();
  }
  else if(hasFinshedStepping())
  {
```

```
      setmotors();
    }
  }
  else
  {
    digitalWrite(A4, HIGH);
    int encoderID = encoder();
    if(fileID != encoderID)
    {
      fileID = encoderID;
      if(encoderID<0)setEconder(0);
      Files = getFile(encoderID);
      if(Files) PrintFileName(Files);
      else if(encoderID>0) setEconder(encoderID-1);
    }
  }
}


/***************** RUN MOTORS *****************/

bool hasFinshedStepping()
{
   return (!stepperA.distanceToGo()
&&!stepperB.distanceToGo() &&!stepperC.distanceToGo()
&&!stepperR.distanceToGo());
}

bool hasFinshedRun()
{
  double CurrentY =
positionY(stepperA.position()/steps,stepperB.position()/steps);
  double CurrentX =
positionX(stepperA.position()/steps,stepperB.position()/steps);
  return CurrentY == Yvalue && CurrentX == Xvalue;
}

void runsteps()
{
  selectD(JointR);
  stepperR.run();
  selectD(JointA);
  stepperA.run();
  selectD(JointB);
  stepperB.run();
  selectD(JointC);
  stepperC.run();
  selectD(JointE);
  stepperE.run();
}

void dalayrun(int delay)
{
  unsigned long currenttime = millis();
  while(currenttime+delay > millis())
  {
    selectD(JointE);
    stepperE.run();
  }
}


/****************** SET MOTORS ******************/

void setmotors()
{
  double CurrentYvalue =
positionY(stepperA.position()/steps,stepperB.position()/steps);
  if(Yvalue>CurrentYvalue)
  {
    CurrentYvalue += 1 - Yvalue%1;
  }
  else
  {
    CurrentYvalue -= 1 + Yvalue%1;
  }
  double CurrentXvalue =
positionX(stepperA.position()/steps,stepperB.position()/steps);
  if(Xvalue>CurrentXvalue)
  {
    CurrentXvalue += 1 - Xvalue%1;
  }
  else
  {
    CurrentXvalue -= 1 + Xvalue%1;
  }

  double currentA =stepperA.currentPosition();
  double currentB =stepperB.currentPosition();
  double currentC =stepperC.currentPosition();

  double displacement =
CalDisplacement(CurrentXvalue,CurrentYvalue,positionX(curre
ntA/steps,currentB/steps),positionY(currentA/steps,currentB/ste
ps));
  double time = CalTime(displacement,Svalue);

  float jointB = CalB(CurrentXvalue,CurrentYvalue);
  float jointA = CalA(CurrentXvalue,CurrentYvalue,jointB);
  float jointC = CalC(jointA,jointB);

  jointA = jointA*57.296*steps;
  jointC = jointC*57.296*steps;
  jointB = jointB*57.296*steps;

  double jointSpeedA = CalSpeed(currentA,jointA,time);
  double jointSpeedB = CalSpeed(currentB,jointB,time);
  double jointSpeedC = CalSpeed(currentC,jointC,time);

  stepperA.setMaxSpeed(jointSpeedA);
  stepperB.setMaxSpeed(jointSpeedB);
  stepperC.setMaxSpeed(jointSpeedC);
  stepperE.setMaxSpeed(Evalue);
  stepperA.moveTo(jointA);
  stepperB.moveTo(jointB);
  stepperC.moveTo(jointC);
  stepperE.moveTo(100000);

  lcd.clear();
  lcd.setCursor(0,0);
  lcd.print((int)Xvalue);
  lcd.print(' ');
  lcd.print((int)Yvalue);
}

float CalA(double x,double y,float B)
{
  double k1 = DistancesA+DistancesB*cos(B);
  double k2 = DistancesB*sin(B);
  return  atan2(y,x) - atan2(k2,k1);
}

float CalB(double x,double y)
{
  float c = (x*x+y*y-DistancesA*DistancesA-
DistancesB*DistancesB)/(2*DistancesA*DistancesB);
  float s = sqrt(1-c*c);
  if(x>0) s = -s;
  return atan2(s,c);
}

float CalC(float a,float b)
{
  if(a>pi/2 && b>0)
  {
    return (pi/2+a-abs(b))-Cvalue/57.296;
  }
  else
  {
```

```
    return -(pi/2+a-abs(b))+Cvalue/57.296;
  }
}

double CalDisplacement(double x1, double y1,double x2,
double y2)
{
  return sqrt((x2-x1)*(x2-x1)+(y2-y1)*(y2-y1));
}

double CalTime(double displacement, double speed)
{
  return abs(displacement)/speed;
}

double CalSpeed(long currentPosition, long position, double
time)
{
  return abs(position-currentPosition)/time;
}



/****************** POSITIONS ******************/

double positionX(double a,double b)
{
return
DistancesA*cos(a/57.296)+DistancesB*cos((a+b)/57.296);
}

double positionY(double a,double b)
{
  return
DistancesA*sin(a/57.296)+DistancesB*sin((a+b)/57.296);
}

/****************** ANGLE ******************/

double angleA()
{
  double i = (MaxAngleDegreesA - MinAngleDegreesA);
  double j = (MaxAngleValueA - MinAngleValueA);
  return -i/j*analogReadC(JointA)+offsetValueA ;
}

double angleB()
{
  double i = (MaxAngleDegreesB - MinAngleDegreesB);
  double j = (MaxAngleValueB - MinAngleValueB);
  double b = i/j*analogReadC(JointB)-offsetValueB;
  return -b;
}

double angleC()
{
  double i = (MaxAngleDegreesC - MinAngleDegreesC);
  double j = (MaxAngleValueC - MinAngleValueC);
  double c = i/j*analogReadC(JointC)-offsetValueC;
  return -c;
}

double angleR()
{
  return NULL;
}



/****************** INTERFACE ******************/

int encoder()
{
  int n = digitalReadC(encoderA);
  if ((encoder0PinALast == LOW) && (n == HIGH))
  {
    if (digitalReadC(encoderB) == LOW) encoder0Pos--; else
encoder0Pos++;
  }
  encoder0PinALast = n;
  return encoder0Pos;
}

void setEconder(int val)
{
  encoder0Pos = val;
}

void PrintFileName(File entry)
{
    lcd.clear();
    lcd.setCursor(0,0);
    lcd.print(entry.name());
    lcd.setCursor(0,1);
    lcd.print(entry.size(), DEC);
}

File getFile(int number)
{
  int count = 0;
  dir = SD.open("/");
  while (true)
  {
    File entry =  dir.openNextFile();
    if (!entry.available())
    {
      return entry;
      break;
    }
    if (!entry.isDirectory())
    {
      if(number == count)return entry;
      count++;
    }
    entry.close();
  }
  return;
}

void NextData()
{
  //lcd.print(",");
  Files.seek(currentPosInFile);
  byte Decimal = 0;
  char currentCommand = 0;
  char nextCommand;
  double value;
  while (true){
    char current = Files.read();
    currentPosInFile++;
    if (current >= '0' && current <= '9' || current == '.')
    {
      switch(current)
      {
        case '0': getnumber(value,0,Decimal); break;
        case '1': getnumber(value,1,Decimal); break;
        case '2': getnumber(value,2,Decimal); break;
        case '3': getnumber(value,3,Decimal); break;
        case '4': getnumber(value,4,Decimal); break;
        case '5': getnumber(value,5,Decimal); break;
        case '6': getnumber(value,6,Decimal); break;
        case '7': getnumber(value,7,Decimal); break;
        case '8': getnumber(value,8,Decimal); break;
        case '9': getnumber(value,9,Decimal); break;
        case '.': Decimal++; break;
      }
    }
    if (current >= 'A' && current <= 'Z')
```

```
{
 if (currentCommand == 0)
 {
  currentCommand = current;
 }
 else
 {
  switch(currentCommand)
  {
   case 'X':Xvalue = value;break; // X pos
   case 'Y':Yvalue = value;break; // Y pos
   case 'R':Rvalue = value;break; // Base Rotation
   case 'E':Evalue = value;break; // End Rotation speed
   case 'C':Cvalue = value;break; // End Angle
   case 'S':Svalue = value;break; // Speed
   case 'D':Dvalue = value;dalayrun(Dvalue);break; //
Delay
  }
  Decimal = 0;
  value = 0;
  currentCommand = current;
  if (currentCommand == 'G')
   {
    setmotors();
    return;
   }
  }
 }
 }
}

void getnumber(double &val,byte number,byte &Decimal)
{
 if(Decimal>0)
 {
  val= val+number/pow(10, Decimal);
  Decimal++;
 }
 else
 {
  val= val*10+number;
 }
}
```

16. Appendix E – Dipping machine program

```
#include <LiquidCrystal.h>
#include <AccelStepper.h>
#include <Plex.h>
#include <math.h>

#define stepsHeight  259
#define stepsRotaion  64
#define maxSpeed 700
#define JointH 1
#define JointR 0
#define LimitTop 3
#define Limitbottom 4
#define encoderA 5//2
#define encoderB 2//5
#define encoderC 7 //button

long HeightValue = 0;
long HeightSpeed = 1;
long RotationSpeed = 1;
long delaytime = 0;
long timestodip = 1;

AccelStepper stepperHeight;
AccelStepper stepperRotaion;

LiquidCrystal lcd(2, 4, 5, 6, 7, 8);

long long encoder0Pos = 0;
int encoder0PinALast = LOW;

void setup()
{
 setupPlex();
 lcd.begin(16, 2);

 pinMode(A4, OUTPUT);
 digitalWrite(A4, HIGH);

 stepperHeight = AccelStepper(1,PinD,19);
 stepperHeight.setMaxSpeed(maxSpeed);
 stepperHeight.setAcceleration(10000.0);
 stepperHeight.setCurrentPosition(0);
 stepperHeight.setPinsInverted(1,0,0);

 stepperRotaion = AccelStepper(1,PinD,19);
 stepperRotaion.setMaxSpeed(maxSpeed);
 stepperRotaion.setAcceleration(10000.0);
 stepperRotaion.setCurrentPosition(0);
 stepperRotaion.setPinsInverted(1,0,0);

 resetmachine();
}

void loop()
{
 bool menu = encoder()%2;
 if(menu)
 {
  lcd.setCursor(0,0);
  lcd.print("> Auto      ");

  lcd.setCursor(0,1);
  lcd.print("  Manual      ");
 }
 else
 {
  lcd.setCursor(0,0);
  lcd.print("  Auto      ");

  lcd.setCursor(0,1);
  lcd.print("> Manual      ");
 }

 if(digitalReadC(encoderC))
 {
  while(digitalReadC(encoderC)){}
  setEconder(0);
  if(menu)
  {
   Auto();
  }
  else
  {
   Manual();
  }
  while(digitalReadC(encoderC)){}
  setEconder(menu);
 }
}

/****************** RUN MOTORS ******************/

void RunDip()
{
 while(digitalReadC(encoderC)){}
 resetmachine();

 lcd.setCursor(0,0);
 lcd.print("    RUNNING!    ");

 digitalWrite(A4, LOW);
 for(int i=0;i<timestodip;i++)
 {
  setmotors();
  stepperHeight.move(HeightValue*stepsHeight);

  while(!digitalReadC(encoderC) &&
stepperHeight.distanceToGo()!=0)
  {
   runsteps();
  }

  dalayrun(delaytime*1000);
  stepperHeight.move(-300);
  while(!hasFinshedStepping())
  {
   stepperHeight.move(-300);
   runsteps();
  }
  stepperHeight.setCurrentPosition(0);

 }
 digitalWrite(A4, HIGH);
 while(digitalReadC(encoderC)){}
}

void RunUp()
{
 setmotors();
 digitalWrite(A4, LOW);
 stepperHeight.setCurrentPosition(0);
 stepperHeight.move(-300);
 while(digitalReadC(encoderC))
 {
  stepperHeight.move(-300);
  runsteps();
  lcd.setCursor(12,0);
  lcd.print(positionhight());
 }
 digitalWrite(A4, HIGH);
}
```

```
void RunDown()
{
 setmotors();
 digitalWrite(A4, LOW);
 stepperHeight.setCurrentPosition(0);
 stepperHeight.move(300);
 while(digitalReadC(encoderC))
 {
  stepperHeight.move(300);
  runsteps();
  lcd.setCursor(12,0);
  lcd.print(positionhight());
 }
 digitalWrite(A4, HIGH);
}

bool hasFinshedStepping()
{
  return (!(stepperHeight.distanceToGo()) ||
digitalReadC(LimitTop) || digitalReadC(Limitbottom));
}

void runsteps()
{
 selectD(JointH);
 stepperHeight.run();
 selectD(JointR);
 stepperRotaion.run();
 stepperRotaion.move(100);
}

void resetmachine()
{

 lcd.clear();
 lcd.setCursor(0,0);
 lcd.print("Reseting      ");

 stepperHeight.setMaxSpeed(700);
 stepperHeight.setCurrentPosition(0);
 stepperHeight.move(-300);
 digitalWrite(A4, LOW);
 while(!hasFinshedStepping())
 {
  stepperHeight.move(-300);
  runsteps();
 }
 digitalWrite(A4, HIGH);
 stepperHeight.setCurrentPosition(0);
}

void dalayrun(int delay)
{
 unsigned long currenttime = millis();
 while(currenttime+delay > millis())
 {
  stepperRotaion.move(100);
  selectD(JointR);
  stepperRotaion.run();
 }
}


/****************** SET MOTORS ******************/

void setmotors()
{
 stepperHeight.setMaxSpeed(HeightSpeed*stepsHeight);
 stepperRotaion.setMaxSpeed(RotationSpeed*stepsRotaion);
 //stepperHeight.moveTo(HeightValue*stepsHeight);
 stepperRotaion.move(100);
}

/****************** POSITIONS ******************/
```

```
double positionhight()
{
 return stepperHeight.currentPosition()/stepsHeight;
}

/****************** INTERFACE ******************/

int encoder()
{
 int n = digitalReadC(encoderA);
 if ((encoder0PinALast == LOW) && (n == HIGH))
 {
  if (digitalReadC(encoderB) == LOW) encoder0Pos--; else
encoder0Pos++;
 }
 encoder0PinALast = n;
 if(encoder0Pos<0)encoder0Pos=0;
 return encoder0Pos;
}

void setEconder(int val)
{
 encoder0Pos = val;
}

void printfirstvalue(int menu,long &value)
{
 lcd.setCursor(12,0);
 lcd.print(value);

 if(digitalReadC(encoderC))
 {
  while(digitalReadC(encoderC)){}
  setEconder(value);
  lcd.setCursor(0,1);
  lcd.print("                ");
  while(true)
  {
   if(digitalReadC(encoderC)) break;
   value = encoder();
   lcd.setCursor(12,0);
   lcd.print(value);
   lcd.print("   ");
  }
  while(digitalReadC(encoderC)){}
  setEconder(menu);
 }
}

void printsecondvalue(long &value)
{
 lcd.setCursor(12,1);
 lcd.print(value);
}

void Auto()
{
 while(true)
 {
  int menu = encoder()%7;
  switch(menu)
  {
   case 0:
    lcd.setCursor(0,0);
    lcd.print("> Dip speed:        ");
    printfirstvalue(menu,HeightSpeed);

    lcd.setCursor(0,1);
    lcd.print("  Rot speed:        ");
    printsecondvalue(RotationSpeed);
    break;
   case 1:
    lcd.setCursor(0,0);
    lcd.print("> Rot speed:        ");
```

```
    printfirstvalue(menu,RotationSpeed);

    lcd.setCursor(0,1);
    lcd.print("  Delay:         ");
    printsecondvalue(delaytime);
    break;
   case 2:
    lcd.setCursor(0,0);
    lcd.print("> Delay:         ");
    printfirstvalue(menu,delaytime);

    lcd.setCursor(0,1);
    lcd.print("  Hight:        ");
    printsecondvalue(HeightValue);
    break;
   case 3:
    lcd.setCursor(0,0);
    lcd.print("> Hight:         ");
    printfirstvalue(menu,HeightValue);

    lcd.setCursor(0,1);
    lcd.print("  No. times:      ");
    printsecondvalue(timestodip);
    break;
   case 4:
    lcd.setCursor(0,0);
    lcd.print("> No. times:      ");
    printfirstvalue(menu,timestodip);

    lcd.setCursor(0,1);
    lcd.print("  Run           ");
    break;
   case 5:
    lcd.setCursor(0,0);
    lcd.print("> Run           ");
    if(digitalReadC(encoderC))
    {
     RunDip();
    }
    else
    {
     lcd.setCursor(0,1);
     lcd.print("  Exit          ");
    }
    break;
   case 6:
    lcd.setCursor(0,0);
    lcd.print("> Exit          ");
    if(digitalReadC(encoderC))return;

    lcd.setCursor(0,1);
    lcd.print("  Dip speed:        ");
    printsecondvalue(HeightSpeed);
    break;
   default:
    lcd.setCursor(0,0);
    lcd.print("> Dip speed:          ");
    printfirstvalue(menu,HeightSpeed);

    lcd.setCursor(0,1);
    lcd.print("  Rot speed:          ");
    printsecondvalue(RotationSpeed);
    break;
  }
 }
}

void Manual()
{
 while(true)
 {
  int menu = encoder()%5;
  switch(menu)
  {
   case 0:
    lcd.setCursor(0,0);
    lcd.print("> Dip speed:      ");
    printfirstvalue(menu,HeightSpeed);

    lcd.setCursor(0,1);
    lcd.print("  Rot speed:      ");
    printsecondvalue(RotationSpeed);
    break;
   case 1:
    lcd.setCursor(0,0);
    lcd.print("> Rot speed:      ");
    printfirstvalue(menu,RotationSpeed);

    lcd.setCursor(0,1);
    lcd.print("  Down          ");
    break;
   case 2:
    lcd.setCursor(0,0);
    lcd.print("> Down          ");
    if(digitalReadC(encoderC))
    {
     lcd.setCursor(0,1);
     lcd.print("               ");
     RunDown();

    }
    else
    {
     HeightValue = positionhight();
     lcd.setCursor(0,1);
     lcd.print("  UP           ");
    }

    break;
   case 3:
    lcd.setCursor(0,0);
    lcd.print("> UP           ");
    if(digitalReadC(encoderC))
    {
     lcd.setCursor(0,1);
     lcd.print("               ");
     RunUp();
    }
    else
    {
     digitalWrite(A4, HIGH);
     HeightValue = positionhight();
     lcd.setCursor(0,1);
     lcd.print("  Exit          ");
    }

    break;
   case 4:
    lcd.setCursor(0,0);
    lcd.print("> Exit          ");
    if(digitalReadC(encoderC))return;

    lcd.setCursor(0,1);
    lcd.print("  Dip speed:      ");
    printsecondvalue(HeightSpeed);
    break;
   default:
    lcd.setCursor(0,0);
    lcd.print("> Dip speed:      ");
    printfirstvalue(menu,HeightSpeed);

    lcd.setCursor(0,1);
    lcd.print("  Rot speed:      ");
    printsecondvalue(RotationSpeed);
    break;
  }
 }
}
```

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