ECE445
Miniterized Langmuir Blodgett Trough

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Contents

1 Introduction

1.1 Problem

The Langmuir-Blodgett (LB) film method has been widely used for producing nano films. In the traditional LB film method, the film is formed by transferring a monolayer of molecules or nanoparticles from the air-water interface to a solid substrate using vertical dipping or horizontal lifting techniques. The LB film method provides a high level of control over the structure and orientation of the film, making it a valuable tool in fields such as surface science, materials science, and nanotechnology. However, the LB film method also has some limitations, including difficulties in characterizing the properties of the ultra-thin films and in controlling the film thickness with high precision. Typically, researchers use a lifter to obtain a sample and a microscope to observe its quality. Despite its widespread use, the traditional LB film method has limitations in terms of effectiveness and control over the system.

1.2 Solution

To address these limitations, a new method has been developed that improves upon the traditional LB film method. This new method utilizes advanced imaging techniques and computer algorithms to monitor and analyze the film in real-time. By using this approach, researchers can gain a more comprehensive understanding of the film's properties, including its thickness, uniformity, and surface roughness. Additionally, this new method provides more precise control over the system, allowing researchers to optimize the film's properties for specific applications. This new LB film method represents a significant advancement in the field of nano film production and has the potential to enable new applications in areas such as nanoelectronics and nanophotonics. Here is how we can solve it, basing on the traditional method, we can increase the efficiency by directly put the PTFE trough under the microscope, which means we can observe the situation of the film in the real time. What's more, basing on the real time image, we can use software to analysis it and control the syringe pump and barriers' motion to get closer to a better film quality and density that we wanted.

1.3 Visual aid

visual aid:

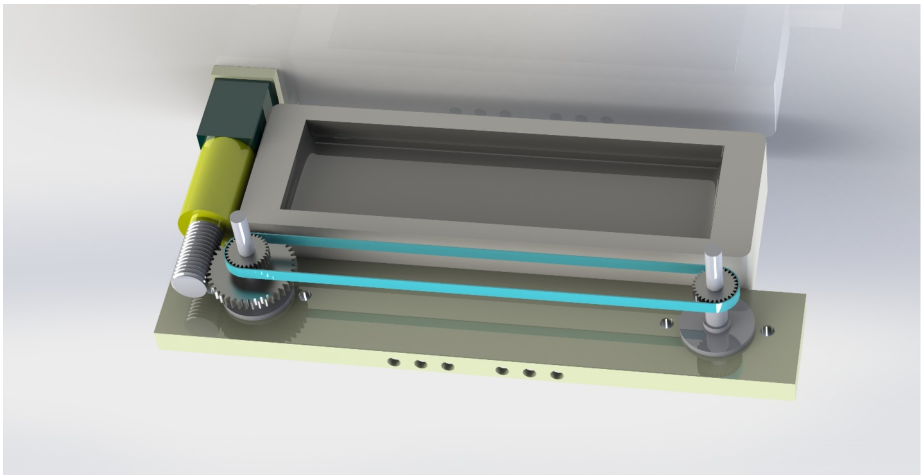

Figure 1: overview of the design

1.4 High-level requirements list

High-level requirements	Description
Barriers' moving speed	To achieve a better film quality, the barriers' moving speed is supposed to reach a range of 1 mm/min to 1 cm/min, which means we need to set a high gear ratio to decelerate the step motor.
Trough requirement	The trough should be smooth enough to reduce the friction between the barriers, ensuring a smooth and fluent operation. Precision of the trough need to be high to reach a flat and horizontal water surface.
Size limitation	The space underneath the microscope is limited, we only have 13cm x 22cm x 3cm space. And we will also need to change the objective while operation, so there won't be any objects on the objective change route.

2 Design

2.1 Power subsystem

Because the power needed to drive three motors (syringe pump, transport system, lifter system each has a motor), so we decided to use a commercial voltage source which can directly connect to a 220V voltage supply and give a 24V output continuously for the three motors.
Requirement1: Continuous and safely output a voltage at 24V and 1.5A to each motor at the same time.

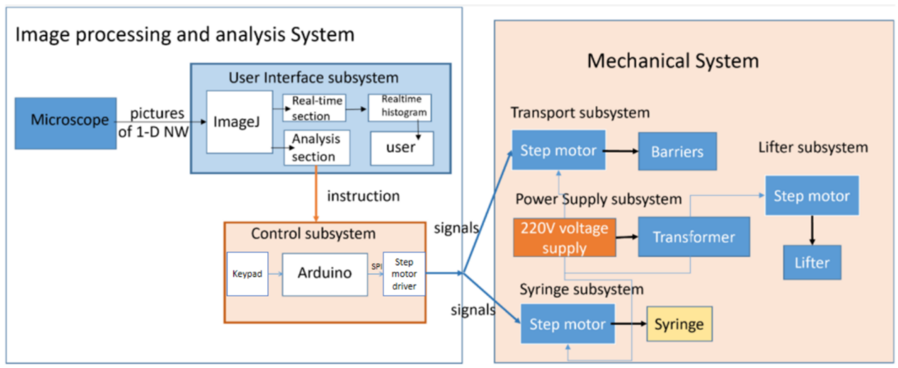

Figure 2: Block Diagram

Requirement2: Work at a 220V voltage input condition.
Requirement3: Have a safety connect wire to the ground and have a switch on it.
Requirement4: At least have 12 pin for output.

Figure 3: Power Supply

Requirement	Verification
Continuous and safely output a voltage at 24V and 1.5A to each motor at the same time	1.Work at a 220V voltage input condition 2.Have a safety connect wire to the ground and have a switch on it 3.At least have 12 pin for output

2.2 Transport subsystem

The transport subsystem is one of the most complex subsystem in our design which is formed by two barriers, one step motor with decelerate gear set with a worm gear head on it and a transport belt with two fixed synchronous belt gear.
This subsystem can achieve the condition that move the barrier at a minimum speed 1mm/min to max speed 10mm/min smoothly with little vibration to the trough.

2.2.1 20*30 gear with decelerate gear set

The motor we choose here is very small so it can place under the microscope, and we choose step motor because comparing to service motor, it can be precisely controlled by PC. This motor need a 24V and 1.5A power input, can work in the RPM from 0-900. In order to work in a relative safe and long term, we choose 100-800 as our working speed.
We add a planetary gear set at the head of the motor so we can decelerate its rotating speed from 100-800 to 0.72-5.75 RPM with a gear ration 1:139.
Requirement1: Continuous work at 100rpm-800rpm and the vibration is really small
Requirement2: Work at 24V and 1.5A condition.

Requirement	Verification
Continuous work at 100rpm-800rpm The vibration is really small	1.Work at 24V and 1.5A condition 2.Rotate at 100rpm for the minimum speed 3.Rotate at 800rpm for the maximum speed

2.2.2 Brass Worm gear

We use a custom make brass worm gear here to transport the power from motor to the belt. Although we already have a 1:139 deceleration at the motor, but to our requirement, it's still to fast, so we add another 1:40 gear ration for the worm gear set which means we have a 1:5560 gear ration in total. Comparing

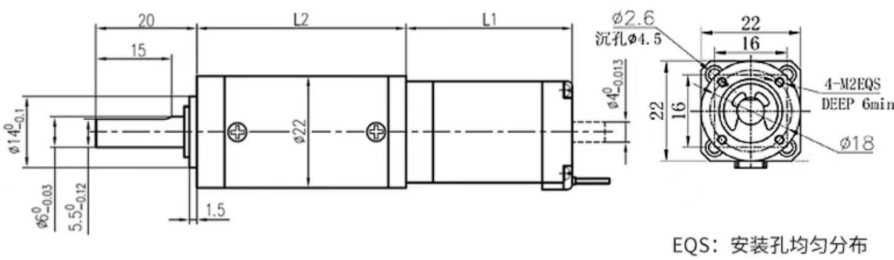

Figure 4: planetary gear set

to the commercial worm gear, the worm gear we used in our product decrease its thickness to the half which will make our product lower in height.
Requirement1:Custom make makes it thickness from 13mm to 9mm.
Requirement2: Has a 1:40 gear ration.
Requirement3: Material is Brass.

Requirement	Verification
Has small size Decelerate the speed High strength	1.Custom make makes it thickness from 13mm to 9mm 2.Has a 1:40 gear ration 3.Material is Brass

2.2.3 Polyurethane Belt

This belt is fixed on two gear and can rotate with them. We use polyurethane because it's ductile and durable.
Requirement1: Can work more than 500 hours.
Requirement2: The total length is well calculated as 399mm.

Requirement	Verification
Ductile Can work more than 500 hours	1.We use Polyurethane as our material 2.The total length is well calculated as 399mm

2.2.4 Delrin Barriers

Using Delrin as the material of our product is mainly because it has low friction and resistance to the chemical and moisture which means it can smoothly work on the trough surface and will not pollute the film. Besides, Delrin is hydrophobic material and exhibits low surface energy and repels water.
Requirement1: Use Delrin as the material which is low friction and hydrophobic.

Figure 5: Polyurethane Belt

Requirement2: Add two humps at the place where our barrier contact the trough which can limit its motion.

Requirement	Verification
Low sliding friction Can move horizontally along the trough Will not pollute the film	1.We use Delrin as the material which is low friction and hydrophobic 2.We add two humps at the place where our barrier contact the trough which can limit its motion

2.3 Control moudle

The control module handles actions of three step motors and hosts with SPI signals. It is powered by a computer through a USB interface. The Arduino Panel consume approximately 7V voltage.

2.3.1 Arduino Panel

The Arduino Panel we use is Arduino UNO R3, which is a development board based on microcontroller ATmega328P. It has 14 digital input/output pins (6 of which can be used as PWM output pins), 6 analog input pins, 16 MHz quartz crystal oscillator, USB interface, power interface, support for online serial programming, and reset keys. Users only need to connect the development board to the computer through a USB interface to use it.

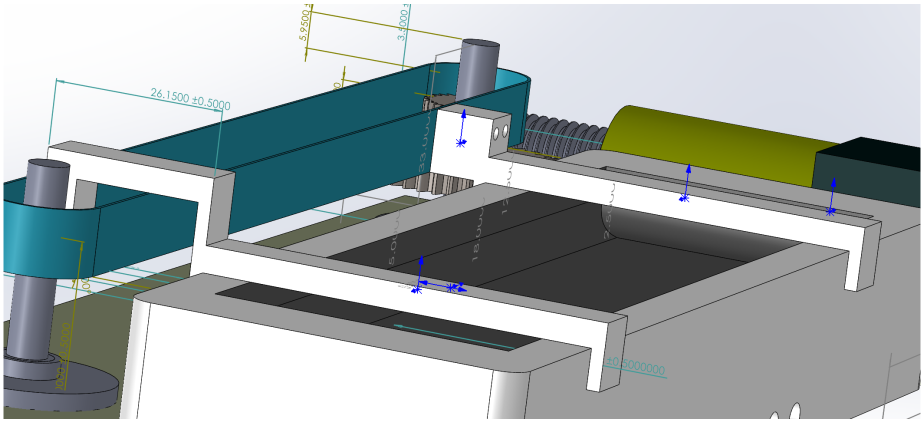

Figure 6: Delrin Barriers

Requirement1: Identify the six different signals input by the keypad.
Requirement2: Can output signal voltage is between 4.5 and 28 VDC, and the current is 10 mA.
Requirement3: Can output pulse+direction signal, A/B orthogonal pulse output.

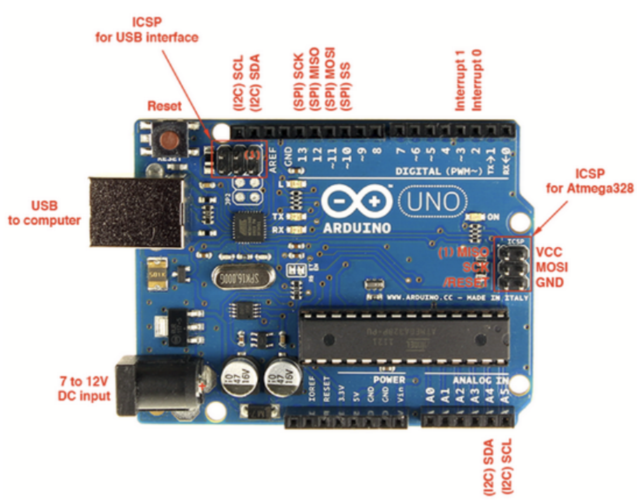

Figure 7: Arduino Panel

Requirement	Verification
1.Can output pulse+direction signal, A/B orthogonal pulse output	1.Connect microcontroller to the step motor driver to ensure it can output the pulse signal required by the driver.
2.Can receive signals input from 4x4 keypad.	Identify the six different signals input by the keypad.
3.It can output signal voltage is between 4.5 and 28 VDC, and the current is 10 mA.	Using the Arduino IDE to burn the required programs into a microcontroller.

2.3.2 4x4 Keypad

We use Risym 4x4 keypad as our input device and the keys are copper microswitches. Keypad interface can be used with DuPont cable.
Requirement1: To be able to output six different signals.
Requirement1: Due to the presence of water and volatile materials, the keys are made of copper to effectively prevent corrosion.

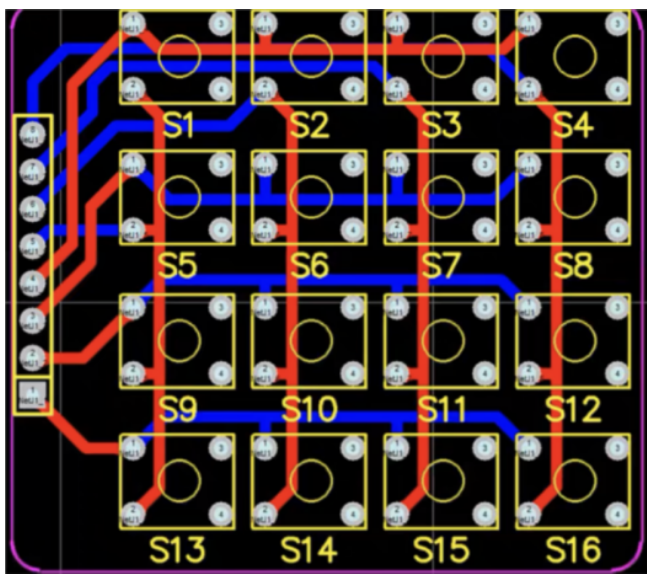

Figure 8: 4x4 Keypad

Requirement	Verification
1.Needs to be connected to the Arduino Panel. 2.To be able to output six different signals.	1.Connect to the Arduino Panel using a DuPont cable. 2.4x4 keypad have 16 microswitches, which means it can output far more than six different signals. 3.Due to the presence of water and volatile materials, the keys are made of copper to effectively prevent corrosion.

2.3.3 Step motor driver

UM242 step motor driver adopts latest 32-bit ARM digital processing technology, and it control algorithm adopts advanced variable current technology and frequency conversion technology. The driver has small heat generation and stable operation. The user can set any subdivision between 200 and 25000 and any current value within the rated current. The driver is internally integrated with a parameter power-on automatic setting function, which can generate optimal operating parameters for different motors.
Requirement1: Use a 24 volt DC power supply. The output current of the driver is 0.2 2.2A.
Requirement2: The width of the pulse signal is set to be greater than 2s. ENA (enable signal) should advance DIR by at least 5s to determined as high. We satisfy the condition by suspending ENA+and ENA - in the air.

Requirement	Verification
1.We use a 24 volt DC power supply. The output current of the driver is 0.2 2.2A. 2.The output current is 0.2 2.2A. The input power supply voltage is generally supplied from a 24V DC power supply. The signal voltage received from the Arduino Panel is between 4.5 and 28 VDC, and the current is 10 mA.	The width of the pulse signal is set to be greater than 2s. ENA (enable signal) should advance DIR by at least 5s to determined as high. We satisfy the condition by suspending ENA+and ENA - in the air.

2.4 User interface

Height can reflect whether materials have formed a film. User interface system will receive data from imageJ and plot a real-time histogram reflecting orientations and height of nano-wire practicals. It includes a picture analyzing system, combined by imageJ and its plug-ins, and a real-time interface system, showing barriers' position and circumstance of material.
Requirement1: Can give specific data and its variation by time.
Requirement2: Able to identify the orientation and density of particles.

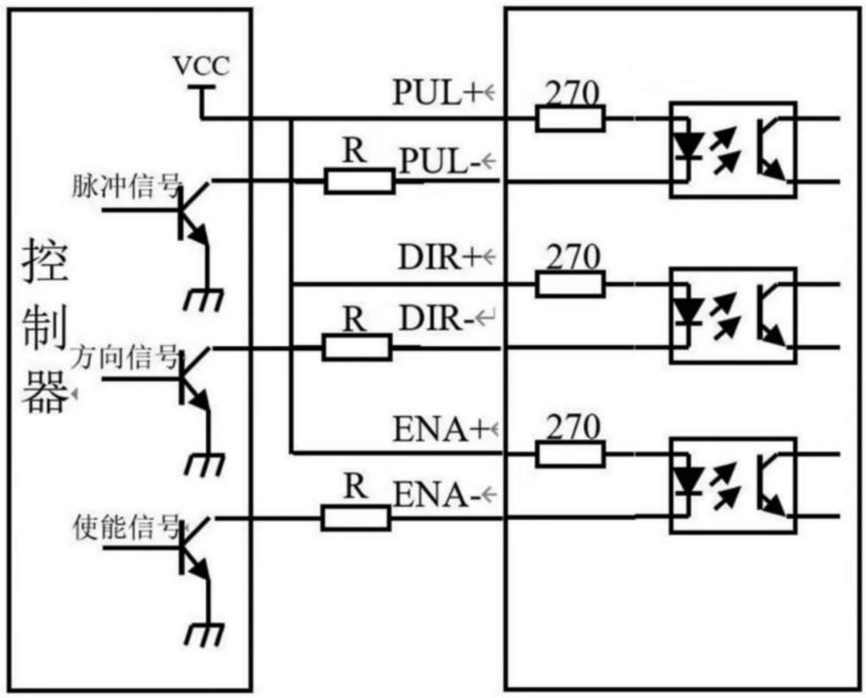

Figure 9: Step motor driver

Requirement	Verification
1.Connect users and image-processing system. 2.Plot real-time histogram based on data from imageJ 3.Reflect height and orientation of the material.	1.User can get a visual graphical interface. 2.Give specific data and its variation by time. Giving signals to the electrical control system to control barriers.

2.5 Syringe

The testing liquid is injected by syringe pump. The whole subsystem contains a pump, a holder, a pipe and a injector. We can adjust the height and orientation of the injector to find a proper position.
Requirement1: Inject steady liquid flow.
Requirement2: Use a high torque but slow motor.

Requirement	Verification
1.Inject steady liquid flow. 2.Use a high torque but slow motor	1.Adjust height and orientation of the injector 2.a. Assemble a movable holder b. Use a flexible pipe

2.6 Lifter

A lifter is used to lift the film to a small platform in order to observe the film on a solid plate.
Requirement1: Use a high torque but slow motor.

Requirement	Verification
Lift the film at a steady speed	Use a high torque but slow motor

2.7 Trough

Trough can contain the solution, then syringe pump will inject the testing liquid on the solution surface. Two barriers is placed and sliding on the trough, to change the density, orientation of the liquid.
Requirement1:Smooth enough.
Requirement2:Flat and horizontal surface.

Requirement	Verification
1.Smooth enough. 2.Flat and horizontal surface	1.Use Delrin, a smooth material 2.Find a high standard store to customize precise trough

2.8 Calendar

week	Zhanyu Shen	Zhanlun Ye	Zhehao Qi	Xiran Zhang
3/13	Design the transportation system.	Design the transportation system. Negate the python solution.	Learn how to turn macros into plug-ins for Imagej.	Clarified requirements for plug-in usages.
3/20	Specific the size of gear and belt.	Redesign the transportation system. Estimate the possible working speed for the transportation system.	Learn how to control the motor by Arduino.	learn the code about orentationj we have and write a simple macro.
3/27	Design and build the barriers. Order baring holder, belts, trough, step motors.Design lifter system.	Adding syringe system.	Use Arduino to control the step motor to do simple action.	Build the simple macro into imagej and test it.
4/3	Design lifter system.	Polish the whole model (add screws and nuts. . . .).	Control the barriers' step motor to shock, closing and other operations.	Make a Imagej macro to calculates the number of particles.
4/10	Assemble all mechanical structures and test their basic functions.	Assemble all mechanical structures and test their basic functions.	Make the panel to control the syringe step motor.	Make a Imagej macro to calculates the orientation aromatically.
4/17	If there is a problem with the mechanical part, identify the problem and make improvements.	If there is a problem with the mechanical part, identify the problem and make improvements.	If there is a problem with the control module, identify the problem and make improvements.	If there is a problem with the Imagej macros, identify the problem and make improvements.
4/24	If there is a problem with the mechanical part, identify the problem and make improvements.	If there is a problem with the mechanical part, identify the problem and make improvements.	If there is a problem with the control module, identify the problem and make improvements.	If there is a problem with the Imagej macros, identify the problem and make improvements.

5/1	On the basis of improving the details of the mechanical part, make small-scale improvements.	On the basis of improving the details of the mechanical part, make small-scale improvements.	On the basis of manual control, attempt to automatically control the movement of the motor.	After macro has the basic functions, graphically display the relationship between the motion of the motor and the density and orientation of particles.
5/8	Mock demo and make a Final Report draft.	Mock demo and make a Final Report draft.	Mock demo and make a Final Report draft.	Mock demo and make a Final Report draft.
5/15	Prepare for Final Presentation and Final Report.	Prepare for Final Presentation and Final Report.	Prepare for Final Presentation and Final Report.	Prepare for Final Presentation and Final Report.
5/22	Final Report and Teamwork Evaluation.	Final Report and Teamwork Evaluation.	Final Report and Teamwork Evaluation.	Final Report and Teamwork Evaluation.

3 Ethics & Safety

In the context of building a miniaturized Langmuir-Blodgett (LB) trough, several ethical and safety issues should be considered. Here are some of the key issues to consider:
Ethical issues:

1) Fairness and impartiality: It is important to ensure that the project is developed in a fair and impartial manner, without bias towards any specific individual, group, or organization.

2) Privacy and confidentiality: If the project involves the use of sensitive or personal data, it is important to maintain the privacy and confidentiality of that data to avoid potential harm to individuals.

3) Responsibility to society: The IEEE and/or ACM Code of Ethics states that engineers should strive to use their skills and knowledge to benefit society and should avoid actions that could cause harm. It is important to consider how the project will benefit society, and to avoid any potential harm that could arise from its use or misuse.

Safety issues:

1) .Electrical safety: If the project involves the use of electrical components, it is important to follow appropriate safety protocols to avoid electrical shock or other hazards.

2) Chemical safety: The LB film method may involve the use of potentially hazardous chemicals, such as solvents or surfactants. Proper safety protocols should be followed to avoid exposure or accidents.

3) Regulatory compliance: It is important to review state and federal regulations, industry standards, and campus policy to ensure that the project complies with all relevant safety regulations.

To avoid ethical breaches, the project should be developed with transparency and openness, with clear communication and collaboration with stakeholders. Any potential conflicts of interest should be identified and addressed, and the privacy and confidentiality of any sensitive data should be maintained. Addressing safety concerns, appropriate safety protocols should be followed throughout the development and operation of the project. This may include appropriate training of personnel, proper handling and disposal of hazardous materials, and regular inspections and maintenance of equipment to ensure its safe operation.

To mitigate the safety concerns associated with building a miniaturized Langmuir-Blodgett (LB) trough, the following procedures can be implemented:

1) Proper training: All personnel involved in the development and operation of the LB trough should receive appropriate training in the handling of potentially hazardous chemicals and equipment.

2) Personal protective equipment: Personal protective equipment, such as gloves, lab coats, and safety glasses, should be worn during all stages of the LB film method to minimize exposure to potentially hazardous chemicals.

3) .Proper ventilation: Adequate ventilation should be provided in the laboratory where the LB trough is being used to prevent the buildup of fumes and other hazardous materials.

4) Chemical storage and disposal: All chemicals used in the LB film method should be stored properly and disposed of according to local regulations to avoid any potential environmental hazards.

5) Equipment maintenance: Regular inspections and maintenance of the LB trough and associated equipment should be conducted to ensure safe operation and prevent any potential accidents.

In addition to these procedures, design decisions can also be made to ensure the safety of both users and developers:

1) Use of non-toxic chemicals: Whenever possible, non-toxic or less hazardous chemicals should be used in the LB film method to minimize potential exposure and harm.

2) Automation of processes: Automation of the LB film method can reduce the need for manual handling of potentially hazardous chemicals and equipment, thereby reducing the risk of accidents.

3) Safety interlocks: Safety interlocks can be incorporated into the design of the LB trough to prevent accidental operation or misuse of the equipment.

By implementing these procedures and design decisions, the safety concerns associated with building a miniaturized LB trough can be adequately mitigated. Regular reviews and updates to these procedures and design decisions can ensure continued safety for users and developers. Overall, it is important to approach the development of a miniaturized Langmuir-Blodgett trough with careful consideration of both ethical and safety issues, and to ensure that appropriate protocols and standards are followed to avoid any potential harm to individuals or society.

4 Cost

We fixed development costs are estimated to be 18rmb/h, 10 h per week for four people. So we can roughly estimate the total cost for the whole project like work for 12 weeks including the design, manufacturing, adjusting and report writing time:

$$418rmb/h \times 10hour \times 12week = 8640rmb$$

Part	Costprototype/rmb	Costbulk/rmb
PTFE Trough	900	480
Delrin Barriers (type1 & 2)	360	150
Brass Worm gear (custom)	100	20
Polyurethane belt	20	10
Motor gear head	16	16
synchronous belt gear *2	13.2	13.2
Bearing holder*2	12.4	12.4
20*30 step motor with decelerate gear set	271.5	250
Arduino board	20	20
Voltage source service(220v)	50	40
Total	1763.1 RMB	1011.6 RMB

Our cost is a little bit higher than our estimation as some parts need to custom make including the PTFE trough, Delrin barriers, Brass worm gear which takes most of our budget. Because we need to put the whole product under a microscope which has very limited space, we need to make some gear thicker than the commercial part, that's why the Brass worm gear will cost 100rmb. However, when we can have a higher order number of those parts, the cost will be greatly reduced.

5 Tolerance Analysis

Our design is aim to use smaller Langmuir-Blodgett film method equipment to produce nano film. The machine should be small enough to place under a microscope plat, in order to see the parameters of the film. The main mechanical parts are two motors and two barriers. For motors, we buy the motors on the internet. From the information they provided, the length error along the axis is smaller than 0.3mm and the length error perpendicular to axis is 0.08mm. The gap in the motor is less than 1, while the common motor's is 2-3. Besides, our motor has motor pattern and control pattern. The upper pattern can reduce the gap. Thus, our motor is relatively precise comparing to common commercial motor. The maximum rotation speed is 6 rpm. And the diameter of the gear is 16mm. In theory, the speed of the barrier can achieve the range of 0-150mm/min. In reality, we can assume the speed to 20-130mm/min. Such speed can perfectly satisfy the requirements of high precision operation.

$$V = \omega \cdot R$$

For barriers, we also customize them on the internet. The barriers are made of

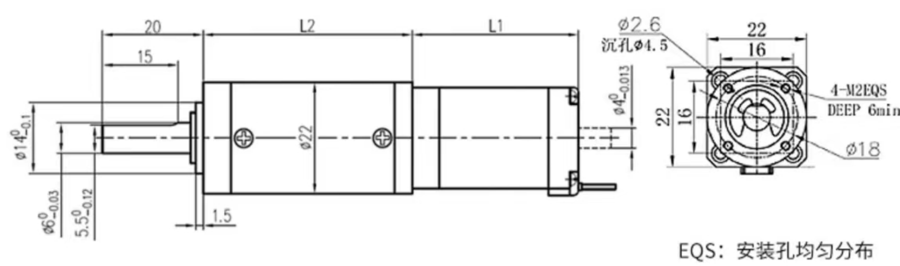

Figure 10: Schematic of the motor

Delrin, which is a smooth and light material. The density is 1420 kg/m3. So, the total weight is 10g for each. Their weight is an aspect to affect whether the system can work smoothly. Total friction could be estimated to 1N.

$$f = \mu \cdot N$$

And the largest torque of the step motor is 1.52 Nm. The farthest position is about 0.02m. Thus, the motor can tolerate more than 70N. The barriers will not affect the success of the whole product.

$$T = F \cdot s$$

6 References

https://blog.arduino.cc/2012/05/29/handy-arduino-uno-r3-pinout-diagram/
http://www.umotmotor.cn/66618109/26.html