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ME470/ECE445
Senior Design document

Continuous Roll-To-Roll LB Film Deposition Machine

By

Boyang Fang
(boyangf2@illinois.edu)

Han Li

(hanl8@illinois.edu)

Ruiqi Zhao

(zuiqiz6@illinois.edu)

Zhixian Zuo
(zhixian3@illinois.edu)

Supervisor: Prof. Kemal Celebi

TA: Zhanyu She

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1. Introduction

1.1 Background

Langmuir-Blodgett (LB) coating technology, developed in the early 20th century by scientists such as Irving Langmuir and Katherine Blodgett, is a well-established method for precise deposition of molecular layers onto solid substrates from a water surface. This technique is crucial in materials science and surface science due to its ability to control molecular arrangement and orientation with high precision.

The recent surge in demand for LB coating technology is driven by the increasing utilization of nanomaterials in ultrathin coatings. Nanomaterials offer unique physical and chemical properties that enhance the functionalities and performance of coatings, making LB coating a critical tool in nanomaterial research and applications.

The advantages of LB coating technology combined with nanomaterials include:

Precise Control: LB coating enables meticulous control over the arrangement and orientation of nanomaterials, facilitating tailored coating properties essential for various applications, such as optimizing conductivity in electronics or adjusting optical properties in photonics.

Uniformity: LB coating produces highly ordered and uniform thin films, crucial for applications like enhancing sensor sensitivity or improving biocompatibility in biomedical devices.

Nanoscale Thin Films: LB coating can create nanoscale thin films, allowing for the production of nanoelectrodes in nanoelectronics or thin films with unique optical properties in nanophotonics.

Scalability: While traditional LB coating faces challenges, advancements in process and technology can potentially scale up LB coating for large-area manufacturing, providing an effective solution for utilizing nanomaterials in ultrathin coatings.Based on this background, this project aims to develop a Continuous Roll-To-Roll Thin Film Deposition Machine based on LB coating technology. Through innovative design and technology, the machine seeks to achieve efficient production and application of nanomaterials, thereby advancing the use and industrialization of nanomaterials in ultrathin coatings.

The application of Langmuir-Blodgett (LB) coating technology has significantly enhanced the performance of material surfaces. Its precise control over molecular layers enables researchers to design and fabricate more complex and efficient nanomaterials, thereby advancing the fields of material science and nanotechnology.

1.2 Problem

Traditional LB coating techniques face challenges with low production efficiency and limitations in scaling up for large-area manufacturing. Traditional LB coating techniques encounter challenges such as limited production efficiency and scalability for large-area manufacturing. These limitations arise from the manual or rudimentary mechanical processes typically used in traditional LB coating, which are inefficient for large-scale production. Additionally, the technique's reliance on water surfaces imposes constraints on coating size, making it difficult to scale up for large-area manufacturing applications. Furthermore, traditional LB coating processes struggle with quality control, often resulting in uneven coating thicknesses or the formation of bubbles. As the demand for nanomaterials in ultrathin coatings grows, traditional LB coating techniques face increasing challenges that necessitate improvements in production efficiency, quality control capabilities, and scalability.

1.2 Solution

Existing solutions forthin film deposition, such as commercial Roll-To-Roll (R2R) machines, often require the use of barriers to prevent contamination and maintain film integrity. However, this reliance on barriers hinders scalability by adding complexity and cost to the manufacturing process. Therefore, there is a growing need for alternative thin film deposition techniques that can achieve scalability without the need for barriers.

To address this challenge, this project aims to develop an instrument based on Langmuir-Blodgett (LB) coating technology, utilizing a Roll-To-Roll dual-roller structure. This innovative approach seeks to enable sustainable production of nanofilms, significantly enhancing production efficiency and film quality compared to traditional LB film production methods. By enabling continuous production, this project aims to overcome the limitations of traditional LB film production, opening new avenues for the commercialization and practical application of LB films.

1.3 Visual Aid

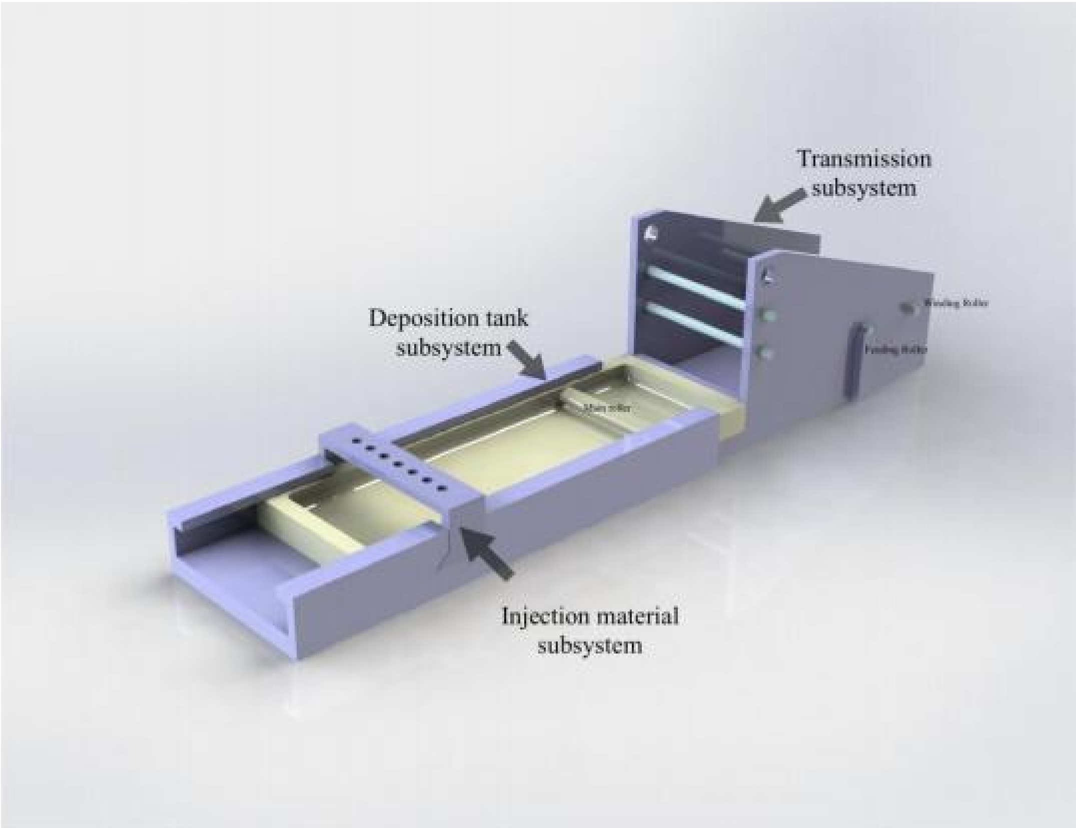

Figure1. Detail Design Sketch

1.4 High Level Requirements

The efficiency of material self-spreading: The uniform spreading of materials on a substrate is essential for producing films with consistent properties. Effective self-spreading guarantees the film's uniformity, directly impacting its performance in diverse applications. Techniques like utilizing moving water can enhance distribution and quality, ensuring a more even coating.

The selection of high-quality Teflon: The selection of high-quality Teflon as the trough material is crucial for effective thin film deposition processes. Teflon's exceptional chemical resistance ensures compatibility with a wide range of solvents and chemicals commonly used in these processes. Its low surface energy prevents material adherence to the trough walls, facilitating uniform film deposition on the substrate. Teflon's smooth surface reduces friction, enabling smooth substrate movement for even material spreading. Additionally, Teflon's high temperature resistance allows for the deposition process to be conducted at elevated temperatures without compromising the material integrity.

The stretched drawing of the polymer film substrate: The stretching and drawing of the polymer film substrate play a crucial role in thin film deposition processes. Stretching the substrate can align polymer chains and increase crystallinity, which can enhance the mechanical and barrier properties of the final film. Drawing the substrate can further orient the polymer chains, improving the film's strength and flexibility. Additionally, stretching and drawing can reduce the thickness of the substrate, allowing for the deposition of thinner films. This process can be controlled to achieve the desired mechanical, barrier, and optical properties of the final film.

2. Design

2.1 Block Diagram

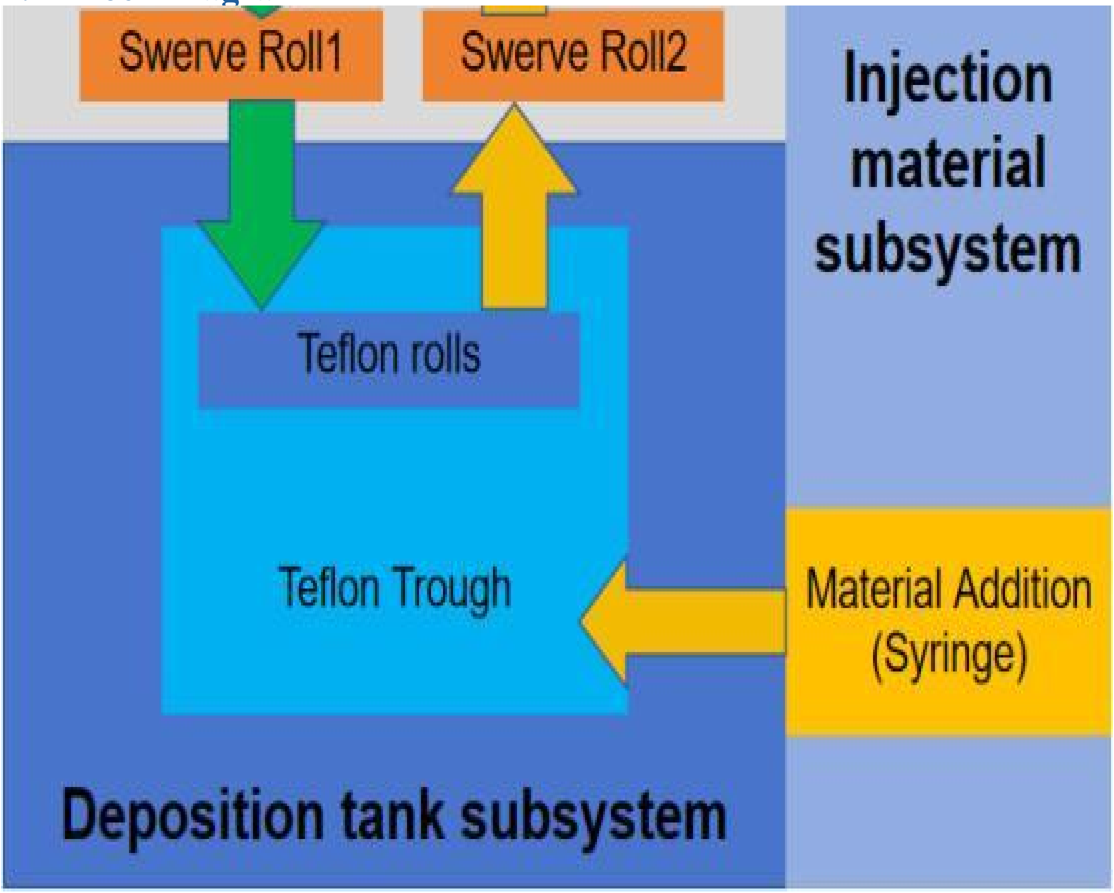

Figure2. Block diagram between electric control and deposition tank subsystem

2.2 Subsystem Descriptions

This subsection gives the description of all subsystem functions and interaction with other subsystems.

2.2.1 Electric control subsystem

2.2.1.1 Transmission subsystem

The drivetrain hardware for the system includes several key components. It consists of a Teflon trough, which serves as the base for the film deposition process. The trough is designed to hold the liquid film material. Additionally, there are four rolls involved in the drivetrain system. Two of these rolls, used for roll-out and collection, are 3D printed and have a larger diameter of 30mm. The other two rolls, with a diameter of 10mm, are also part of the system. These rolls help guide and control the movement of the film material within the trough.

The drivetrain is powered by a stepper motor, which provides the necessary rotational motion to drive the rolls. Belts are used to connect the stepper motor to the rolls, ensuring synchronized movement. The diameter of the Teflon roll is 10mm, which is standard for this type of application. Overall, the drivetrain hardware is designed to provide precise control over the movement of the film material, ensuring uniform deposition and high-quality results.

2.2.1.2 Injection material subsystem

The Injection Material Subsystem is composed of several components, including one motor, one large syringe, eight small syringes, and one bracket. The motor is responsible for controlling the movement of a plate positioned above the bracket, generating thrust to compress the large syringe. This action extrudes the material from the syringe, facilitating balanced feeding through a configuration where one syringe feeds in and eight syringes feed out.

This subsystem is crucial for the controlled delivery and distribution of materials within the system. The motor's precise control allows for accurate and consistent extrusion of material from the large syringe, which is then distributed through the smaller syringes. This setup enables the system to achieve uniform and controlled material deposition, ensuring the quality and integrity of the final product.

2.2.2 Deposition tank subsystem

The deposition trough, fabricated from Teflon, is housed within a frame constructed of 3D printed parts. The Teflon trough's interior surface is intentionally smooth, facilitating easy cleaning and minimizing the risk of material residue accumulation.

The bracket's design features a mortise and tenon structure that securely connects it to the frame supporting the rolls. This structural arrangement ensures stability and precise alignment of the components. Additionally, the feeding table is rigidly affixed, further enhancing the overall stability of the system.

By limiting the movement of the Teflon trough to a one-way direction, the design promotes consistent and controlled material deposition, crucial for achieving the desired film thickness and uniformity. Overall, these design features contribute to the system's reliability and efficiency in thin film deposition processes.

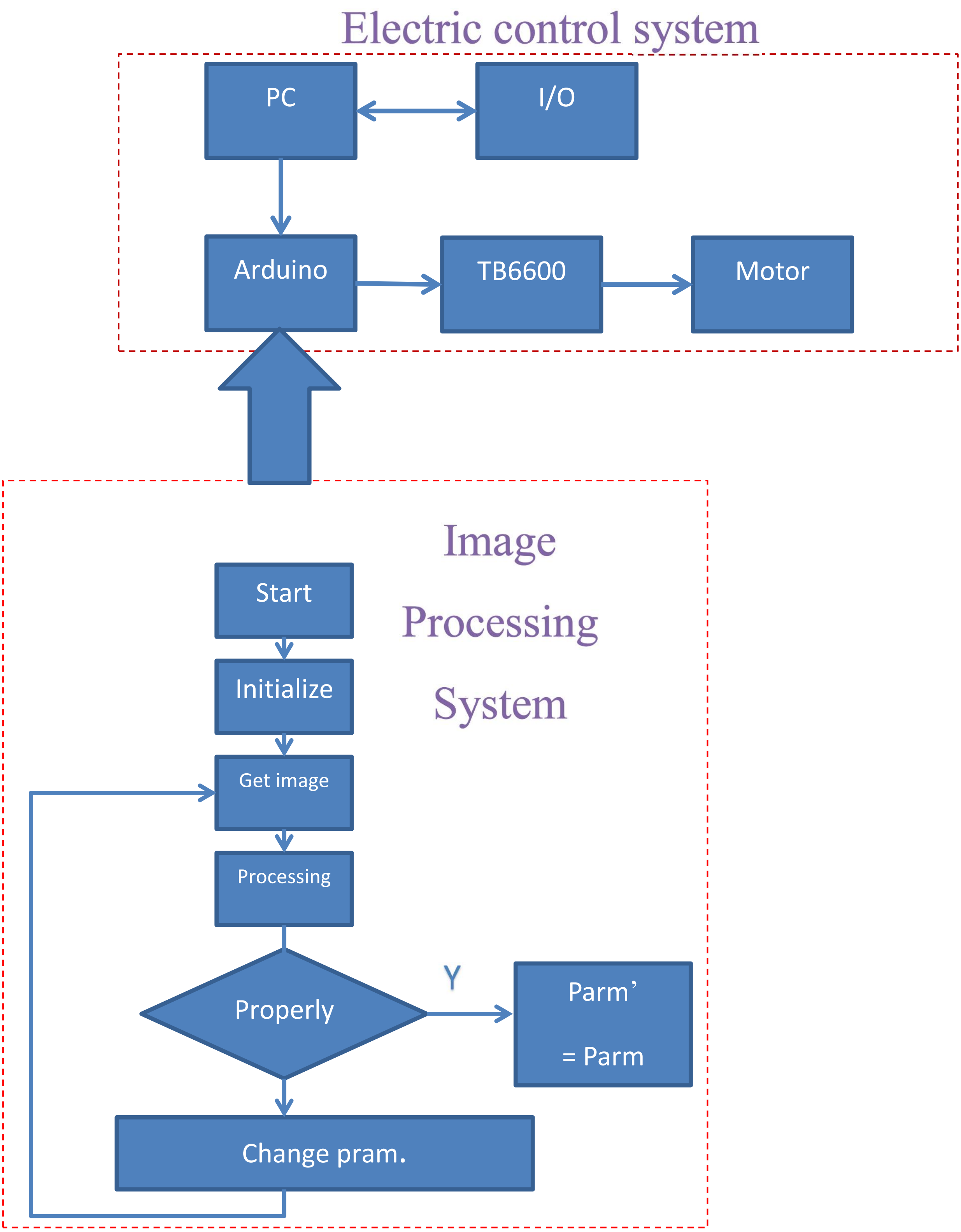

Figure3. Block diagram between electric control and image processing subsystem

2.2.3 Image processing subsystem

In the film deposition process, the Brewster Angle Microscope (BAM) or a digital camera is employed to acquire real-time image data of the liquid surface. This data is then subjected to image processing algorithms, typically implemented in Python or other software, to analyze the thin film material's proportion. This proportion is calculated by dividing the material's area by the liquid surface area, providing a crucial metric for monitoring the deposition process.

The obtained proportion data is utilized for closed-loop control of the system using an Arduino microcontroller. For instance, if the calculated proportion falls below a predetermined threshold, such as 0.9, indicating an inadequate film deposition rate, the Arduino adjusts the speed of the stepper motor responsible for driving the film rotation. This adjustment aims to either decrease or increase the motor's speed, thus regulating the deposition rate and ensuring a more uniform film thickness.

This closed-loop control mechanism enables real-time adjustments to the deposition process, enhancing the system's efficiency and the quality of the deposited thin films.

2.3 Calculation and Simulation

The design and development of a Langmuir-Blodgett (LB) roll-to-roll (R2R) machine for the continuous production of nanofilms represent a significant advancement in thin film deposition technology. This section presents a detailed description of the calculation and simulation methods employed in the design process, focusing on critical aspects such as film thickness control, substrate tension management, and energy consumption optimization.

2.3.1 Film Thickness Calculation

The film thickness in an LB R2R machine is crucial for ensuring the desired properties and performance of the nanofilms. The film thickness can be calculated based on the molecular area of the molecules being deposited and the number of monolayers transferred per cycle. The formula used for calculating the film thickness (t) is given by:

$$t = n \times A$$

Where:

- t is the film thickness,

- n is the number of monolayers transferred per cycle, and

- A is the molecular area of the molecules.

2.3.2Substrate Tension and Alignment

Proper substrate tension is essential to prevent wrinkles and ensure proper alignment during the coating process. The required tension can be calculated using the formula:

$$T = \frac{F}{W}$$

Where:

- T is the substrate tension,

- F is the force required to stretch the substrate, and

- W is the width of the substrate.

Here are some data for commonly used materials in LB R2R thin film deposition, including film thickness, tensile modulus, and density. These data can be used to calculate mechanical parameters and energy consumption during the deposition process.

1. Polymer Films:

-Thickness: Typically ranges from a few micrometers to tens of micrometers.

-Tensile Modulus: Approximately 1-3 GPa.

-Density: Approximately 1-1.3 g/cm^3.

2. Metal Films:

-Thickness: Typically ranges from tens of nanometers to a few micrometers.

-Tensile Modulus: Approximately 100-400 GPa (depending on the metal type).

-Density: Approximately 7-19 g/cm^3 (depending on the metal type).

3. Oxide Films:

-Thickness: Typically ranges from tens of nanometers to a few micrometers.

-Tensile Modulus: Approximately 100-300 GPa (depending on the oxide type).

-Density: Approximately 3-7 g/cm^3 (depending on the oxide type).

4. Nanoparticle Films:

-Thickness: Typically ranges from tens of nanometers to hundreds of nanometers.

-Tensile Modulus: Depends on particle size and material, typically ranging from tens of MPa to hundreds of MPa.

-Density: Depends on particle material and packing density, typically ranging from 1-2 g/cm^3.

2.3.3 Speed and Throughput

The speed of the R2R system directly affects the throughput and film quality. The optimal speed can be determined based on the transfer rate of the monolayers, substrate size, and drying time. The throughput (Q) can be calculated using the formula:

$$Q = V \times W \times t$$

Where:

- Q is the throughput,

- V is the speed of the R2R system, and

- t is the width of the substrate.

The relationship between the film running speed (V) and the stepper motor can be determined by considering the gear ratio of the stepper motor system. Let's denote the pitch of the gear as P and the diameter of the gear as D. The linear speed of the gear (v) can be calculated as:

$$v = \frac{2\pi r}{T}$$

Where:

- r is the radius of the gear, and

- T is the period of one step of the stepper motor.

Assuming the gear has a pitch diameter of D and a pitch of P, the radius of the gear can be approximated as $r = \frac{D}{2}$. The period of one step of the stepper motor (T) can be calculated as $T = \frac{1}{f}$, where f is the stepping frequency of the motor. Thus, the relationship between the film running speed and the stepper motor can be expressed as:

$$V = \frac{2\pi \times \frac{D}{2}}{\frac{1}{f}} = \pi \cdot D \cdot f$$

2.3.4 Consumption

The energy consumption of the LB R2R machine is a critical factor in its design and operation. It can be estimated by considering the power requirements of the motors, heaters, and other components. The total energy consumption (E) can be calculated as:

$$E = P \times t$$

Where:

- E is the total energy consumption,

- P is the power consumption per unit time, and

- t is the operating time.

For a stepper motor, the work done can be approximated as the torque (τ) produced by the motor multiplied by the angular displacement (θ) per unit time (ω). Therefore, the power consumption of the stepper motor can be expressed as:

$$P = \tau \times \omega$$

Where:

- τ is the torque,

- ω is the angular velocity.

The torque required to drive the system can be calculated using the formula:

$$\tau = F \times r$$

Where:

- F is the force required to drive the system, and

- r is the radius of the gear.

Substituting the expressions for torque (τ) and angular velocity (ω) into the power consumption formula, we get:

$$P = F \times r \times 2\pi f$$

2.3.5 The relationship between film deposition Angle and horizontal distance of tank

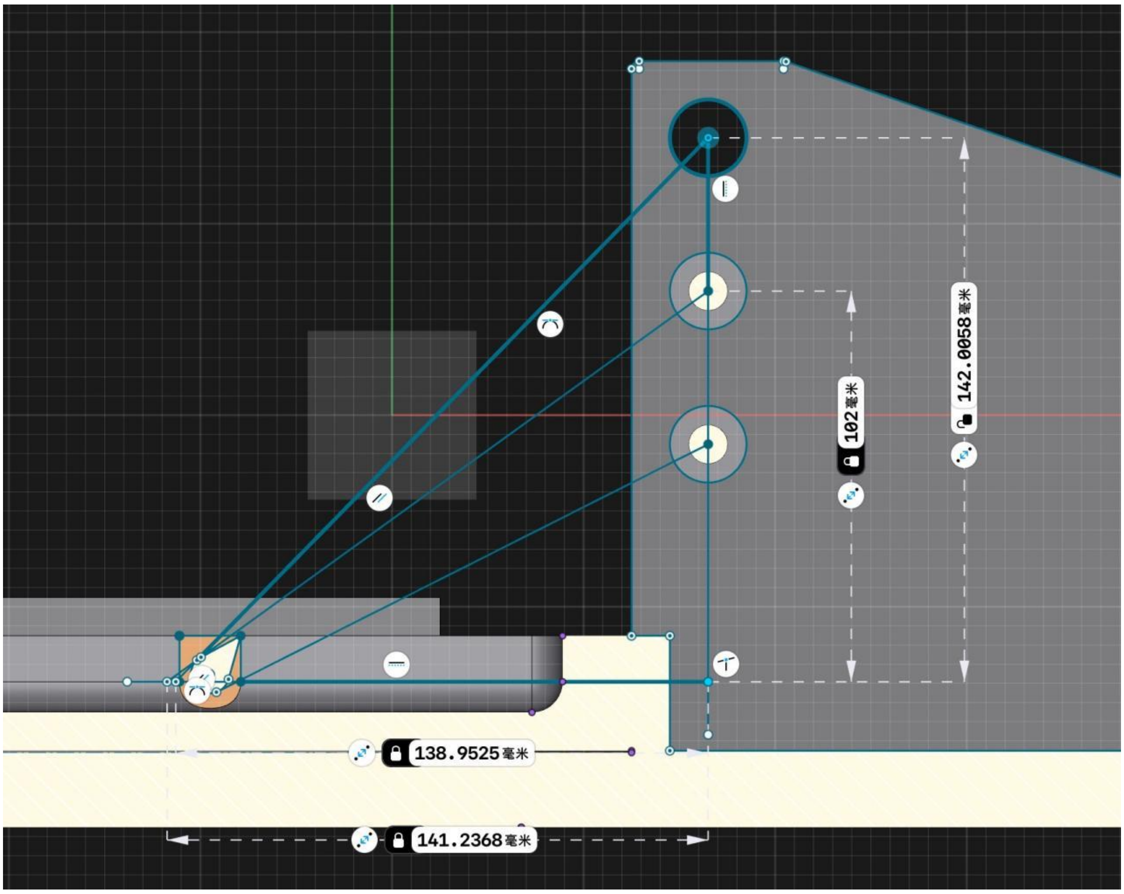

Figure4. Film deposition Angle and horizontal distance of tank

This part involves a special triangle formed by the shafts on the traction roller and deposition tank of an LB (Liquid-Based) film production machine. There are two scenarios to consider:

Low-perforation roller scenario: In this case, one leg of the right triangle is denoted as $141.24\text{mm} + \text{x in(mm)}$, the other leg is 102mm, and the corresponding angle is denoted as α , the deposition angle.

High-perforation roller scenario: In this case, one leg of the right triangle is denoted as $138.95\text{mm} + \text{x in(mm)}$, the other leg is 142mm, and the corresponding angle is denoted as β, the deposition angle.

Calculations:

For both scenarios, the length of the hypotenuse c of the triangle can be calculated using the Pythagorean theorem:

$$c = \sqrt{(141.24\text{mm} + \text{x})^2 + 102^2}$$

$$c = \sqrt{(138.95\text{mm} + x)^2 + 142^2}$$

For the low-perforation roller scenario, the deposition angle α can be found using:

$$\alpha = \arctan(\frac{102}{141.24 + x})$$

For the high-perforation roller scenario, the deposition angle β can be found using:

$$\beta = \arctan(\frac{142}{138.95 + x})$$

These equations provide the relationship between the deposition angle and the horizontal distance of the tank for both low-perforation and high-perforation roller scenarios, considering x ranging from 0 to 225mm.

Low-perforation roller scenario:

For the maximum angle (α_{max}):

$\alpha_{max} = \arctan(\frac{102}{141.24}) \approx 38.262°$

For the minimum angle (α_{min}):

$$\alpha_{min} = \arctan(\frac{102}{141.24 + 225}) \approx 24.154°$$

High-perforation roller scenario:

For the maximum angle (β_{max}):

$\beta_{max} = \arctan(\frac{142}{138.95}) \approx 46.703°$

For the minimum angle (β_{min}):

$$\beta_{min} = \arctan(\frac{142}{138.95 + 225}) \approx 27.031°$$

These values represent the range of deposition angles for both scenarios with x ranging from 0 to 225 mm.

3.1 Subsystem Requirements and Verifications3.1.1 Electric control subsystem

Requirements

- **Winding Roller Assembly:** This assembly includes a roller integrated with a stepper motor. Its primary purpose is to control the winding of material onto the system. The stepper motor used has the following specifications:
  - Step Angle: 1.8 degrees
  - Phase Current: 1.5A
  - Static Torque: 0.7 N*m
- **Power Supply for Stepper Motor (TB6600 Driver):** The TB6600 driver is powered by a dedicated power supply with the following specifications:
  - Voltage: 15V
  - Current: 1.5A
- **Power Supply for Arduino:** The Arduino microcontroller is powered by a separate power supply with the following specifications:
  - Voltage: 5V
  - Current: 0.5A
- **Control Code:** The stepper motor is controlled using the Arduino programming language, which is based on C/C++.

Verifications

- **Winding Roller Assembly:** Use a digital protractor to measure the actual step angle of the stepper motor. Use a clamp meter to measure the phase current while the motor is in operation. Use a torque wrench to measure the static torque of the motor. Verify that the assembly can control the winding of material onto the system effectively by observing the material winding process under different operating conditions.

- **Power Supply for Stepper Motor (TB6600 Driver):** Use a multimeter to measure the output voltage and current of the power supply. Ensure that the voltage is stable at 15V and the current is within the specified range of 1.5A. Use an oscilloscope to verify the stability of the voltage and current over time.

- **Power Supply for Arduino:** Use a multimeter to measure the output voltage and current of the power supply for the Arduino. Ensure that the voltage is stable at 5V and the current does not exceed 0.5A. Use an oscilloscope to verify the stability of the voltage and current over time.

- **Control Code:** Upload the control code to the Arduino and monitor its behavior using the Arduino IDE serial monitor. Verify that the code effectively controls the stepper motor according to the specified requirements by observing the motor's behavior and the winding of material onto the system.

- **Overall System Verification:** Integrate the electric control subsystem into the larger system and test its interaction with other subsystems. Use the above-mentioned instruments to verify the operation of the electric control subsystem under various operating conditions. Conduct a series of tests to ensure that the subsystem operates as intended and contributes to the overall functionality of the deposition machine.

3.1.1.1 Transmission subsystem

Requirements

- **Frame:** The frame of the system is a key structural component, designed in a trapezoidal shape and manufactured using 3D printing technology. It is constructed from photosensitive resin material, providing durability and stability to the entire transmission subsystem. The frame serves as the foundational support, ensuring proper alignment and functionality of all system components.
- **Feeding Roller Assembly:** The feeding roller assembly, a critical component of the system, comprises a roller integrated with an adjustable damping mechanism. This mechanism plays a pivotal role in regulating the material feeding process onto the system. By controlling the damping mechanism, operators can finely adjust the material feed rate, ensuring optimal deposition conditions for the thin film. This precise control is essential for achieving uniform film thickness and high-quality deposition results.

Verifications

- **Frame:** Verification of the frame includes ensuring its trapezoidal shape matches design specifications using a measuring tape or ruler, verifying its material through material analysis tests or manufacturing documentation, conducting stability tests with controlled forces to assess its load-bearing capacity, and checking alignment with a level to ensure proper functionality of all system components.
- **Feeding Roller Assembly:** Verification of the feeding roller assembly involves verifying the integration of the damping mechanism with the roller, conducting feeding tests to observe and measure the material feed rate under various damping settings, ensuring the adjustment mechanism of the damping mechanism functions smoothly and accurately, and measuring the film thickness at different points on the substrate to verify the uniformity achieved by the feeding roller assembly.

3.1.1.2 Deposition tank subsystem

- **Deposition Tank:** The deposition tank is a specialized container constructed from Teflon material, meticulously designed to store and dispense the deposition material essential for the manufacturing process. This tank is engineered to provide a suitable environment for the deposition material, ensuring its integrity and preventing contamination. Its design includes features that facilitate easy filling, dispensing, and cleaning, ensuring efficient and reliable operation throughout the deposition process.
- **Special Shaft:** This specialized Teflon shaft plays a crucial role in the

deposition process, ensuring the uniform distribution of deposition material onto the substrate or film surface. Its design and material properties are tailored to facilitate smooth and consistent material flow, preventing uneven deposition or buildup. The shaft's precise engineering enables it to efficiently distribute the material across the substrate, contributing to the overall quality and uniformity of the deposited film.

- **Sliding Platform:** The sliding platform serves as a movable base for the deposition tank within the system. It facilitates easy access to the tank for maintenance and material replenishment. Additionally, it connects to the base of the transmission subsystem, ensuring proper alignment and integration between the two subsystems.

Verifications

- **Deposition Tank:** Verification of the deposition tank includes ensuring it is constructed from Teflon material, verifying its design for storing and dispensing deposition material, checking that the design allows for easy filling, dispensing, and cleaning, and testing its operation to ensure efficient and reliable performance throughout the deposition process.

- **Special Shaft:** Verification of the specialized Teflon shaft involves ensuring it is installed correctly, conducting tests to verify its ability to facilitate uniform distribution of deposition material onto the substrate or film surface, checking for smooth and consistent material flow along the shaft, and measuring the distribution of material across the substrate to confirm the shaft's effectiveness in achieving uniformity.

- **Sliding Platform:** Verification of the sliding platform includes verifying its functionality as a movable base for the deposition tank, ensuring it allows easy access to the tank for maintenance and material replenishment, checking the alignment and integration between the platform and the base of the transmission subsystem, and testing its stability and movement to ensure proper functionality within the system.

3.1.2 Injection material subsystem

Requirements

- **Bracket for Injector Installation:** The bracket is a mounting structure designed to securely hold and position the injectors within the system. It is capable of simultaneously accommodating up to eight injectors, providing versatility and scalability to the injection process.

- **Injectors:** These specialized devices are responsible for precisely dispensing the injection material onto the designated surface or substrate. Their configuration, including nozzle design, flow rate, and control mechanisms, will be tailored to the specific requirements of the manufacturing process.

- **Injection Pump:** The injection pump is responsible for accurately delivering the injection material to the injectors, ensuring a controlled and consistent flow during operation. Its design may incorporate features such as reservoirs, feed mechanisms, and sensors to monitor material levels and flow rates effectively.

Verifications

- **Bracket for Injector Installation:** Verification of the bracket for injector installation involves ensuring that it securely holds and positions up to eight injectors within the system. This includes checking the bracket's mounting structure for stability and compatibility with the injectors. Additionally, the verification process should ensure that the bracket allows for easy installation and removal of injectors as needed.

- **Injectors:** Verification of the injectors includes conducting tests to verify that they precisely dispense the injection material onto the designated surface or substrate. This involves checking the configuration of the injectors, including the design of the nozzles, flow rate, and control mechanisms, to ensure they meet the specific requirements of the manufacturing process.

- **Injection Pump:** Verification of the injection pump involves several steps. Firstly, the pump should be tested to ensure it accurately delivers the injection material to the injectors. Secondly, it should be verified that the pump maintains a controlled and consistent flow during operation. Additionally, features such as reservoirs, feed mechanisms, and sensors should be checked to ensure effective monitoring of material levels and flow rates. Lastly, the pump's design should facilitate easy maintenance and adjustment of flow rates.

3.1.3 Image processing subsystem

Requirements

- **Real-time Image Acquisition:** The subsystem must be capable of acquiring high-resolution images of the liquid surface at a high frame rate to ensure accurate analysis of the thin film material.

- **Image Processing Algorithms:** The subsystem must implement advanced image processing algorithms to accurately calculate the proportion of thin film material. These algorithms should be efficient and capable of handling large amounts of image data in real-time.

- **Integration with Arduino:** The subsystem should be able to communicate effectively with the Arduino microcontroller to receive and process commands related to the deposition process, such as adjusting the speed of the stepper motor driving the film rotation.

- **Closed-loop Control:** The subsystem should enable closed-loop control of the deposition process based on the calculated proportion of thin film material. This control mechanism should allow for real-time adjustments to the deposition rate to ensure uniform film thickness.

- **Compatibility with BAM or Digital Camera:** The subsystem should be compatible with either a Brewster Angle Microscope (BAM) or a digital camera for image acquisition, providing flexibility in the choice of imaging hardware.

Verifications

- **Real-time Image Acquisition:** Verification of the Image Processing Subsystem includes ensuring it can acquire high-resolution images of the liquid surface at a high frame rate. This involves testing the system to verify that the images acquired are of sufficient quality for accurate analysis of the thin film material.
- **Image Processing Algorithms:**Verification of the Image Processing Subsystem involves implementing and testing advanced image processing algorithms to accurately calculate the proportion of thin film material. Additionally, it includes verifying that these algorithms are efficient and capable of handling large amounts of image data in real-time.
- **Integration with Arduino:** Verification of the Image Processing Subsystem includes ensuring effective communication between the subsystem and the Arduino microcontroller. This involves testing the subsystem's ability to receive and process commands from the Arduino related to the deposition process, such as adjusting the speed of the stepper motor.
- **Closed-loop Control:** Verification of the Image Processing Subsystem includes verifying that it enables closed-loop control of the deposition process based on the calculated proportion of thin film material. Additionally, it involves testing the control mechanism to ensure it can make real-time adjustments to the deposition rate to achieve uniform film thickness.
- **Compatibility with BAM or Digital Camera:** Verification of the Image Processing Subsystem includes ensuring compatibility with both Brewster Angle Microscopes (BAM) and digital cameras for image acquisition. Additionally, it involves testing the subsystem with both types of imaging hardware to ensure flexibility and compatibility.

2.4 Tolerance Analysis

The main load that affects the work of the product comes from the tension between the output roll and the collection roll. We need to make sure the film stays tight while having enough power to drive the overall motion. We plan to put the output of the motor through the reduction gear set to achieve a low speed.

Gear ratio: 1:100

film moving speed: 5-20mm/h

Friction on the resistance roll: 2-5N

Single operation duration: 5-20hours

3. Cost Analysis

Part	Model number	cost/yuan
Arduino circuit board		165
Step motor1	DFRobotTB6600	85
Step motor2	42BYGH40	125
Teflon parts		2980
3D resin print part		1280
Bearing	40/30mm	25
Belt	85J	25
Total		4685

Figure5. Cost of all parts

4.Schedule

date	Monday	Tuesday	Wednensay	Thursday	Friday	Saturday	Sunday	EE Group member
3/11	Project Proposal due 11:59p	Mechanical system &Control system design draft			Cost evaluation	**Model design determination**		ME Group member
3/18	**Animated demonstration**	Control system drive demonstration	CustomizeTeflon parts					Whole Group
3/25	Project Proposal Regrade due	manufacturing	Submit design document	The design enables a fixed Teflon trough scheme				
4/1	Power system operation test, through the reducer drive roll to achieve low speed operation		Material addition subsystem test	Teamwork Evaluation I due 11:59p	Assembly test, friction part test			
4/8	Production result inspection	The first analysis and summary	Individual Progress Report due 11:59p					

Figure6. Time schedule for different major members

5. Ethics and Safety

5.1 Ethics

Inspired by the The ethic of community[1], we summarize the following ethical concerns that apply to this project:

1. Evaluate the societal impact of our project: It is imperative to assess how our project affects society comprehensively, encompassing social, economic, and environmental dimensions. This entails adopting a holistic perspective to consider not only immediate advantages but also potential long-term ramifications.

2. Adhere to principles of equity and impartiality: We must ensure that our project is equitable and impartial, devoid of any discrimination based on attributes such as race, gender, religion, or nationality. This necessitates acknowledging and addressing potential biases.

3. Demonstrate honesty and transparency: Upholding honesty and transparency in our professional conduct, including communication with team members, teaching assistants, instructors, and the public, is essential. This involves candidly addressing potential risks and uncertainties and disclosing any conflicts of interest.

5.2 Safety

Drawing inspiration from lab safety research[2], we outline the following safety considerations relevant to this project:

1. Lab safety: The design and testing of our LED display system involves working with various tools, equipment, and materials that can pose hazards to our members. This includes ensuring that all of us are trained in proper safety procedures, that appropriate safety equipment is available, and that all testing and assembly is performed in a designated and controlled laboratory environment.

2. Electrical safety: The power system involved in our project could pose risks of electrocution or electrical fires if proper safety measures are not taken. This includes ensuring that all wiring is properly insulated and grounded, that circuits are appropriately sized and protected, and that appropriate safety equipment is available for handling and testing electrical components.

3. Mechanical safety: The rotating motor involved in our project could pose risks of injury or damage to equipment if not properly installed or operated. This includes ensuring that the

motor is securely mounted and that all moving parts are properly guarded to prevent contact with users or other objects.

Reference

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[2] Ménard, A. D., & Trant, J. F. (2020). A review and critique of academic lab safety research. Nature chemistry, 12(1), 17-25.

[3] Hassan, M., Ghaffar, A., Lou, G., Miao, Z., Peng, Z., & Celebi, K*. (2024). Enhanced Transport Kinetics of Electrochromic Devices by W18O49 NW/Ti3C2Tx Composite Films. Advanced Functional Materials. Just accepted.

[4] Ghaffar, A., Hassan, M., Penkov, O. V., Yavuz, C. T., & Celebi, K*. (2023). Tunable Molecular Sieving by Hierarchically Assembled Porous Organic Cage Membranes with Solvent-Responsive Switchable Pores. Environmental Science and Technology, 6(4), 1801570.https://doi.org/10.1021/acs.est.3c05883

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