ZJU-UIUC Institute
ME470/ECE445
Senior Design Proposal

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 Shen

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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 for thin 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

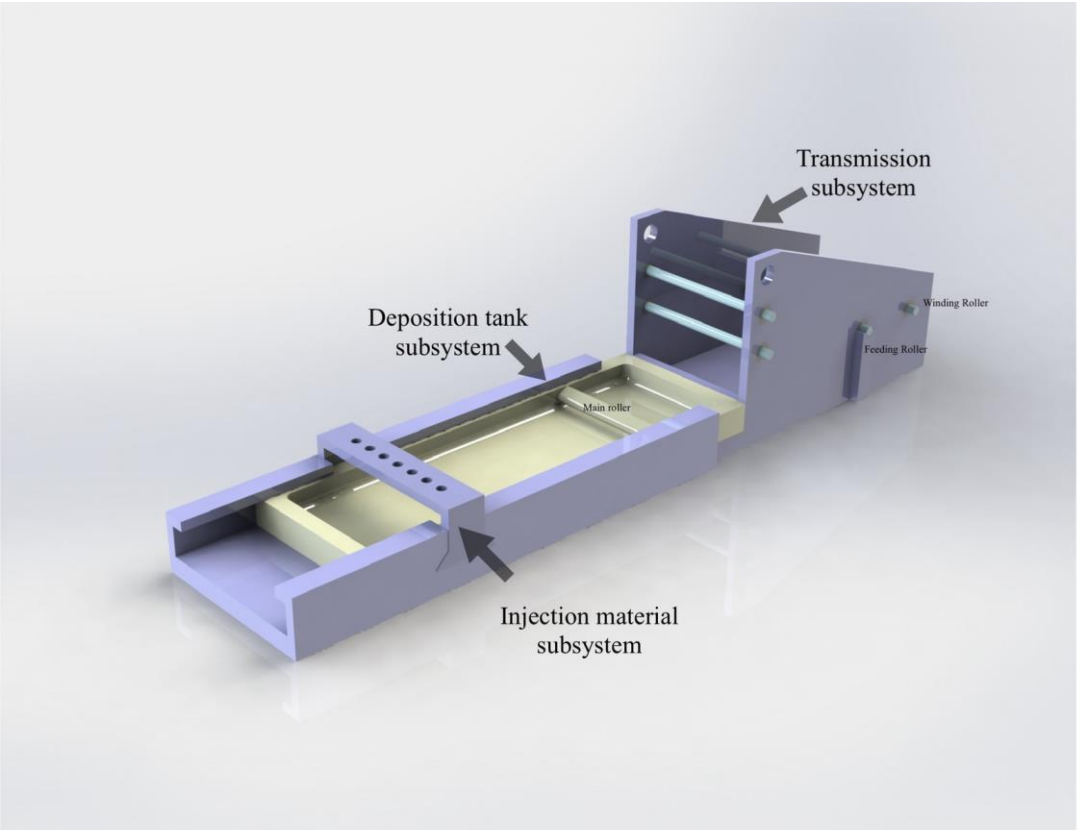


Figure1. Detail Design Sketch

1.4 High Level Requirements

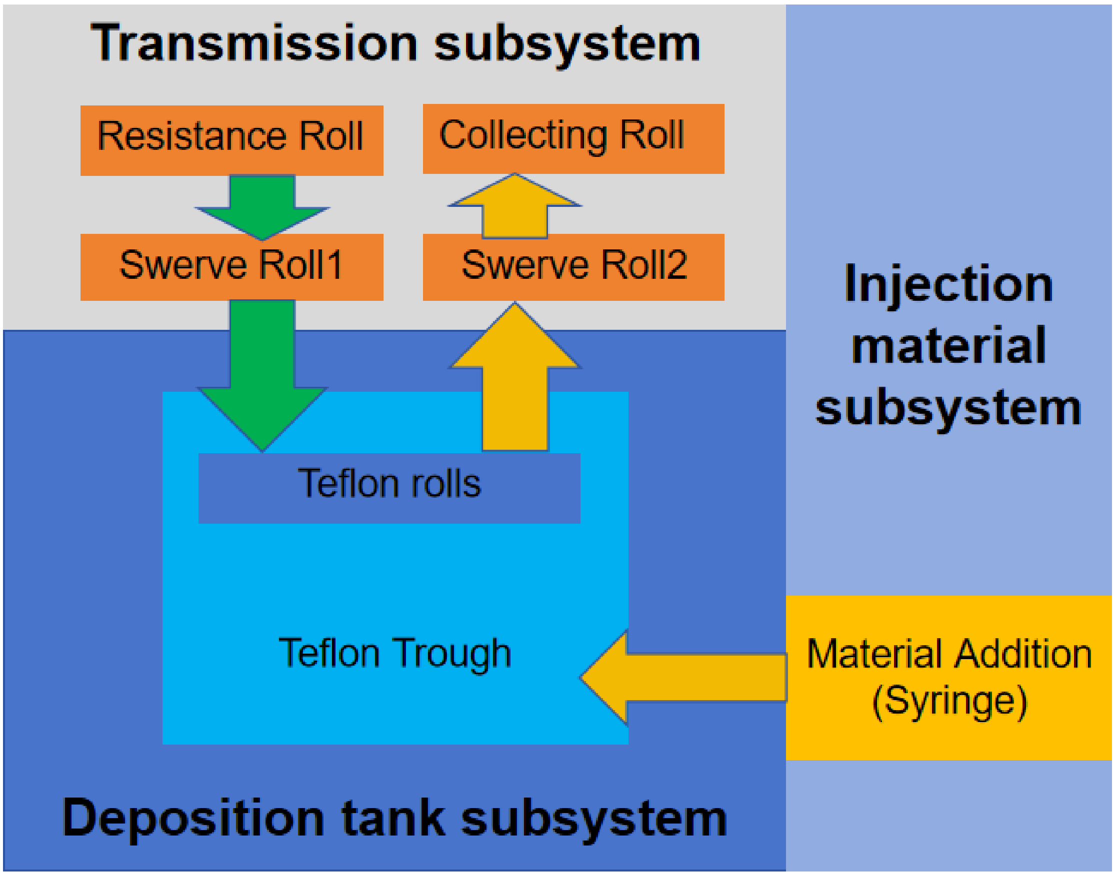
The efficiency of material self-spreading: The uniform spreading of materials on a substrate is essential for producing films with consistent properties. Effective self-spreading guarantees the film's uniformity, directly impacting its performance in diverse applications. Techniques like utilizing moving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



2.2 Subsystem Descriptions

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

2.2.1 Transmission subsystem

The drivetrain hardware consists of a Teflon trough, four 3D printed parts rolls, a stepper motor and belts. The diameter of the Teflon roll is 10mm, the diameter of the two 3D printed parts rolls (roll-out and collection) is 30mm, and the diameter of the other two rolls is 10mm.

2.2.2 Deposition tank subsystem

The deposition trough is manufactured by Teflon and placed in a frame made of 3d printed parts. The interior surface of the Teflon trough is smooth and easy to clean. The shape of the bracket is connected with the rolls frame by mortise and tenon structure, and the feeding table is fixed at the same time, limiting the movement of the Teflon trough in a one-way direction.

2.2.3 Injection material subsystem

The Injection material subsystem consists of 1 motor, 1 large syringe, 8 small syringes and 1 bracket. The motor controls the movement of a plate above the bracket and generates thrust, which can squeeze the large syringe, extruding the material from the syringe, and then achieve the function of balanced feeding through the form of 1 syringe in and 8 syringe out.

2.3 Subsystem Requirements

2.3.1 Transmission subsystem

- **Frame:** The frame is composed of a trapezoidal structure manufactured using 3D printing technology and constructed from photosensitive resin material. It serves as the structural support for the entire transmission subsystem.
- **Feeding Roller Assembly:** This assembly includes a roller equipped with an adjustable damping mechanism. Its function is to regulate the feeding of material onto the system.
- **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++.

2.3.2 Deposition tank subsystem

- **Deposition Tank:** The deposition tank is a container made of Teflon material specifically designed to store and dispense the deposition material used in the manufacturing process.
- **Special Shaft:** This specialized shaft, also made of Teflon material, is responsible for uniformly distributing the deposition material onto the surface of the substrate or film being processed.
- **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.

2.3.3 Injection material subsystem

- **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.

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. Ethics and Safety

3.1 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.

3.2 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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[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.

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