MINIATURIZED LANGMUIR BLODGETT

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Abstract

The Langmuir-Blodgett (LB) film method is a widely used technique for producing nano films with precise control over their structure and orientation. However, the traditional LB film method faces challenges in terms of characterizing the properties of ultra-thin films and achieving precise control over film thickness. To overcome these limitations, a new method has been developed that combines advanced imaging techniques, computer algorithms, and real-time monitoring.

In this paper, we propose a solution to enhance the efficiency and control of the LB film method. By directly placing the PTFE trough under a microscope, real-time observation of the film formation process becomes possible. Furthermore, leveraging the captured images, software analysis can be employed to monitor and control the motion of the syringe pump and barriers. The integration of imaging, software analysis, and motion control within the LB film method showcases the potential for advancements in nano film fabrication and application development.

Key word: LB film; Miniaturized; nano film.

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 nanophotonic. Here is how we can solve it, basing on the traditional method, we can increase the efficiency by directly putting the PTFE trough under the microscope, which means we can observe the situation of the film in 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 high level requirement

Table 1 High-level requirement and description

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.

1.4 block diagram

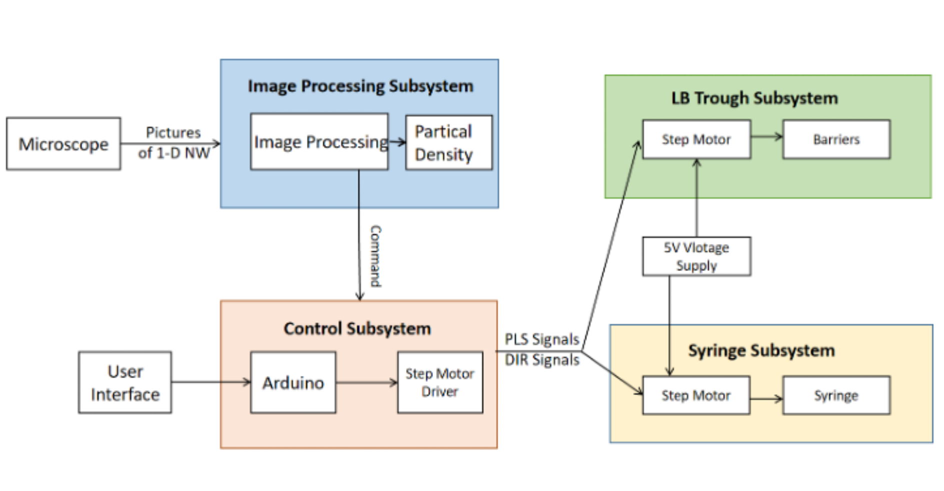


Figure 1 Block Diagram

The figure1 shows that there are 4 basic subsystems in our design: image processing subsystem, LB trough subsystem, control subsystem and syringe pump subsystem. Once we get the image from microscope, image processing subsystem can analyze the picture and then send command to control subsystem. After that, LB trough subsystem and syringe subsystem are pushed by PLS signals and DIR signals from control subsystem.

2 Design

2.1 Mechanical design considerations

During the design progress, I mainly consider the following factors which can influence the quality of film: 1. Vibration from the motor. 2. The moving speed of the barriers. 3. The size of the whole Test bed.

2.1.1 Vibration of the motor

Vibration is important for LB film method as any small vibration will lead to a shake on the water face which might destroy the nano film and make the whole process hard to control.

2.1.2 The moving speed of the barriers

To make the film more controllable and less vibration while working, we need to make a slow speed for the barriers which can adjust from 1mm/min to 8mm/min. This speed is hard to achieve only by step motor, so we need to add a decelerate gear box. Finally I decided to add a 1:139 gear ration planetary gear box at the end of the step motor and also add a 1:40 gear ration for the worm gear set. In this way, our barrier can move slowly and steadily.

2.1.3 The size of the test bed

The space under the microscope is very limited, so we need to make our test bed as small as possible to fit in there.

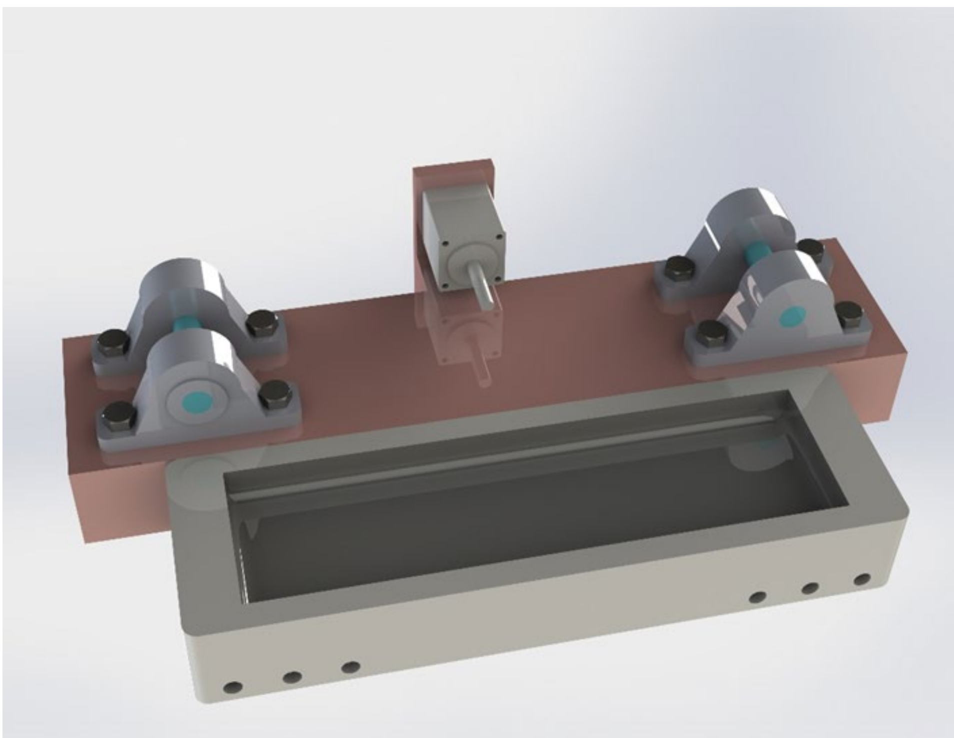


Figure 2 Version1 Test bed

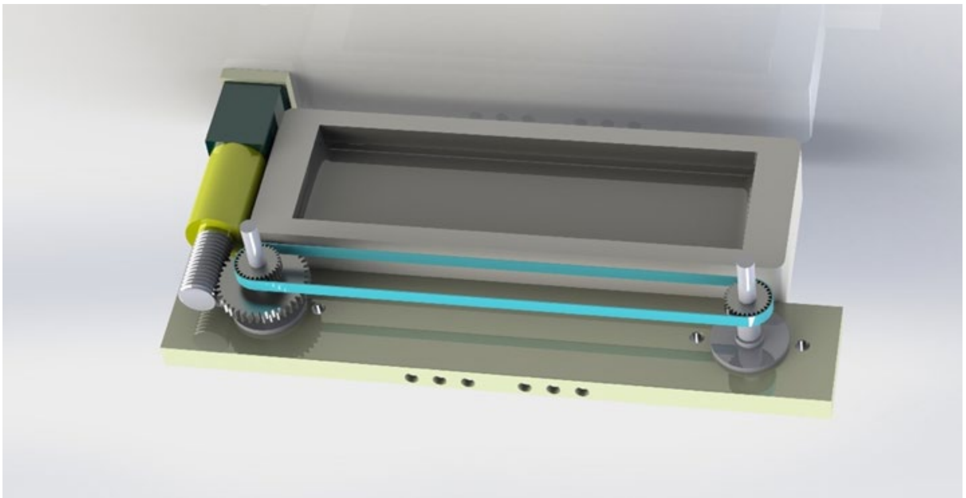


Figure 3 Version2 Test bed

2.2 CAD Design

With the above mechanical considerations, we basically design two version for the CAD prototype, the version one has the problem of size and moving speed. The version 1 is design based on the commercial LB film machine. However, the commercial machine does not have the need for size, the arrangement of belt and step motor will increase the height and length, and the orientation of the belt will cause a collision with the object when we want to change the object. Therefore, we develop the version two which well fix the above problem. We take the step motor from center to the side which will leave enough space for the deceleration gear box, and we also use a worm gear to change the direction of the belt which will leave more space for the object to rotate.

2.3 Speed estimation

Because the Barriers' moving speed needs to be small enough to avoid the possible vibration, we expected to design our transport system to have the smallest speed within 1mm/min. However, the initial speed of our step motor is far beyond our requirements, so we add a deceleration gear box and a worm gear to decelerate the step motor. The gear ration we choose are 139 for the gear box and 40 for the worm gear so we can get our overall gear ration is:

$$\gamma_{Gear\ box} \times \gamma_{worm\ gear} = \gamma_{Total} \tag{2.1.1}$$

Where $\gamma_{Gear\ box}$ and $\gamma_{worm\ gear}$ is the gear ration of gear box and worm gear, so the overall gear ration is γ_{Total} = 5560. The step motor we chosen can work from 0-900 RPM (rotation per minutes). We set the distance between two bar is $D_{belt} = 18mm$, so we can get our theoretical speed from

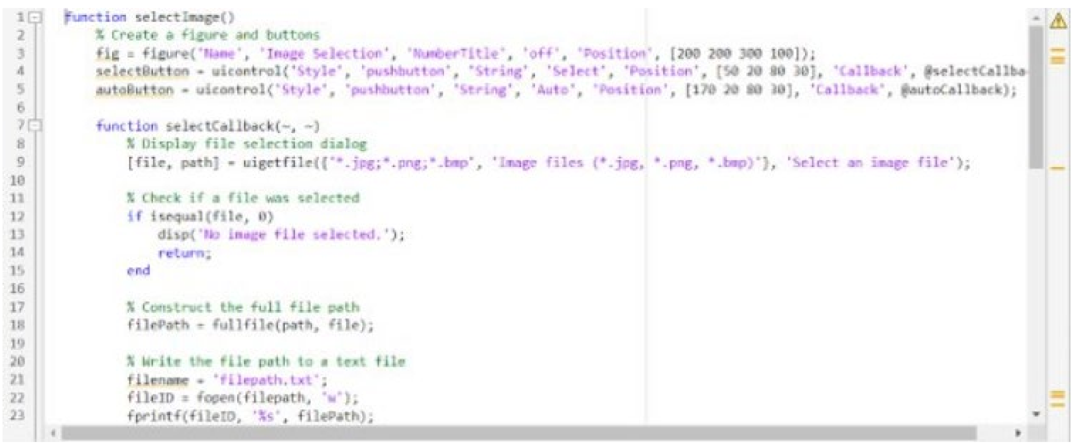
$$\frac{\pi * D_{belt} * V_{step}}{\gamma_{Total} * C} = V_{barrier} \tag{2.1.2}$$

Where V_{step} is the rotation speed of the step motor and C is the step division factor which can changed by the step motor controller. Therefore, if we choose our step division factor to 2, we can get our theoretical barrier moving speed range from 0.55mm/min to 8.13mm/min.

2.4 Image Processing

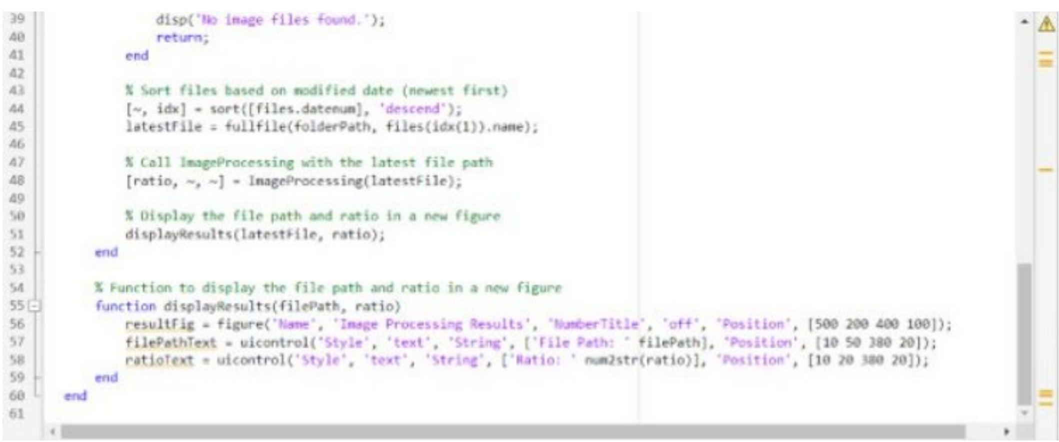
2.4.1 image selection

There are two ways to select the image, There are two buttons on the interface window, one is select and the other one is auto. By pressing “select”, user can process one specific image and get the data. This can be used for testing and provide standard values for later “auto” patterns. “Auto” pattern can read the newest file path from the specified folder, When connecting to the microscope, the capture from the microscope saved in the folder can be processed and transfer instructions to the following control subsystem to control the movement of the barriers, promoting the formation of thin films. This can realize the real-time automatic control to the device.



```
function selectImage()
    % Create a figure and buttons
    fig = figure('Name', 'Image Selection', 'NumberTitle', 'off', 'Position', [200 200 300 100]);
    selectButton = uicontrol('Style', 'pushbutton', 'String', 'Select', 'Position', [50 20 80 30], 'Callback', @selectCallba
    autoButton = uicontrol('Style', 'pushbutton', 'String', 'Auto', 'Position', [170 20 80 30], 'Callback', @autoCallback);

    function selectCallback(~, ~)
        % Display file selection dialog
        [file, path] = uigetfile({'*.jpg;*.png;*.bmp', 'Image files (*.jpg, *.png, *.bmp)'}, 'Select an image file');

        % Check if a file was selected
        if isequal(file, 0)
            disp('No image file selected.');
            return;
        end

        % Construct the full file path
        filePath = fullfile(path, file);

        % Write the file path to a text file
        filename = 'filepath.txt';
        fileID = fopen(filepath, 'w');
        fprintf(fileID, '%s', filePath);
```

Figure 4 Code for image processing 1



```
            disp('No image files found.');
            return;
        end

        % Sort files based on modified date (newest first)
        [~, idx] = sort([files.datenum], 'descend');
        latestFile = fullfile(folderPath, files(idx(1)).name);

        % Call ImageProcessing with the latest file path
        [ratio, ~, ~] = ImageProcessing(latestFile);

        % Display the file path and ratio in a new figure
        displayResults(latestFile, ratio);
    end

    % Function to display the file path and ratio in a new figure
    function displayResults(filePath, ratio)
        resultFig = figure('Name', 'Image Processing Results', 'NumberTitle', 'off', 'Position', [500 200 400 100]);
        filePathText = uicontrol('Style', 'text', 'String', ['File Path: ' filePath], 'Position', [10 50 380 20]);
        ratioText = uicontrol('Style', 'text', 'String', ['Ratio: ' num2str(ratio)], 'Position', [10 20 380 20]);
    end
end
```

Figure 5 Code for image processing 2

2.4.2 processing

To do preparation for the following steps, we should cut the edges of captures. Because of the Lighting method, the edge of the capture is dimmer. Since the following analysis is based on pixels, we need to get rig of the dim part.

After that we used a filter to remove Gaussian noise from captures. Because of the movement of particles on the water, the captures from microscope has Gaussian noise. By applying Gaussian filter, the effect of the noise can be reduced and eliminated. Gaussian noise removal helps to restore the original details and clarity of the image. The noise reduction process smooths out the random variations caused by noise, resulting in a cleaner and visually more appealing image.

In the following image measurement, accurate image analysis is crucial. Removing Gaussian noise helps to reduce false defections or errors caused by noise interference, leading to more reliable and accurate results.

2.4.3 image segmentation

Image segmentation part divides the images into meaningful regions or objects. It is used to identify and isolate specific areas of interest within the image. Segmentation can be based on various criteria, and in our segmentation the criteria is the color. It plays a crucial role in object recognition, tracking, and image understanding.

Grayscale threshold segmentation is used in image processing to separate an image into distinct regions based on pixel intensity values. The image is typically represented in grayscale, where each pixel has a single intensity value ranging from black (0) to white (255) in an 8-bit image.

1)Convert to Grayscale: convert the original colored image, it needs to be converted to grayscale. This is typically done by averaging or weighting the color channels to obtain a single intensity value for each pixel.

2)Select Threshold: Otsu's method is used here.

3)Apply Threshold: Compare the intensity value of each pixel with the threshold value. If the intensity is greater than or equal to the threshold, assign the pixel to the foreground; otherwise, assign it to the background.

4)Generate Binary Image: After applying the threshold to all pixels, the result is a binary image where foreground pixels are represented as white and background pixels as black. This binary image can be used for further analysis or visualization.

2.4.4 analyzing

The Otsu method automatically determines an optimal threshold for image thresholding. Calculate the frequency of occurrence for each pixel intensity level in the image. It finds a threshold that maximizes the separation between foreground and background pixels in an image. And in our captures, it split the particles' pixels and the water pixels. The Otsu method where the intensity distributions of foreground and background overlap significantly or are not well-defined, the Otsu method may struggle to find an accurate threshold, leading to misclassification, But in the capture examples, the difference between particles and water background is specific.

By calculating the ratio of white pixels, we can get whether the film meets the requirements.

2.5 Control Module

The control part of our device plays a critical role in governing the mechanical aspects of the system. It encompasses the control of two stepper motors—one dedicated to the barriers and the other to the Syringe pump. To ensure precise and efficient control over these components, we have developed dedicated control programs and a user interface (UI).

2.5.1 Hardware Required for Control

We have selected Arduino as the microcontroller platform for its ease of use, versatility, and extensive community support. The Arduino board will be responsible for executing the control program and coordinating the barriers' actions. 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 usedas PWM output pins), 6 analog input pins, 16 MHz quartz crystal oscillator, USB interface, power interface, support for online serial programming, and reset keys. To control the stepper motors, we will employ TB6600 stepper motor driver module. This driver module is compatible with Arduino and enables precise control of the stepper motors, allowing us to command their movements accurately.

2.5.2 Control Program

We developed a control program in the Arduino IDE using the AccelStepper library to efficiently control the stepper motor. Our decision to use this library stems from the limitations of Arduino's built-in stepper library, which doesn't allow simultaneous control of two motors with different parameters. By directly outputting pulse signals through Arduino, we encountered difficulties in adjusting the motor's speed and accurately tracking the number of steps it had moved.

With the control program, we can easily configure the motor's movement by setting its direction and speed. Additionally, we can record the position changes of the motor and return it to its initial position, effectively fulfilling most of our desired functions.

```
void PrintCommands()
{
    //Printing the commands
    Serial.println(" 'C' : Prints all the commands and their functions.");
    Serial.println(" 'P' : Make the barriers seperating.");
    Serial.println(" 'N' : Make the barriers closing.");
    Serial.println(" 'R' : Make the barriers moving in an absolute positive position (seperating).");
    Serial.println(" 'r' : Make the barriers moving in an absolute negative position (closing).");
    Serial.println(" 'S' : Stops the barriers immediately.");
    Serial.println(" 'A' : Sets an acceleration value.");
    Serial.println(" 'L' : Prints the current position/location of the barriers.");
    Serial.println(" 'H' : Goes back to 0 position from the current position (homing).");
    Serial.println(" 'U' : Updates the position current position and makes it as the new 0 position. ");
    Serial.println(" 'p' : Making the Syringe push. ");
    Serial.println(" 'n' : Making the Syringe pull. ");
    Serial.println(" 's' : Stop the Syringe. ");
}
```

Figure 6 Commends

To facilitate instruction input, we opted to use serial communication. This approach offers two distinct advantages. Firstly, it provides a convenient means of inputting instructions, making it easier to interact with the program. Secondly, it allows for instructions to be inputted using other software, expanding the versatility of the control system.

When a corresponding instruction is received through the serial communication, such as the input "P 100000 5000", the code will respond accordingly. Upon encountering the case 'P', the program utilizes the Serial.parseFloat() function to extract the first available floating-point value from the buffer, which is then assigned to the variable 'receivedSteps'. The subsequent Serial.parseFloat() function retrieves the next floating-point value and assigns it to 'receivedSpeed'. Consequently, adjusting the speed and displacement of the barrier motion merely requires modifying the float value input through serial communication.

```
case 'P': //P uses the move() function of the AccelStepper library,

    receivedSteps = Serial.parseFloat(); //value for the steps
    receivedSpeed = Serial.parseFloat(); //value for the speed
    directionMultiplier = 1; //We define the direction
    Serial.println("Barriers Seperating."); //print the action
    RotateRelative(); //Run the function
```

Figure 7 Case 'P'

By leveraging serial communication and utilizing the available functions in the Arduino IDE, we have achieved a flexible and efficient control system for the stepper motor. The ability to modify instructions through the serial interface grants users the freedom to adapt the motor's behavior to specific requirements, enhancing the overall functionality and usability of the system.

2.5.3 User Interface

To facilitate seamless operation, our device features a user-friendly interface (UI) that comprises two main sections: the Barriers Control Part and the Syringe Control Part. Each section serves a specific function to enhance the user experience.

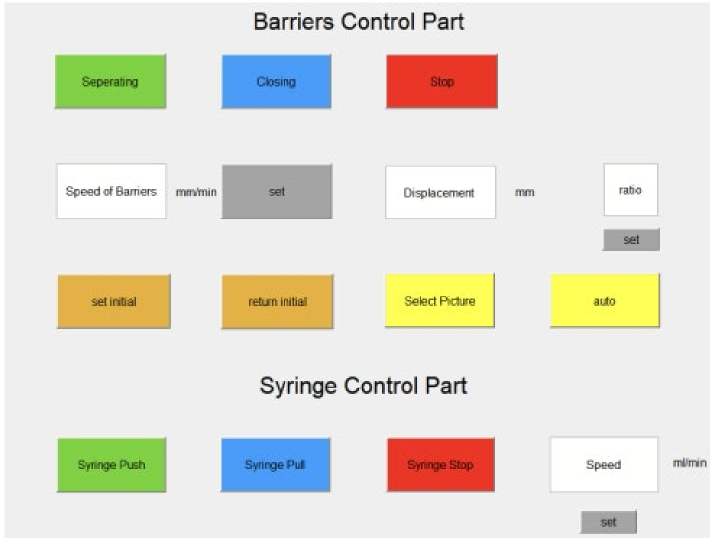


Figure 8 User page

In the Barriers Control Part, users have precise control over the movement of the barriers. This includes the ability to adjust their separation and closure, allowing for precise manipulation during the LB film creation process. Users can easily modify the speed and distance parameters to achieve their desired barrier movement, ensuring optimal film deposition.

After successfully creating an LB film, users can obtain a ratio through the image analysis section. By analyzing the captured images, the system calculates the desired ratio that relates to the film's properties or quality. This ratio can then be inputted into the UI.

To further control the barrier movement, users can utilize the select picture section in the UI. By inputting the calculated ratio, the barriers' movement can be adjusted accordingly, ensuring precise and consistent film deposition. Additionally, the system is equipped with a microscope that automatically captures images and saves them to a designated folder. By activating the auto button in the UI, the barriers' movement can react in real-time to the latest pictures in the folder. This automation streamlines the process, reducing the need for manual intervention and enhancing efficiency.

In the Syringe Control Part of the UI, users have the capability to set the speed at which the syringe adds materials to the trough. This feature allows for precise control over the material deposition process, ensuring accurate and consistent.

3. Design Verification

The miniaturized LB trough has been specifically designed for real-time microscopic observation of LB films. In order to verify its functionality, we conducted a series of three tests to assess the stability and feasibility of the trough. These tests were conducted to ensure that the trough performs reliably and meets our requirements.

3.1 Function Test

Once we assembled the final prototype, we poured pure water in the trough and let barriers push the pure water surface. Observe how the barriers would move and whether the water would leak. Especially, feel if the vibration is significant.

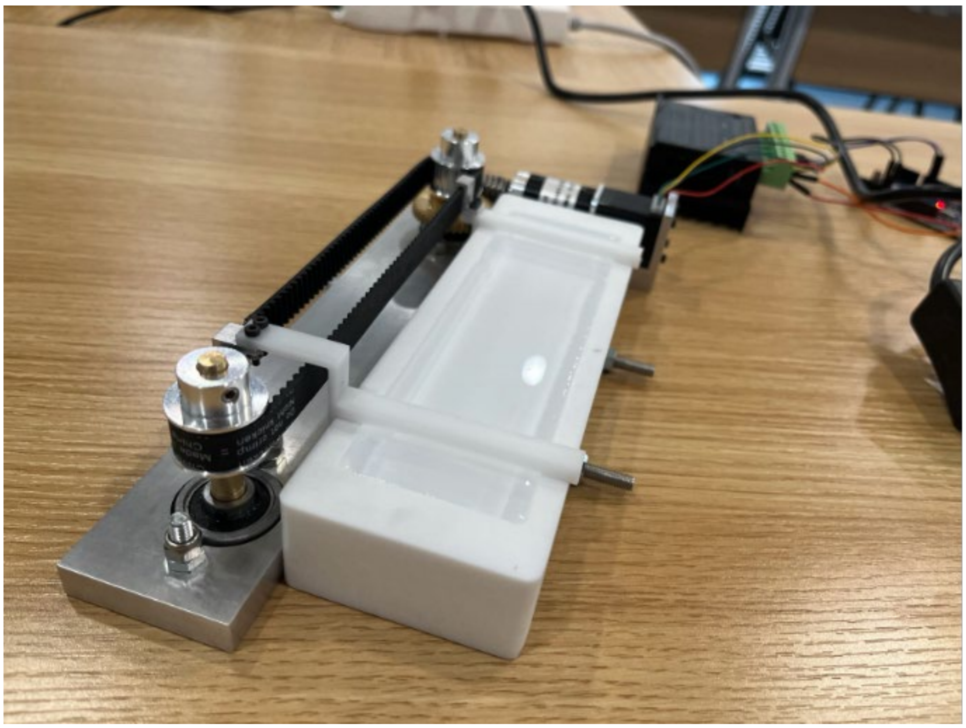


Figure 9 Final prototype during function test

Figure 9 showed no leaking water while working. Once we set the speed within reasonable range, the vibration was really small, which should be OK for LB film formation. Besides, we also placed the whole system under the microscope. The longest objective would not touch the barriers. So, the size of design is within the allowable range. In general, the whole system could work without problem.

3.2 Final Test

For the final test, we found two materials to verify the function of the trough. Both materials were formed LB films successfully. Thus, we can say our design meets all requirements raised and is stable while using.

3.1.1 Graphene

Figure 10 is the image of final LB film of graphene observed under 20x objective. During the process, we could see an obvious change in density. A live formation process could be seen on the computer screen. Once we have finished film formation and opened the barriers, the film would still remain on the water surface. A successful LB film will not return to nano particles. We can conclude that our design works successfully with graphene particles.

Figure 10 Final graphene LB film

3.1.2 Silver Nanowire

Figure 11 is the image of LB film of final silver nanowire under 100x objective. During the process, we could see an obvious change in density. A live formation process could be seen on the computer screen. In this test, we should also observe the orientation of the silver nanowire. Try to change them to a relative perfect position. The final LB film looked like a golden mirror. While at beginning, it looked like wires floating on the water surface. Like graphene particles, when we opened the barriers, the films could remain on the water surface. This was also a successful test.

Figure 11 Final silver nanowire LB film

3.3 Display and two models

Example of capture after processing:

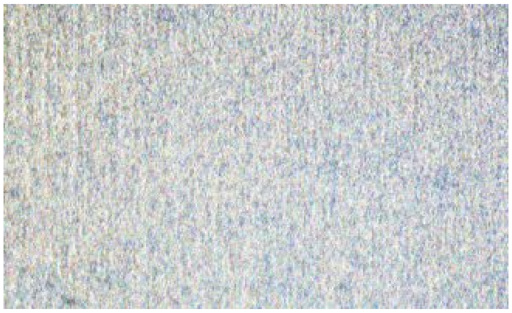


Figure 12 Example of capture after processing

Example of capture after segmentation:

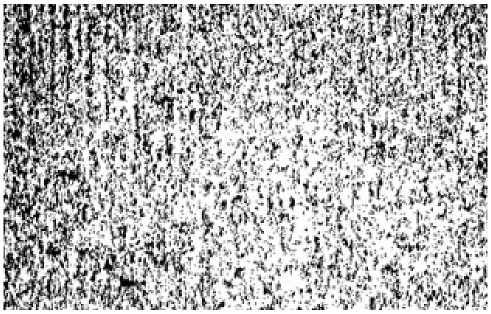


Figure 13 Example of capture after segmentation

4. Costs

4.1 Parts

Table 2 Cost table

Part	Cost（prototype）/rmb	Cost（bulk）/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 be custom made including the PTFE trough, Delrin barriers, Brass worm gear which takes up most of our budget. Because we need to put the whole product under a microscope which has extremely limited space, we need to make some gear thicker than the commercial part, that is why the Brass worm gear will cost 100rmb. However, when we can have a higher order number of those parts, the cost will be reduced.

4.2 Labor

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:

$$4 \times 18\text{rmb/h} \times 10\text{hour} \times 12\text{week} = 8640 \text{ rmb}$$

5. Conclusion

5.1 Accomplishments

Leveraging the capabilities of our miniaturized Langmuir-Blodgett (LB) Trough, we have effectively streamlined the conventional film creation process, significantly augmenting the experimental efficiency in producing high-quality films. This compact machine is designed to seamlessly fit under a microscope, thereby ensuring its unobstructed operation and avoiding any potential collisions with adjacent objects during use.

Throughout the testing phase, we successfully fabricated films of various materials, namely, graphene particles, silver nanowires, and polystyrene. This success underscores the flexibility and precision of our method, demonstrating its applicability across a wide spectrum of materials and scales. To further enhance the user experience, we have developed a user-friendly interface that facilitates effortless control of the step motor integrated within the barrier and the syringe pump. This intuitive user interface greatly simplifies the experimental process, thus increasing productivity and reducing the possibility of errors.

Moreover, acknowledging the necessity for cleanliness in experimental procedures, we've incorporated a feature into our design that allows for easy disassembly of the trough and barriers. These components can be swiftly removed and cleaned after each experiment, a crucial step to prevent contamination and maintain the integrity of subsequent trials. This thoughtful design consideration not only ensures the reliability of our results but also prolongs the lifespan and efficiency of the machine itself.

5.2 Uncertainties

The elements of uncertainty that pervade this scientific domain primarily originate from the conditions of the environment and the distinctive properties of the materials under examination. More specifically, the immediate surroundings serve as a potentially significant source of vibrations, introducing an element of unpredictability into the mix. The slightest gust of air, whether it originates from natural sources or from man-made instruments, has the capacity to generate vibrations. Similarly, even the minutest of shakes stemming from the cable or the surface of the table could incite a considerable amount of turbulence. When such disruptions occur, they are exponentially magnified under the intensely scrutinizing gaze of the microscope, thereby rendering a clear, stable view nearly impossible.

Furthermore, the choice of material used for creating the film test also introduces another layer of complexity to the situation. This selection inevitably impacts the end result and our ability to observe it accurately, given the wide array of properties unique to each material. Each material's physical characteristics, including size and shape, coupled with its inherent attractive forces, can significantly impact the film's behavior and, consequently, the outcome of the test. Such properties play a vital role in not only determining how the material interacts with the surrounding environment but also how it performs under microscopic observation, thereby directly influencing the overall quality of our findings.

5.3 Ethical considerations

In the design and development of any product, ethical considerations and safety measures play a crucial role in ensuring user well-being and preventing potential harm. This section discusses the ethical aspects and safety features incorporated into the design of a specific device, focusing on user safety, material selection, and maintenance practices.

To prioritize user safety, several design features have been implemented. The corners of the trough have been rounded to prevent users from getting scratched during operation. This proactive approach mitigates the risk of injuries and reflects a commitment to user well-being.

To minimize the potential harm caused by the device's motion, all barriers have been designed to be detachable. In the event that a user's fingers or other body parts become caught by the barriers and belt, the barriers will detach, preventing further harm. This safety measure demonstrates a responsible approach to reducing the risk of accidents and injuries.

Considering the possibility of contact with corrosive materials, the device's trough is constructed using Teflon, a material known for its corrosion-resistant properties. This selection effectively prevents corrosion and ensures the longevity and durability of the device. The barriers, made from derlin, not only offer resistance to corrosion but also contribute to the overall safety and functionality of the device.

The device's trough and barriers have been intentionally designed to be detachable, allowing users to easily disassemble and clean them. This design consideration promotes hygiene and prevents bacterial growth or contamination. By enabling users to maintain a high level of cleanliness, the device ensures the well-being and safety of its users.

The ethical considerations and safety measures implemented in the design of the device prioritize user safety, minimize potential harm, and ensure the longevity and functionality of the product. The rounded corners of the trough, detachable barriers, corrosion-resistant materials, and easy cleanability all reflect a responsible approach to design. By addressing these ethical considerations, the device provides users with a safe and user-friendly experience, demonstrating a commitment to both ethics and safety in its design and use.

5.4 Future work

Overall, we have successfully design and make a Miniterized trough which can successfully make a film and can be observed in the microscope in a real time. However there are still some parts that need to be improved:

1. Adjust foot to keep horizontal: in the film test, we found that the liquid surface is not strictly horizontal, there is some cases that right liquid level is higher than the left, though the difference is small but it still will influence the film quality.
2. The barrier moving speed range need to be larger: In our design, the barrier can move from 0.25mm-12mm/min, the speed range is enough but in the real experiment, we found we don’t need the smallest speed to be so slow and we also need to wait a long time for the barrier to open when we finish the experiment.
3. The vibration sources: During the experiment, we found that the vibration is quite large under the X100 objective, we think the possible vibration source could be: 1. The cable wire connect the PC

and arduino board. 2. The air motion from speaking and AC. 3. The particle thermal movement (for smaller particles, the thermal movement will be larger)

So we think we can decrease the vibrations by use wireless connection, adding a physical cover to the microscope to isolated from the possible air motion. And set a extremely low temperature while observing.

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Appendix A Requirement and Verification Table

Table 3 RV table

Requirement	Verification	Verification status (Y or N)
1.The barriers can move smoothly with low friction. 2.The barriers can move vertically to the belt.	1. Run the barrier under both with water and without water 2. Run the barriers for some minutes and check its orientation	Y
1. The step motor moving speed can adjust from 0.25mm/min to 12mm/min. 2.The vibration is small enough that it will not influence the film process.	1. Run certain minutes and measure its distance 2. Use hand to feel its vibration	Y
The whole trough should be able to be placed within 13cm x 22cm x 3cm space. Make sure nothing will touch the objects.	Put the whole system on the platform of microscope then check whether it will touch any objective.	Y
1. Analysis the images input, output the density of the particle film. 2. Analysis whether the film is formed, output instructions to the control system.	Analysis the input captures, output instructions to the control system, and display ratio of the particle density.	Y
The user interface is simple to understand so	Different types of function buttons in the UI are marked with different colors. At the same time, there	Y

that the freshman can use the project to finish an experiment.	are sufficient text prompts for the parts that require user input	