



JOURNAL ON COMMUNICATIONS

ISSN:1000-436X

REGISTERED

Scopus®

www.jocs.review

FLOW CONTROL OF POLYMER USING SYRINGE PUMP APPARATUS FOR ELECTROSPINNING NANOFIBER FABRICATION

R.VITHIYA¹, K.DINESH RAM², M.JAYAGANESSE³, S.GOWTHAM⁴

¹Assistant Professor, Dept of ECE, Manakula Vinayagar Institute of Technology, Puducherry.

^{2,3,4}Final Year Students, Dept of ECE, Manakula Vinayagar Institute of Technology, Puducherry.

ABSTRACT

Electrospinning is a nanofabrication technique. The process of electrospinning is commonly used to produce ultrafine fibers with nano meter-scale diameters. Through the use of a needle or spinneret, a polymer solution is electrostatically charged in this method., forming a fine jet that is accelerated towards a collector. In this method, a syringe pump with a stepper motor controller is used to provide the correct flow rate of the polymer solution to the spinneret. Controlling the diameter and shape of the generated fibers depends heavily on the syringe pump. By adjusting a number of variables, including the flow velocity, the voltage being used, and the separation between the spinneret and the collector, the electrospinning process can be optimized to create fibers that possess specific properties. Thus improves the capability of generating high-quality nanofibers.

KEYWORDS: Syringe , Syringe Needle, Stepper Motor, Stepper Motor Driver

INTRODUCTION

In the process of electrospinning, a syringe pump is utilized to regulate the speed of delivering the polymer solution to the spinneret. The spinneret, which can be a needle or a nozzle, is where the polymer solution is extruded into an electric field to produce fibers. The syringe pump is crucial in maintaining a stable flow rate of the polymer solution to ensure consistent fiber diameter and quality. By adjusting the pump speed, the syringe pump provides precision in controlling the flow rate, and it also helps prevent the polymer solution from becoming too diluted or drying out. To apply an electric potential to the spinneret, a tubing system typically links the syringe pump to the spinneret, with a high voltage power supply often integrated, which helps in the formation and stretching of the polymer fibers. The utilization of a syringe pump in electrospinning offers precise control of the polymer solution flow rate, which is necessary to attain the fiber properties.

LITERATURE SURVEY

In [1] represents a syringe pump that is affordable and consumes low power, which has been designed to administer intravenous infusion. Syringe pumps in hospitals with limited resources. The device is equipped with a constant-force spring to offer mechanical energy for depressing the syringe plunger.

It can operate on rechargeable batteries for up to 66 hours, making it ideal for settings with unreliable power grids. The device is compatible with 5 to 60 mL syringes and has a flow rate range of 3 to 60 mL/hour. It costs around \$500 to produce one AutoSyP device. The device underwent laboratory and clinical pilot testing and its laboratory accuracy matched the planned flow rate within 4%.

In [2] the most widely utilized technique for creating nanofibers is suggested to be electrospinning. This tool has a high cost to buy on the market. It offers a cheap substitute for the construction of an electrospinning set up. The electrospinning setup's three fundamental components are as follows: The initial part of the system is a syringe pump that forces the fluid into the syringe in order to produce a Taylor cone that is hit by high voltage. An electrical power source with a high voltage produces electrostatic force, which is the second component. The collector builds up a collection of nanofiber goods. The setup's construction cost of \$220.26 is less than that of prior or shop-produced electrospinning setups. The article provides step-by-step directions on how to build the electrospinning setup and breaks down each of the three major components in detail.

In [3] the method applied by commercial syringe pumps to measure the flow rate by the diameter of the syringe . This volume's flow rate is then computed by dividing it by the amount of time. This study suggests using a Sensiron LD20 (SF04) flow sensor for direct flow monitoring to improve the security of the delivery of high-risk drugs. It will be possible to assess the temperature of the medication that has been infused and to spot air bubbles and occlusions as a result.

In [4] the Arduino nano ATmega328P, which uses the A4988 stepper driver to control a NEMA 17, is used to power the push-pull syringe pump (PPSP). An oled screen that has been C ++ programmed and a digital encoder can be used to change the Push-Pull Syringe Pump's configuration. A PCB was created and produced to make the device's assembly easier. A dampener designed specifically for this device and four non-return valves guarantee constant flow. flow rates and linearity are the final two.

In [5] The medical devices known as infusion pumps (IP) provide blood flow rate pressure is greater than the average blood pressure. They are necessary for therapies that demand the precise and consistent administration of food or medication. Due to their classification as Class III (high-risk) devices, they require regular maintenance in order to function properly and to protect the operator and patient. A lack of maintenance on the apparatus may lead to a volume that is unknown and the administration of substances with inaccuracy. This monitoring, which also offers an indication of the efficacy of the finished product, ensures the quality of the desired infusion outcome.

In [6] the capacity to create electrospun polymer nanofibers that are the right diameter and shape. By adjusting the polymer solution's concentration, electrical conductivity, and surface tension, the size and shape of the nanofibers may be changed.. The electrospinning process needs to be better managed in order to manufacture polymer nanofibers in an efficient manner. With typical dimensions ranging from 100 to 400 nm, this technology made it possible to successfully produce polyacrylonitrile and polyvinylidene fluoride nanofibers. Real-time electrical and optical

observations were used to monitor the electrospinning process and change experimental variables.

In [7] A control system for a syringe pump can optimize the volume and flow rate of the solution. The syringe pump's stepper motor drives the syringes, while an Arduino Uno board manages the pump's operation. For input, a matrix of keypads and a four-digit seven-segment display are utilized. The system makes use of an injection pump with speed adjustment to adjust the flow rate to the appropriate level. The flow rate and volume may be adjusted by the stepper motor. The syringe pump can handle flows that vary from 0.10 to 12.00 ml/hour. In addition, the technology can be used to regulate drug fluid flow rate and volume in clinical settings.

The [8] SEM was used to qualitatively investigate the electro spinnability of different aqueous solution concentrations and PVA to Gly weight ratios. Where electrospun for each concentration, resulting in fibers with an average diameter ranging from 232 nm to 591 nm. The effect of solution c was also investigated.

In [9] Infusion pumps are medical equipment used in clinical settings to manage the administration of fluids like nutrients into patients' bodies. Infusion pumps are machines used often in hospitals, nursing homes, and other healthcare institutions to provide essential fluids, including high-risk drugs. They come in many different forms, some of which are made expressly for stationary usage by a patient's bedside, such as large volume, patient-controlled analgesia, and insulin pumps. Pump malfunctions may affect the patients' safety. It produces a compact syringe pump smaller than the conventional ones, weighing less and can be lifted with one hand.

In [10] to improve drug safety, this article advocates using technology to administer medications. Infusion devices known as "smart pumps," which have drug concentrations, doses, and other characteristics preprogrammed, are crucial to the digital safety revolution. It is impressive how well they can cross-check each other and guard against unintentional dose or concentration variations. It will take a lot of work to implement this technology, thus careful, collaborative, and coordinated efforts are required..

In [11], Using only four processes and no pumps, a three-layered device is presented that might be used to produce core layers that are aligned in a hydrogel sheet. A possible option is a sensor chip in the form of a sheet for sensor-cell arrays. The usage of microfluidic devices with syringe pump systems led to a reduction in sample volume and an increase in setup time in order to produce heterogeneous cell pattern hydrogel sheets. A small amount of sample and a single hand pipette can be used with the designed equipment to produce hydrogel sheets.

EXISTING TECHNOLOGY

A .PUSH-PULL SYRINGE PUMP [4]

The Push-Pull Syringe Pump (PPSP) is driven by an Arduino small ATmega328P under the control of a NEMA 17 that is micro-stepped by an A4988 stepper controller. Push-Pull Syringe Pump settings can be altered using a digital encoder (Manual Input) and an oled screen made in C++. A PCB was developed to facilitate the creation of the device. Continuous flow is guaranteed by four non-return valves and a dampener that is sized and optimized for usage with this apparatus. Tests were done at the conclusion to assess the flow rates and linearity of the flow.

WORKING

The sketch is divided into 5 tabs; the main one is named PPSP Software (supplementary materials) and runs the main loop; the other 4 are additional functions, one for the auto home function at startup, one for screen management, and two others for the management of the digital encoder. The NEMA17 is driven in 14 step (micro stepping), the power supply is connected to the NEMA17, and the software was written and implemented using the Arduino IDE equipped with the U8g2lib library.

HARDWARE SETUP

The slider location is known. At this point, The movement of the slider can be managed by two for loops. To move the slider from right to left, The driver of the NEMA motor receives explicit digital HIGH and LOW signals that are switched with a specified delay from a for loop. The slider is similarly moved from left to right by the other for loop. The amount of time between HIGH and LOW signals is determined by the flow rate that the user sets; this time is expressed in milliseconds for low flow rates and microseconds for high flow rates.

The software's other component was created to make it simple for the pump and human activity to interact. The code required to display the flow rate on screen as well as an instruction to the pump is specifically found in the file "Message_to_Oled.ino."

The pump will turn on when the power plug is plugged in, and each time it does, the system will run an Auto Home to reassess the location and distances.

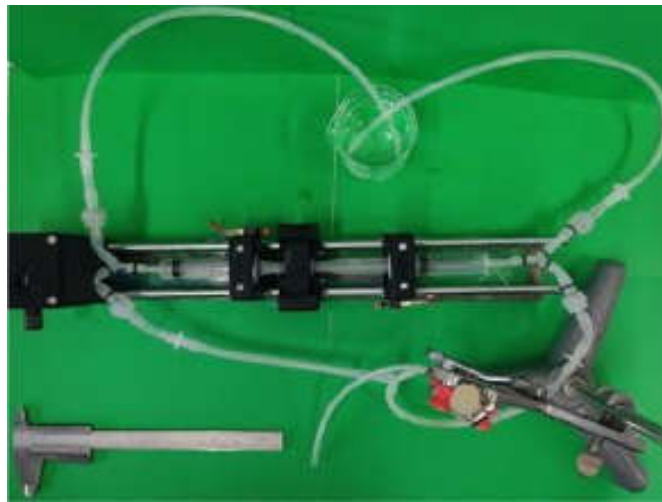


Figure 3.1 Pictorial Representation of PUSH-PULL SYRINGE PUMP [4] diagram

PROPOSED SYSTEM

A . PRELUDE

Choosing the proper syringe and needle, adding the polymer solution, and attaching the syringe to the syringe pump are all steps in the procedure. After that, the syringe pump is adjusted to guarantee a predictable and controlled flow rate. For the particular experiment, operating factors like voltage, the distance between the needle and the collector, and flow rate are optimized. To produce uniform nanofibers during the electrospinning process, feedback on the syringe pump's performance must be closely monitored. To preserve the syringe pump's longevity and accuracy in subsequent studies, it should be properly cleaned and maintained after each experiment. These steps can be used by scientists to use the syringe pump configuration in electrospinning to create superior nanofibers.

B . DESIGN

The functionality of the syringe pump relies on a system driven by a piston, which allows for the configuration to operate at a constant or pulsatile flow rate. The system applies pressure to the polymer solution through the use of a piston in the syringe, which forces the solution through the tubing to the spinneret. By adjusting the pump's speed via a programmed control unit, it is possible to precisely regulate the flow rate of the pump, which also makes it possible to precisely manage the volumetric flow rate and the solution delivery rate. The syringe pump's ability to regulate both its flow rate and electric potential allows for consistent and uniform production of nanofibers in terms of size, shape, and morphology. In conclusion, the syringe pump is an indispensable component of the electrospinning process, which enables consistent and stable production of high-quality nanofibers with uniform diameters.

An Arduino microcontroller, a stepper motor, a syringe pump, and a motor driver make up the device. The stepper motor, which is managed by the engagement of the driving screw, drives the piston of the syringe pump. The amount of fluid dispersed by the system is directly proportional to the number of step rotations, and the direction and speed of the step rotation determine the pumping speed. Effective motor control is made possible by the motor driver.

The Arduino microcontroller controls the motor and determines how quickly polymer solution is delivered. By providing electrical signals to the motor driver, which initiates the direction and steps, the programmed running on the Arduino controls the motor.

The implementation of the method, which makes use of a, allows for the precise control of the pump flow. The stepper motor interfaced with the Arduino microcontroller plays a crucial role in maintaining the syringe pump's operation to ensure consistent flow rates that enable uniform nanofiber diameter and quality. The precise and accurate flow rates due to volumetric control enable the production of nanofibers with uniform characteristics.

Using a stepper motor and an Arduino microcontroller in the electrospinning process provides a cost-effective, precise, and accurate syringe pump system. This hardware allows for a controlled and precise flow rate of the polymer solution, which ultimately enables consistent and uniform nanofiber production.

C.METHODOLOGY

Setup Of Equipment

A syringe pump, a high-voltage power source, a spinneret (needle or capillary), a collection substrate, and a grounded plate are common components of an electrospinning system. Make sure that every part is securely fastened and connected.

Making of Materials

Prepare the electrospun polymer suspension or solution. In order to do this, the polymer must be dissolved or dispersed in an appropriate solvent or solvent mixture. Adjust the concentration of the polymer solution based on the desired fiber properties.

Syringe Filling

Fill a syringe with the prepared polymer solution. Ensure that there are no air bubbles trapped inside the syringe, as they can disrupt the flow and affect the electrospinning process. The infusion filling are made up of organic polymers like PVA Polyvinyl Alcohol

Configuration of the Syringe Pump

The syringe pump should be set up in accordance with the manufacturer's instructions. In order to do this, the control panel of the syringe pump must normally be programmed with the desired flow rate, volume, and other parameters. Make sure the syringe pump is calibrated correctly and prepared for use.

Electrospinning Parameters

Electrospinning Conditions Establish the electrospinning parameters, such as the applied voltage, the separation between the spinneret and the substrate for the collection, and the ambient temperature and humidity. Depending on the particular polymer and desired fiber qualities, these factors might need to be optimized. The physical environmental conditions outside and the characteristics of the polymer substrate utilized in the process are what determine the parameters.

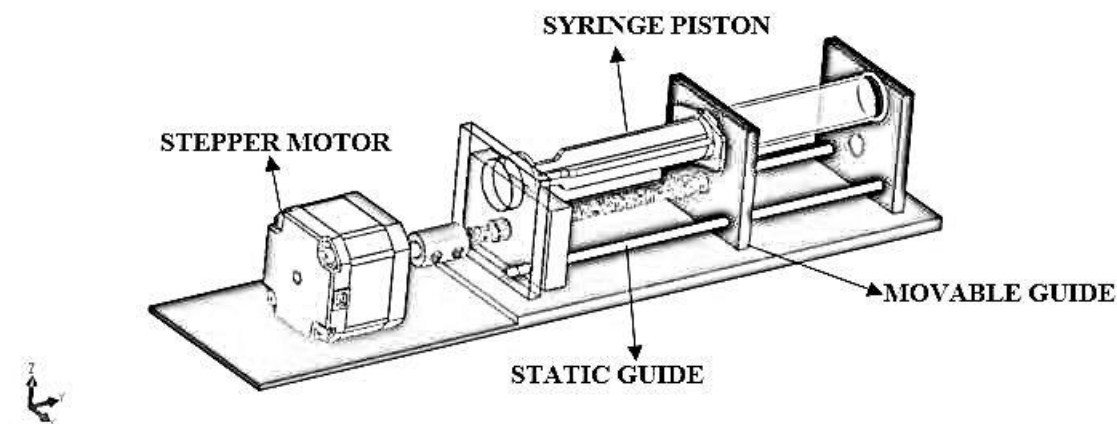


Figure 4.1 Pictorial Representation of Proposed hardware system design diagram

Figure 4.1 shows a single Pump is designed in the solid works software to run independently of the rack's other pumps. Software is used to execute simultaneous pump movements.

D.WORKING

A syringe pump equipped with a stepper motor and an ArduinoUno board can further enhance the efficiency, precision, and adaptability of the electrospinning process.

The stepper motor controls the rotating plunger that pushes the polymer solution through the needle and out of the syringe. The stepper motor allows for incredibly precise and fine-grained control of the plunger's movement, while the Arduino Uno board's pulses regulate its spin. To control the stepper motor's speed and pulse width modulation, the Arduino Uno board can be programmed. This will control how quickly the polymer solution flows. The syringe pump with stepper motor and Arduino Uno board has the capacity to deliver a steady and accurate feed rate of the polymer solution to the needle tip in order to guarantee a consistent fiber diameter.

The use of an Arduino Uno board further enhances the capabilities of the syringe pump by providing a controller for the entire electrospinning system. The Arduino Uno board can control various parameters of the electrospinning process, including the applied voltage, distance between needle and collector, feeding rate, and other operational parameters. The applied voltage causes the fibers to stretch and elongate as they travel from the needle to the collector, resulting in the formation of thin fibers. Syringes with capacities of 5ml, 10ml, and 20ml can be fastened to the pump thanks to the design.

For electrospinning, the polymer solution is put into the syringe, and the stepper motor and Arduino Uno board of the syringe pump regulate the speed at which the solution is delivered to the needle. By applying a high voltage when the needle is positioned at a specific distance from the collecting plate, the polymer solution is electrospun

onto the collector. Varying the parameters allows for precise control of fiber diameter, alignment, and morphology. A syringe pump equipped with a stepper motor and an Arduino Uno board can further enhance the efficiency, precision, and adaptability of the electrospinning process.

The stepper motor controls the moving plunger that presses the polymer solution from the syringe and through the needle. Because of the stepper motor, which rotates the plunger using pulses sent by the Arduino Uno board, movement can be done with fine control and extraordinary precision. To control the flow rate, the Arduino Uno board can be programmed to control the step angle of the stepper motor. As a result, a consistent and accurate feed rate of the polymer solution to the needle tip may be provided by the syringe pump with stepper motor and Arduino Uno board, resulting in a fiber with a consistent diameter.

The use of an Arduino Uno board further enhances the capabilities of the syringe pump by providing a controller for the entire electrospinning system. The Arduino Uno board can control various parameters of the electrospinning process, including the applied voltage, distance between needle and collector, feeding rate, and other operational parameters. The applied voltage causes the fibers to stretch and elongate as they travel from the needle to the collector, resulting in the formation of thin fibers.

The polymer solution is injected into the syringe before the stepper motor-driven syringe pump is used to electrospin the material and Arduino Uno board controls the feed rate of the solution to the needle. By providing a high voltage when the needle is positioned at a specific distance from the collecting plate, the polymer solution is electrospun onto the collector. Varying the parameters allows for precise control of fiber diameter, alignment, and morphology.

E.RESULT

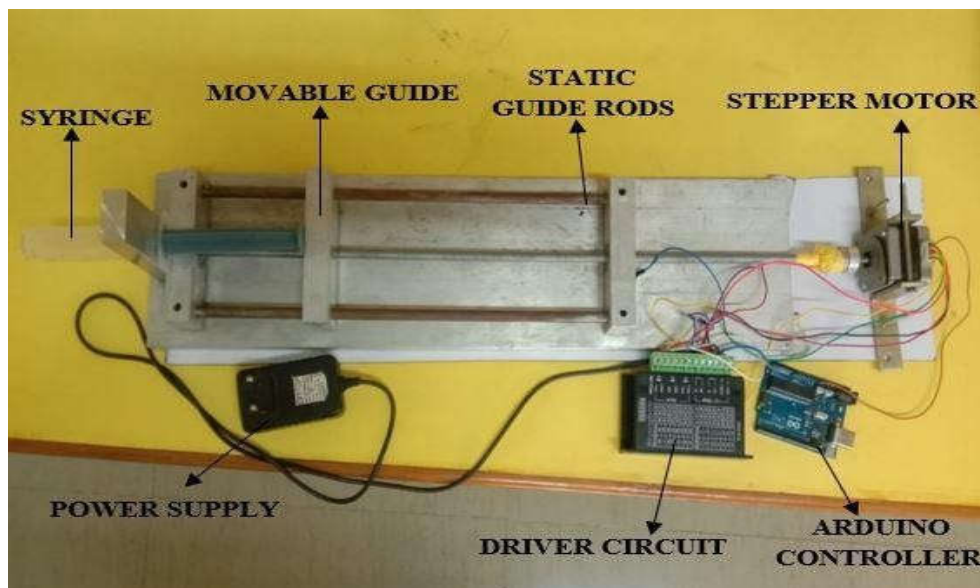


Figure 4.2 Pictorial Representation of Prototype model of the Hardware System design

The prototype model is shown in Fig. 4.2 is the hardware setup. The components are connected. These hardware

components impacts the syringe pump's output, including the following:

Motor speed and torque

The stepper motor in the syringe pump is responsible for driving the pump's plunger, and its speed and torque determinethe fluid flow rate and the accuracy of the delivered volume.

Drive mechanism

The drive mechanism of the syringe pump controls the position of the plunger, and its accuracy and precision impact the volume of the fluid delivered.

Syringe size

The syringe size impacts the volume and flow rate of the delivered fluid. The hardware set up should be compatible withthe syringe size selected for the experiment.

Syringe holder

The syringe holder holds the syringe in place, ensuring thatthe plunger moves precisely to control the fluid flow rate.

Power supply

The hardware set up requires power to provide control the syringe pump's operation. The appropriate power supply will depend on the specific syringe pump model and manufacturer.

CONCLUSION

1. We conclude that the use of syringe pump in electrospinninghas proven to be highly effective in controlling the flow rate ofpolymer solutions.
2. It offers accurate control and precision overthe electrospinning process, ensuring the production of uniformand consistent nanofibers. The use of syringe pump in electrospinning, it can be concluded that it is a highly effective technique for controlling the flow rate of polymer solutions to produce uniform and consistent nanofibers.
3. The syringe pump offers accurate control and precision during the electrospinning process, making it an essential tool in polymer nanofiber fabrication. The syringe pump has proven to be an essential toolfor electrospinning, and its future scope holds a lot of potentialfor innovation and progress in the field.

REFERENCES

- [1] Juarez, Alexa, Kelley Maynard, Erica Skerrett, Elizabeth Molyneux, Rebecca Richards-Kortum, Queen Dube, and Z. Maria Oden. "AutoSyP: a low-cost, low-power syringe pump foruse in low-resource settings." The American journal of tropical medicine and hygiene 95, no. 4 (2022): 964.
- [2] YUSRO, MUHAMMAD, and Kadarisman Kadarisman. "Development of Low-Cost Electrospinning to Fabricate Structured Nanofiber for Biomedical Designs with Manageable Flowrate and Voltage." Indonesian Journal of Electronics, Electromedical Engineering, and Medical Informatics 4, no. 3 (2022): 123-130.

- Gopinath, D., R. Deiva Nayagam, G. Sivakumar, S. Karthik, and P. Deepak Chakravarthi. "Intelligent Intravenous Syringe Pump." In 2023 International Conference on Intelligent Systems for Communication, IoT and Security (ICISCoIS), pp. 230-234. IEEE, 2023.
- [3] Iannone, Marco, Diego Caccavo, Anna Angela Barba, and Gaetano Lamberti. "A low-cost push–pull syringe pump for continuous flow applications." *HardwareX* 11 (2022): e00295.
- [4] Silva, Mayla dos S., Joabe Lima Araújo, Gustavo AM de A. Nunes, Mário Fabrício F. Rosa, Glécia V. da Silva Luz, Suélia deSRF Rosa, and Antônio Piratelli-Filho. "Precision and reliability study of hospital infusion pumps: a systematic review." *BioMedical Engineering OnLine* 22, no. 1 (2023): 26.
- [5] Liu, Suqi, Kevin L. White, and Darrell H. Reneker. "Electrospinning polymer nanofibers with controlled diameters." *IEEE Transactions on Industry Applications* 55, no. 5 (2020): 5239-5243.
- [6] Supriyanto, Amir, Rani Anggriani, Sri Wahyu Suciyati, Junaidi Junaidi, and Sutopo Hadi. "A Control System on the Syringe Pump Based on Arduino for Electrospinning Application." *Journal of Physical Science*, 32, no. 1 (2021): 1-12.
- [7] Alazzawi, Marwa, Nabeel Abid Alsahib, and Hilal Turkoglu Sasmazel. "Optimization of Electrospinning Parameters for Poly (Vinyl Alcohol) and Glycine Electrospun Nanofibers." No. 5102. *EasyChair*, 2021.
- [8] Sankaran, Sakthivel, J. Deny, M. Pallikonda Rajasekaran, Vishnuvarthanan Govindaraj, Rameeze Raja Mahaif, Abinaya Srinivasan, and Sanjai Lakshmanasamy. "Design and Development of a Low Cost, Smart Infusion Pump to Deliver Medications for Patients using Labview Interface With Arduino." *International Journal of Advanced Technology and Engineering Exploration* 9, no. 1S4 (2019): 753-758.
- [9] Sutherland, Adam, Matthew D. Jones, Moninne Howlett, Sara Arenas-Lopez, Arif Patel, and Bryony Dean Franklin. "Developing Strategic Recommendations for Implementing Smart Pumps in Advanced Healthcare Systems to Improve Intravenous Medication Safety." *Drug Safety* 45, no. 8 (2022): 881-889.
- [10] Kato, Aoi, Haruka Oda, Sho Takamori, Hisatoshi Mimura, Toshihisa Osaki, Norihisa Miki, and Shoji Takeuchi. "Hand-Driven Device for Preparation of Linearly Aligned Hydrogel Sheets." In 2023 IEEE 36th International Conference on Micro Electro Mechanical Systems (MEMS), pp. 313-314. IEEE, 2023.