



FABRICATION OF ELECTROSPINNING DEVICE USING MICROCONTROLLER FOR FORMATION OF NANOFIBERS

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Abstract- Design and fabrication of Electrospinning device is done by controlling flow rate of the polymer solution and the high voltage generation using flyback were done and observed with theoretical analysis and considerations. Microcontroller based bipolar stepper motor controlling is used to control the rate of polymer from a syringe and the high voltage of 32kV 5milliamps generated using flyback transformer, is measured and kept constant for the analysis. The switching circuits of MOSFET with snubber protected are used for driving the flyback line output transformer. Whole setup of the syringe is made adjustable vertically for varying the distance between the tip of a needle and the collector from 0mm to 9.2 mm. The polymer solution Poly Vinyl Alcohol (PVA) of 8wt% is used for the formation of the sample and the film is analyzed for the nanostructure. By the analysis, nonaligned PVA polymer nanofiber of various in size from 900 nm and below in size is formed at the flow rate of 4ml/ hour at 7mm distance between jet and the collector. The 5 ml syringe of 0.55mm in diameter and 25mm in length is used. Though the distance between the collector and the jet of the syringe affects the formation of the nanofiber, at and below 5mm distance the PVA pendant drop sputters immediately and the Taylor cone is not even form.

Index terms: Electrospinning, Flyback transformers, MOSFET, Switching Circuits, Flow rate of polymer. Taylor cone, Electrostatic repulsion, Formation of nanofibers and materials, Stepper motor, Linear actuator, Geared wheel rotation.

I. INTRODUCTION

Electrospinning device used for the fabrication of polymer Nanofibers consists of, a controlled constant flow of the polymer solution drops in a High Voltage (HV) static electric field from positive(+) the jet of the polymer solution to the Negative(-) collecting plate or the rotating drum. Pendant Polymer solution drops in the HV static electric field causes an internal repulsion in the drops due to charge potential carried by it and forms the spun towards the collector the ground [1]. Due to the spinning and the repulsion, the fibers in diameter of nanometre are formed. Formation of fiber depends upon, the concentration of the polymer solution for different materials, the static charge applying, the flow rate of the polymer drops in vertical and horizontal positions, the collector of the fibers and its distance from jet[3],[4]. There are different methods in electrospinning for the production of Nanofibers using polymer solution in HV field such as, making a flow of pendant drops constantly using a syringe needles, specially designed multiple let needles, needle less bubble formation[2]. And also by making collector in motion as rotating sticks and drums, moving plates and disc edges. In this setup controlled flow of a single syringe needle holding setup is used for the flow of polymer solution and an insulated ground plate as collector.

II. METHOD AND EXPERIMENTAL DESIGN OF THE INSTRUMENT

The fabricated instrument of the Electrospinning consists of two sections,

- Mechanical Setup and the controlled flow rate of the polymer using microcontroller and
- Second the high voltage circuit power supply designing using flyback transformers and switching circuits.

i) Mechanical Setup and the controlled flow rate of the polymer using microcontroller

The rate of flow of the concentrated polymer solution is analyzed and the exert load of the syringe solution, the instrumentation set up is designed for the constant flow rate of the pendant drops by pressuring the syringe for particular distance using a stepper motor and a gear wheel attached with mechanical linear actuator setup on the centre of its axis, which is kept on the position of vertical as top to bottom. The linear actuator consists of the rod with 5cm in length with 45 square threads from top to bottom and 3mm in diameter. This linear actuator is attached with centre axle of a spur type gear wheel vertically which has 48 with the diameter of 3cm. Now this setup can give precise step rotation as one step rotation of gear wheel can segment the 1mm of linear movement into 10 steps. By the theoretical analysis of the simple machine energy transformation, the more

number of threads within the length can give more precise linear movement and less stroke length for the single rotation with accuracy which is needed here to pressurize the syringe with high concentration can exerts a pressure up to 1 kg/cm^2 . The runner in the threads of screw needs an additional support of hold for regular linear movement which is shown in the picture **Figure-1** below the setup. The runner pushes the syringe down which gets holdup in the setup.

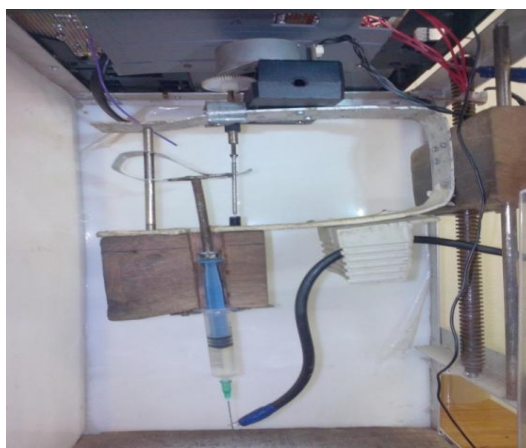


Figure-1: Instrument designed

The spur type gear wheel is attached and rotated by a stepper motor with torque of 0.2 kg-force-meter and angle of rotation 7.5 degree per step which gives 48 steps per rotation. This stepper motor controlled using microcontroller PIC 16F84A programmed gives a control signal in bipolar four wire stepping sequence for forward and reverse in direction and the L6203 as the chopper bipolar stepper motor driver is used. The software programming is done using MPLAB ICD2 and universal XelteK SuperPro model 3800 is used for programming the microcontroller. This stepper motor controlling unit can drive the speed of motor in bipolar phase from 30 rotations per minute to 95 rotations per minute which can be controlled as step by step. The driver unit is capable of driving the stepper motor with supply voltage from range of 35V 2A to 12 V 3.5A as maximum supply power continuously. The L6506 is used as current controller for the stepper motor drive.

ii) Second the high voltage circuit power supply designing using flyback transformers and switching circuits

After analyzing Flyback topology and DC-DC Converters, constant and uniform high voltage is formed by using flyback transformer with the driver circuit consists of, power switching circuits using IRFP260 MOSFET and the calculated snubber for its protection, the PWM generation and power supply of 12V DC, 10Amps. The values of the components are calculated theoretically and kept constant for achieving 32kV and for controlling the over load to the flyback transformer [7]. The perfect insulation is made for no leakage of the electrostatic charge where the tip of the high voltage cable is connected with clipping it in tip of the needle. The flyback consists of the 5+5 turns of primary coil with magnetizing inductance of 126 micro Henry. The b+ve, frequency control and ABL are the general pins which is not connected and the ground pin taken to the collector plate. Higher the frequency with the minimum low pulse width can drive the flyback correctly. Improper PWM switching leads to short circuit and power losses. Sudden switch off of the MOSFET break in driving current forms the high voltage spike reverse due to leakage inductance of the primary coil can damage the MOSFET and so that calculated RCD snubber is added in the side of primary coil of flyback which forms the antiparallel freewheeling diode clamping which suppress the voltage and dissipates some of the power across resistor when switch off takes place. The switching of the MOSFET delays because of its internal resistance where the $R_{ds\ ON}$ should be below 100 milliohms. So the MOSFET can be used for high frequency fast switching. The PWM generated consists of 15.287 kilohertz as switching frequency. Hence the Flyback is capable of producing high voltage for more than hours. Higher the inductance of the flyback leads to damage the flyback and the driver. Hence more than turns the 10 turns of 120 micro Henry of the primary coil in the flyback, leads to proper switching and reliable. The implementation of ZVS and ZCS Switching like mazilli's inductance based switching will leads to less in power loss and consumption which can give more reliable than the voltage switching with $R_{ds\ ON}$.

III. RESULT AND DISCUSSION

The polymer solution of PVA at 8wt% is prepared by keeping water as the solvent and stirring well using the magnetic stirrer [8]. Then the solution is loaded in the 5ml syringe with 0.55mm inner diameter of needle with 5cm length. The loaded syringe fixed in the holding setup and the high voltage pin is clipped with the tip of the

needle. The pressuring unit is switched on and direction of the stepper motor rotates anticlockwise and the runner presses the syringe downwards in steps. After the polymer drop occurs the high voltage is switched on. The Taylor cone forms due to static electric field which is kept at the distance of 7mm from the ground plate and the drop disperse immediately after the Taylor cone because of the static charge internal repulsion and travel towards the collector ground plate, which is kept under the tip. After the practical consideration for the flow rate of the polymer, the speed of the motor has been controlled and speed of linear movement of the runner is calibrated for three values as 3cm/hour, 4cm/hour, and 5cm/hour. The 5ml syringe exactly contains 1ml for 1cm and the 5ml for 5cm. after applying the HV and controlling the flow rate below 3.2 ml/hour the Taylor cone is not even form and the drops sputter immediately which could leads to discontinue in formation of fibers. Above 4.8ml/hour the very small beading droplet forms and excessive polymer get coated on substrate regularly after 2 seconds effects the fiber formation at constant high voltage used. Hence speed of motor for 4cm/hour kept constant for the device, to form constant flow rate of polymer pendant drop solution. Different polymers like polystyrene and polypyrrole at 10 wt% are taken into experiment and the samples analyzed for nanostructures using SEM. The continuous nonaligned polymer nanofiber of PVA is formed in diameter of 900nm and some of them below 600nm **Figure-2**. There is some different size nanofibers formed because of the ground of HV and shows that there is a need of more the insulation. The HV kept constant for all the samples as 32kV which is enough to produce the nanofibers of 100 nm. Even though HV is uniform, the production of uniform size nonaligned nanofibers needs proper ground. Multiple experiments were done using HV for long duration and the continuous usage of it is tested for uniform output which results good for all the samples and polymers tested. The high voltage formation depends upon the switching PWM kept constant and controlled without error or noise signal and also output of it is restricted for drawing more current by the transistors. The power supply for HV always needs 12V 6A that 72W as minimum for producing exact output of HV. Lower the Ampere rating of the power supply leads entire section of HV as damaged. The 10A 12V transformer power supply is the best for the HV section which can draw more current when the HV terminals shorted and remains the section unharmed and damaged.

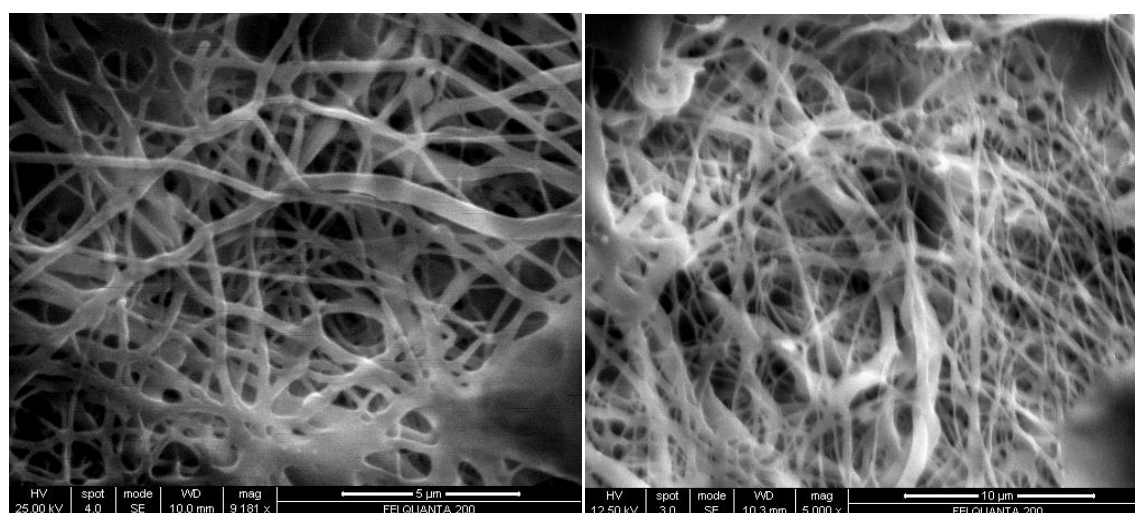


Figure-2: Nano structures of PVA sample

By analyzing the **Figure-2** we can see that left-hand sided picture of 5μm has nonaligned fiber structure in the size of less than 1μm and below and that the right-hand sided picture of 10μm in size shows the groups of nonaligned fiber structures. Some of the fibers get coated as layers as one and upon them shows that fibers form without beading and no other buckling in the morphology [9].

IV. CONCLUSION

Because of controlling the flow rate of the polymer solution leads to form a precise nanofiber were the high voltage kept constant for all the samples which could be reliable for the usage of long duration. The increase in the distance between tip and the collector forms the nanofibers in diameter less then 600nm and below at constant flow rate fixed. Though the high voltage kept constant which has some leakage in static electric charge could cause affects in the size of nanofibers. The instrument is versatile and there is possible of producing other polymer nano fibers repeatedly for long time which also depends upon the solvent concentration. The aligned polymer can be formed by keeping the rotating drum and the precise uniform vertical aligned nanofibers can be formed.

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