Design of Electrospinning Collector for Vascular Tissue Engineering Applications

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***Abstract*— Vascular scaffolds produced by bio-fabrication methods can provide ideal conditions for attachment and proliferation of ECs (endothelial cells). But these grafts might not allow migration of cells into the scaffold. Therefore, scaffolds, which resembles ECMs (extracellular matrix) should produce by changing scaffold size and shape. The diameter of nanofibers can be controlled by using electrospinning method to enhance vascular scaffold functionality and produce scaffolds that mimic the nanostructure of natural ECMs. In this study, electrospinning collectors with different diameters were designed to control scaffold diameters. Vascular scaffolds produced with these collectors are proposed to mimic the nanostructure of natural ECMs.**

Keywords — scaffold, electrospinning, vascular graft

I. INTRODUCTION

Solid nanofiber scaffolds for vascular tissue engineering can be produced by using bio-fabrication methods. Although these vascular scaffolds can provide ideal conditions for attachment and proliferation of ECs (endothelial cells), they might prevent cell migration on the lumen of the scaffold. Electrospinning allows the control of the diameter of the electrospun nanofibers to enhance vascular-scaffold functionality and produce scaffolds that resemble the nanostructure of natural ECMs (extracellular matrix). These scaffolds improve vascular cell attachment and spreading. Functionalization of vascular scaffolds by optimizing internal vascular graft surface improves the differentiation of stem cells into progenitor endothelial cells. Electrospinning allows the fabrication of nanofibers in different composition, shape and size. This variety of electrospun nanofibers

In this work, electrospinning collectors with different diameters were designed to produce vascular scaffolds that mimic the nanostructure of natural ECMs. These collectors would allow control of scaffold diameter. Therefore, vascular grafts produced by these collectors could resemble different types of vessels in the body. In addition to functionality gained by electrospun nanofibers, these scaffolds are planning to modify with different techniques such as plasma treatment, peptide conjugation to improve mechanical properties, cell proliferation and differentiation.

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II. METHOD

A. Mechanical Design

Layer-by-layer portable collector design was drawn by Computer Aided Design (CAD) program SolidWorks (Figure 1). The components were designed accurately and each part was suitable for DC Motor bed and each mile. Miles used as collector diameters were designed as 2 mm, 4 mm, and 6 mm to produce vascular grafts in different sizes.

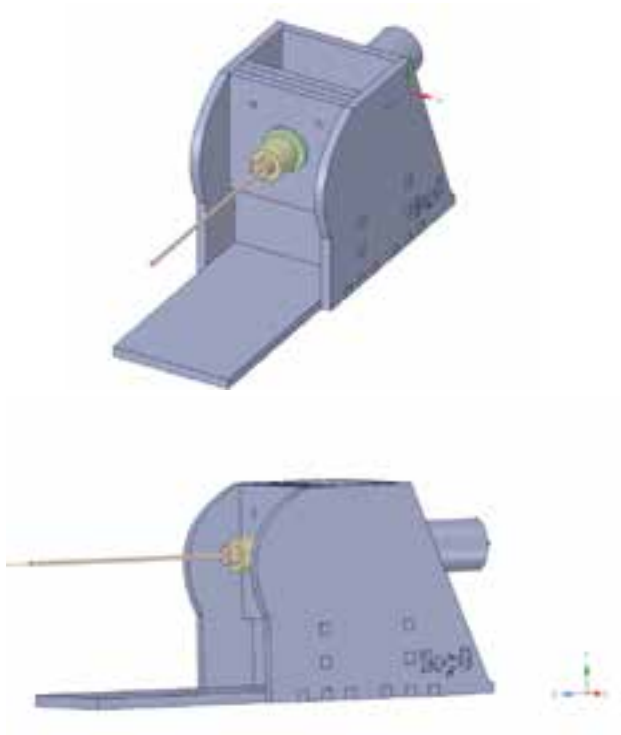

Figure 1. Assembly of Portable Collector

Mechanical support units were produced from Poly (methyl 2-methylpropenoate) also called Plexiglas. Plexiglas was preferred, since it is light, and non-conductive to prevent nanofiber formation on itself. Titanium was used to produce

miles as a conductive material to create electric field with nozzle (Figure 2).

Figure 2. Design of miles of Portable Collector

B. Electronical Design

Portable collector was controlled by microcontroller Arduino Uno R3 and DC motor (37 mm, 12 Volt, 100 Rpm) controlled by National Instruments software LabVIEW 2016. This design provides real-time measurement and control of motor speed. When multiple parameters are measured, the results can be visualized by using a programmable microcontroller. Arduino, which is an open-source electronics platform based on easy-to-use hardware and software, was used to contribute people in interactive projects [1]. The portable collector system is controlled by Arduino®3 microcontroller [2], which is powered by ATmega328. It has advanced characteristics such as 14 digital input/output pins (6 PWM outputs and 6 analog inputs), AVR Core, 16 MHz's [3]. Arduino is preferred due to ideal digital input/output pin number to connect to environment hardware. Motor speed and Arduino®3 are controlled with National Instruments software LabVIEW 2016). LabVIEW supports visual programming and basic controlling via computer screen (Figure 3).

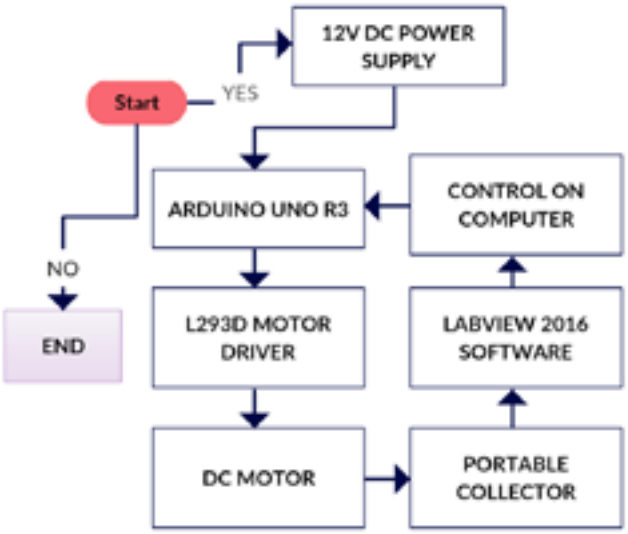

Figure 3. NI LabVIEW to the Arduino using serial communication

First, communication is occurred from NI LabVIEW to the Arduino using serial port address. Then Arduino transfers these commands to L293D motor controller about speed of motor command. In this way, the DC motor is controlled via computer screen (Figure 4).

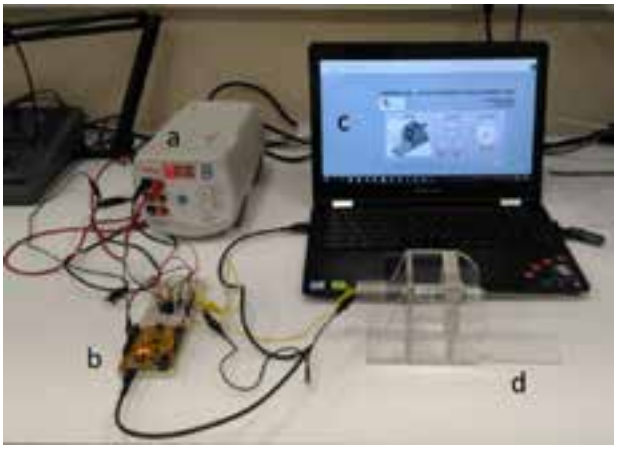

Figure 4. Setup of Portable Collector Device; a) DC source b) Arduino Uno R3 c) Prepared LabVIEW Software and Computer Control System d) Portable Collector

A flowchart is used to understand the working principle of the collector and explain the algorithm of DC Motor Speed Control in LabVIEW with (Figure 5).

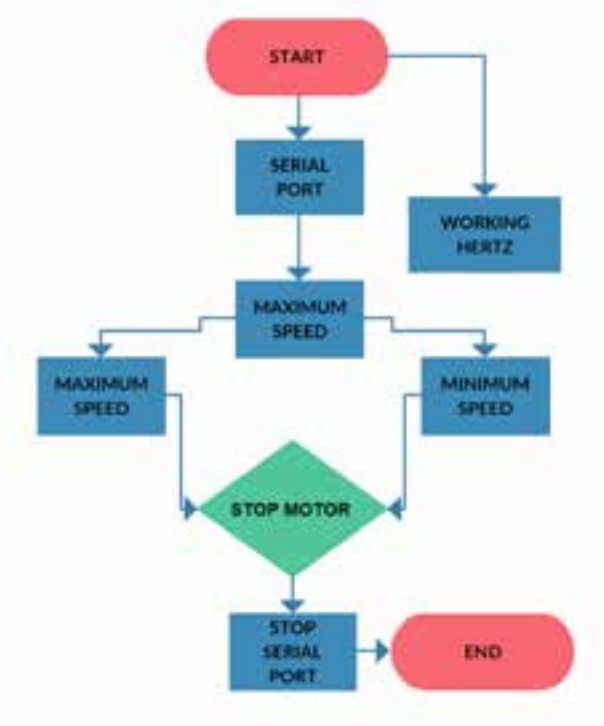

Figure 5. Algorithm of Software and Microcontroller in LabVIEW software

C. *Electrospinnig and Nanofiber Characterization*

A blend of 7 wt % PLGA was dissolved in 1,1,1,3,3,3-hexafluoro-2-propanol (HFIP) solvent. The polymer solution was transferred and injected from a 1-ml syringe through a 21-gauge needle by using a syringe pump. The needle was connected to the positively charged electrode of a high-voltage power supply. The aligned nanofibers were collected by designed rotating collectors, powered by a high-speed DC motor, was used to collect the aligned. The previously optimized electrospinning conditions of 1.0 ml/h injection rate, 20 kV electrical potential, needle-to-collector distance of 15cm, and rotation speed of 1200 rpm were used to produce aligned nanofibers.

After coating with gold (QUORUM Q150 RES), the vascular grafts were attached to a stub and imaged with a scanning electron microscope (SEM; Carl Zeiss 300 V) at 10 kV accelerating voltage.

III. RESULTS

Vascular scaffolds were producing in the diameter of 2mm, 4 mm and 6mm (Figure 6). Thickness was measure by SEM (239±5µm) and fiber diameter analyzed by ImageJ. Average fiber diameter in the structure was 320±4nm (Figure 7).

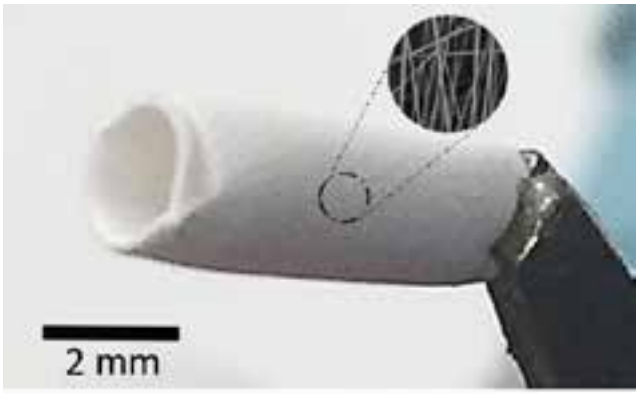

Figure 6. 2mm diameter vascular graft produced by custom-made collector

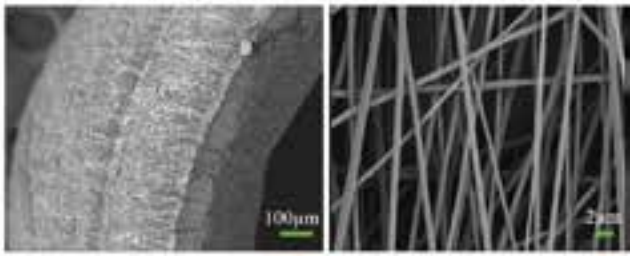

Figure 7. SEM Images of Vascular Scaffolds

IV. CONCLUSION

Custom-made collectors in different diameters designed to produce nanofiber grafts, which resemble the vessels in the vascular system. Producing nanofibers in desired thickness and diameter might help to mimic nanostructure of natural ECMs in vascular system. Functionality could be improved by adding biological cues, such as low molecular weight drugs, peptides, hormones, to electrospinning solution. Therefore, cell proliferation and migration can be improved without any surface modification. Our ongoing studies focus on producing vascular grafts with custom-made collectors by conjugating electrospinning solution with laminin derived peptides.

REFERENCES

1. Monk, S., *Programming Arduino Next Steps: Going Further with Sketches*. 2013: McGraw Hill Professional.
2. Schmitt, L.I., et al., *Thalamic amplification of cortical connectivity sustains attentional control.* Nature, 2017. **545**(7653): p. 219-223.
3. Guo, F., et al., *Circadian neuron feedback controls the Drosophila sleep-activity profile.* Nature, 2016. **536**(7616): p. 292.