Generating Programmable Nanofibers

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**Design**

Considerations:
Major design objectives included relatively low operating voltage, small size and weight, ease of operation, safety, high precision and low cost.

Modeling:
The device was modeled entirely using SolidWorks CAD software. This ensured that parts were compatible and would assemble snugly. Most non-metallic parts were 3D-printed.

Final Design:
The final XY stage design uses two motors to drive belts that are attached to sliders. The sliders move along metal rods. The substrate is a silicon wafer; aluminum is slightly more effective because of its high conductivity, but not very reflective, so patterns on it are difficult to view.

The brain of the device is an Arduino Mega 2560, which can be controlled by a remote or by an attached computer. The system is powered by a 5 kV power supply and a wall-plug, and also has a battery for onboard electronics. A WiFi enabled microscope camera sits near the substrate and can be used to view patterns up to 1000x magnification.

The electrospinning process operates at 800-1000 V, with a gap distance of about 3 mm. It is initiated by running the needle over a dry wipe attached next to the substrate.

**Results**
The completed device is a robust platform for electrospinning. It is capable of fine movement with sub-millimeter (~0.2 mm) precision, as well as position and speed tracking and patterning. Examples of its patterns include circles, rectangles, and other polygons, as well as text.

If replicated or produced widely, the device would cost about $1000 (most of it being the power supply) and could be packaged with extra polymer solution and syringes/needles, CAD files and a user manual. It could also be distributed as a package of metal parts and electronics, and a flash drive of CAD files to print, to be used with an existing power supply.

Going forward, the main focus is improving mechanical precision and consistency of both positioning and fiber production, which will be achieved by adding a multimeter for precise voltage measurement and improving gear transmission and contact. Stepper motors may replace the current motors to simplify and improve the device precision.

The final device is an exciting tool for table-top scale electrospinning.

**Acknowledgments**

Dr. Chang’s graduate student Danny Shin assisted in equipment setup and training, design, and polymer solution preparation, and the project wouldn’t have been possible without his help.

**Introduction**

Electrospinning is a method of producing fibers by using electric force to draw a liquid solution from a source reservoir to a collector. The products are useful in medical, textile, manufacturing applications and more for their structural properties and high strength-to-weight ratio.

The purpose of this project is to design and build a table-top scale, inexpensive platform capable of precise patterning of electrospun nanofibers. Controlled electrospinning facilitates the creation of structures that are otherwise difficult and expensive to fabricate, such as cell culture scaffolds.

**Analysis**

Electric Field:
To ensure safety and gain a better understanding of electrospinning physics, a 3D model of the electric field was generated using COMSOL.

Inspecting the field, it can be seen that the maximum electric field is near the needle; this means that electrospinning will be successful at a variety of gap distances for a particular voltage (this was verified by testing). Thus, voltage is the critical success parameter for a given polymer. The maximum strength of the electric field in the simulation gives an estimate of the smallest safe gap distance for a given voltage; the breakdown electric field of air is 3 kV/mm, and arcing will occur in stronger fields.

Mechanical:
To slow the syringe movement, the motors are geared down with 3D-printed gearboxes, whose gear ratios are 7.11 (two 40-tooth to 15-tooth transfers → (40/15)^2).

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