Effect of Polarization on the Electrical Field when Electrospinning Tissue Engineering Scaffolds

Emily Blair, Gerardo A. Montero, Jessica M. Gluck, Martin W. King, Bhupender Gupta
College of Textiles, North Carolina State University, Raleigh, NC 27695-8301

Statement of Purpose: Electrospinning of nanofiber webs is of increasing importance in the preparation of scaffolds for soft tissue engineering applications [1]. The process normally relies on applying a positive charge to the polymer solution passing through a capillary and, as the charged polymer creates a Taylor cone and forms charged filaments, they are attenuated as the nanosized fibers accelerate towards a grounded collector plate [2, 3]. The objective of this study was to evaluate the effect of changing the direction of polarization within the electrospinning system, and to determine whether negatively charged polymer particles will result in Taylor cone and lead to a unified web, as they accelerate towards the positively charged collector plate. The experiment is one in a series of studies in our laboratory in which we are optimizing the electrospinning conditions of various polymer /solvent systems, so as to prepare scaffolds with appropriate fiber diameters, pore size distributions and orientations suitable for soft tissue culture experiments.

Materials and Methods: The experiment was performed using a 10% solution of polycaprolactone (PCL, Mw = 65,000 g/mol) (Sigma-Aldrich) in a 3:1 chloroform / methanol solvent mixture. Electrospinning was undertaken on a vertical system with 12 cm separation between the plates (Figure 1). A 0.5 mm inner diameter capillary was used with a flow rate of 0.25 mL/min., and the electrical charge was first applied to the top plate which was connected to, and at the same electrical potential as the needle.

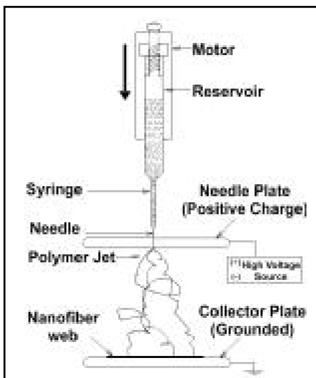

Figure 1: Vertical Electrospinning System

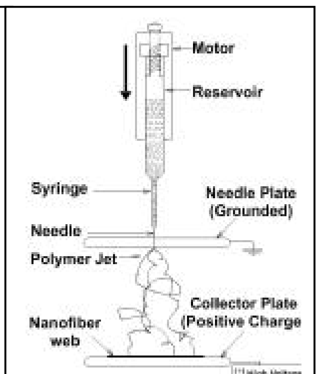

Figure 2: Vertical Electrospinning System - Reversed Polarization

Then in the second part of the experiment the positive charge was applied to the collector plate (Figure 2).

During the experiments the stability of the Taylor cone and the threadline, and the diameter of the area of collected web were monitored. Electrospinning trials were performed with 15 kV, 30 kV and 45 kV applied voltage in both polarization directions.

Results: The following observations were recorded, indicating that nanofiber webs were obtained under both directions of polarization as long as the other electrospinning conditions were suitable.

Table 1: Observations of electrospinning process.

Polarization	Applied Voltage	Observations	Diameter of Collected Web
Top plate positive	15kV	Threadline unstable, Polymer drips	None
	30kV	Whipping threadline, Elongated Taylor cone	20 mm
	45kV	Whipping threadline, Shortened Taylor cone	15 mm
Collection plate positive	15kV	Threadline unstable, Polymer drips	None
	30kV	Whipping threadline, Elongated Taylor cone	20 mm
	45kV	Whipping threadline, Shortened Taylor cone	15 mm

Figures 3 and 4 show Scanning Electron Microscope (SEM) images of the webs collected under the different directions of polarization.

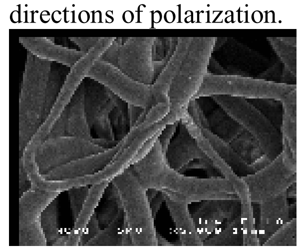

Figure 3

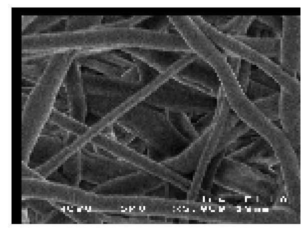

Figure 4

Figure 3: Nanofiber web with positively charged top plate. Figure 4: Nanofiber web with positively charged collector plate.

Figures 3 and 4 show a variety of fiber sizes. Figure 4 illustrates a more uniform web, not only in the diameter sizes of the fibers, but also in their morphology. With the positive charge on the collector plate, there appears to be a more uniform electrical field, thus giving more control over the fabrication process of the nanofibers.

Conclusions: Changing the direction of polarization of the electrical field did not prevent the formation of nanofiber webs. PCL nanofibers were produced when the collector plate was either grounded or positively charged. Further work is continuing to evaluate the effect of the direction of polarization on the diameter and orientation of the nanofibers, as well as the pore size distribution and mechanical strength of the electrospun web.

References:

1. Venugopal, J, Nanotechnology, 2005; 16: 2138-2142
2. Montero, G., Gluck, JM and King, MW Proceedings of the 10th European Meeting on Supercritical Fluids, 2005, Strasbourg/Colmar,France
3. Theron, SA, Polymer, 2004; 45: 2017-2030