ELECTROSPINNING OF POLYMERS: FUNDAMENTALS AND MEDICAL APPLICATIONS

Gary E. Wnek

Department of Chemical Engineering, Case Western Reserve University, Cleveland, Ohio 44106 USA

Electrospinning is a versatile technique for the fabrication of polymer micro- and nanofibers, and has attracted much interest due to the ability to prepare such thin fibers from many different polymers using simple equipment. Upon exceeding a critical potential which is sample-dependent, a thin liquid jet is ejected from the tip of the cone. The jet will undergo break-up into droplets unless there is a mechanism to stabilize the jet, and for polymer solutions this is provided by chain entanglements. Jet stabilization followed by solidification via solvent evaporation is the essence of the electrospinning process, and a key consideration for polymer/good solvent mixtures is the number of entanglements [1] in solution. In actuality, jet stabilization is a bit more complicated, since polymer solutions which favor the formation of small, embryonic crystallites (early stage of gelation) can undergo electrospinning below a critical entanglement density [2]. In other words, microcrystallites act at least in part like entanglements. These ideas have recently been reviewed and compared with key parameters that drive conventional (i.e., non-electrostatic) spinning [3].

One of the challenges to the field of biomaterials for tissue engineering is the design of ideal scaffolds/synthetic matrices that mimic the structure (mechanical aspects) and biological functions of natural extracellular matrix (ECM). The main purpose of the scaffold is mechanical support to allow for tissue regeneration while at the same time guiding cell differentiation and function. Some of the ideal scaffold requirements include biocompatibility, not inducing an undesirable host response and completely biodegradable while remaining non-toxic during replacement by cellular ECM components. Another challenge for the scaffolding is to be reproducibly produced in a variety of shapes and compositions (chemically and morphologically) with minimal time and cost. Electrospinning represents a particularly attractive approach for the fabrication of scaffold materials for tissue engineering. Of particular interest is the ability to generate polymer fibers of sub-micron dimensions, down to about 0.05 microns (50 nm), a size range that is otherwise difficult to access. Examples from our laboratories include the first successful electrospinning of collagen using fluorinated alcohol solvents [4] and release of drugs from electrospun ethylene-co-vinyl acetate polymer fibers [5]. Electrospun collagen is particularly appealing as a scaffold since it mimics well naturally-synthesized collagen scaffolding and exhibits excellent cell infiltration [6]. Electrospinning can be extended from homogeneous solutions to suspensions, affording the ability to generate polymer fibers with aqueous domains containing proteins and other water-soluble materials [7]. The key findings of this body of work will be summarized, along with new directions for medical applications that are under investigation.

References

[1] S.L. Shenoy, H. L. Frisch, W. D. Bates and G. E. Wnek, "Role of Chain Entanglements on Fiber Formation During Electrospinning of Polymer Solutions: Good Solvent, Non-Specific Polymer-Polymer Interaction Limit," *Polymer*, **2005**, *46*, 3372.

[2] S. L. Shenoy, W. D. Bates and G. E. Wnek, "Correlation between "Electrospinnability" and Physical Gelation," *Polymer*, **2005**, *46*, 8990.

[3] S. L. Shenoy, W. D. Bates and G. E. Wnek, "Perspectives on Fiber Formation in Electrospinning," *Polymer*, in press.