Improving the Electrospinnability of Poly(ε-caprolactone) (PCL) for Tissue Engineering Applications

Ajit K. Moghe[1], Rudolf Hufenus[2], Samuel Hudson[1], Bhupender S. Gupta[1]
[1] College of Textiles, North Carolina State University, Raleigh, NC, USA, [2] EMPA, St. Gallen, Switzerland

Statement of Purpose: The suitability of using electrospun Poly(ε-caprolactone) (PCL) fibers as scaffolds for tissue engineering, in an effort to mimic the native extra cellular matrix (ECM), has been reported in the literature [1-3]. In order to simulate ECM physically, it is essential that the dimensions of the fibers match those of the elements of ECM. The diameters of the fibrils present in the ECM range from 50-500 nm [4]. Accordingly, electrospinning of PCL for the purpose of tissue engineering should result in fiber sizes falling in this range. Many investigations published, however, have fallen short of achieving such a range of fiber diameters. The present study achieves the goal of producing by electrospinning uniform ultra fine nanofibers from PCL with narrow fiber diameter distribution. This is achieved by increasing the conductivity of the solution, which has been shown to greatly affect the fiber morphology in the electrospun materials [5]. The conductivity of the solution can be enhanced by adding an organic or inorganic salt, or other compounds, such as the polyelectrolytes and conductive nanoparticles that form charged ions. However, these additives remain in the solidified fibers after the fiber formation process, which can be undesirable in engineering tissues. To cope up with this problem, our proposed solution for increasing the conductivity of a polymer solution has been to use a fugitive salt that evaporates along with the solvent during the spinning process.

Methods: PCL was dissolved in glacial acetic acid to form a solution for electrospinning. Different amounts of Pyridine (0.2, 0.5, 1% vol/vol) were added to obtain solutions with different conductivities. Effect of solution conductivity on the morphology of the resulting fibrous scaffold, in terms of mean fiber diameter & its distribution, was investigated. Also, to study the effect of polymer solution concentration on the scaffold morphology, different amounts of PCL (12.5, 15, 17.5 % wt/vol) were added to acetic acid and pyridine solutions. Processing conditions during electrospinning, such as polymer feeding rate and applied voltage were kept constant. The scaffold structures were characterized using SEM.

Results/Discussion: Pyridine reacts with acetic acid and forms a fugitive salt 'pyridinium actate', which, in effect, increases the conductivity of the solution. We found that the conductivity of the solution increased directly with the amount of salt in the solution (Figure 1). Characterization of scaffolds demonstrated that without the salt, either beaded, globular (>1 μm) or mixed fibers were formed (Figure 2). However, amount of salt as small as 0.5% was sufficient to suppress the bead formation and to produce ultrafine fibers with narrow fiber diameter distribution.

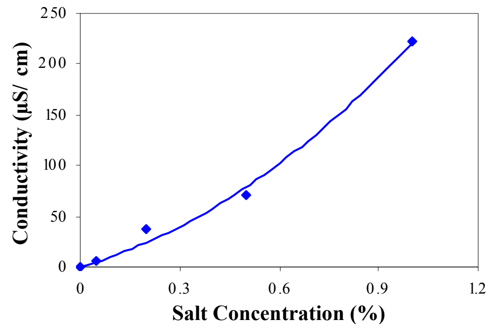

Figure 1. Effect of salt concentration on conductivity

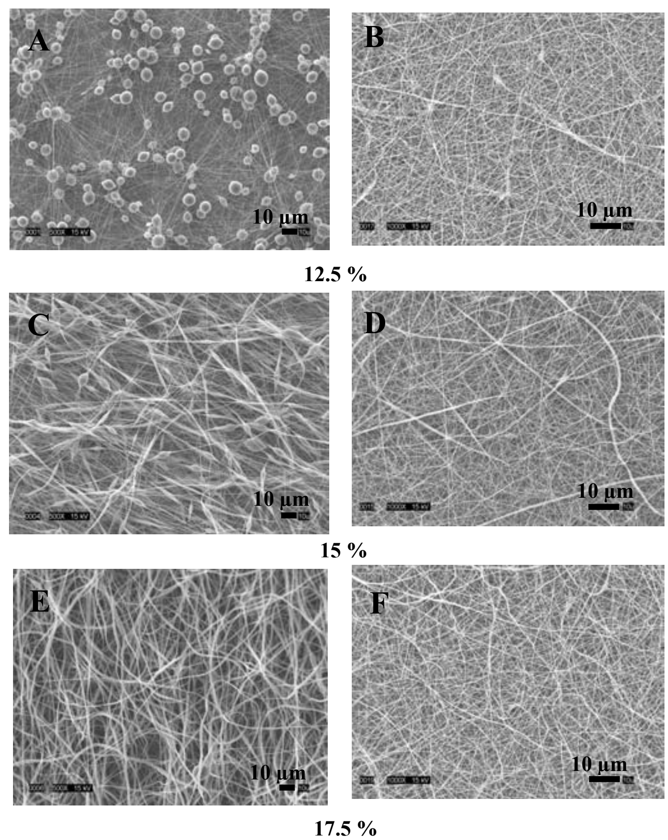

Figure 2. Effect of salt addition on the morphology of the scaffolds (A,C,E: no salt, B,D,F: 0.5% salt)

Conclusions: This study shows that by increasing the conductivity of the PCL solution by the addition of a fugitive salt, scaffold structures with fibers in nano-scale range and narrow diameter distribution can be formed.

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