Engineering Anisotropic Janus-type Polymer Nanofiber Scaffolds via Centrifugal Jet Spinning

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Statement of Purpose: Polymer nanofiber scaffolds have been produced using techniques like electrospinning, and centrifugal jet spinning (CJS). This study is focused on CJS as a technique to fabricate Janus-type polymer nanofiber scaffolds, where a high speed rotational nozzle extrudes nanofibers by solvent evaporation. We chose CJS since it can overcome some of the limitations of electospinning- requirement for a high voltage electric field and sensitivity to solution conductivity. Multi-phasic materials have recently gained interest because it allows the incorporation of several properties like biocompatibility, mechanical strength, addition of growth factors, better alignment and porosity features to a single material. Janus-type is one such example that possesses a hemi cylindrical morphology. We studied how the ratios and speeds affect this Janus-type behavior and hypothesized that we can produce highly aligned Janus-type nanofiber scaffolds for the first time by employing this technique which would serve as a biomaterial for its use in tissue engineering.

Methods: A dual reservoir nozzle was designed and machined out of aluminum with a sidewall orifice of 250µm at the base of each reservoir. 7% weight/volume solutions of polycaprolactone (PCL) and gelatin solutions were dissolved in 1,1,1,3,3,3-hexafluoro-2-propanol at different ratios (3:1, 2:1, and 1:1). The reservoir was spun at various speeds (20,000, 25,000 and 30,000 RPM) to yield nanofibers. These fabricated nanofibers were characterized using scanning electron microscopy, energy dispersive X-ray spectroscopy, and attenuated total reflectance-Fourier transform infrared spectroscopy to prove the Janus-type behavior. Cell attachment, biodegradation and mechanical properties of the nanofiber scaffolds were also studied to understand if these nanofibers can be used for tissue engineering applications.

Results: Scanning electron micrographs of the Janus-type nanofibers showed (Fig. 1) that our fiber diameter ranged between 400-600 nm and had high alignment suggested by our orientation parameter analysis. The EDX results (Fig. 1) also demonstrated an increase in nitrogen content when scanned at the Janus fiber level owing to the increase in gelatin content. ATR-FTIR spectrographs further proved the Janus-type behavior at the bulk scale of the nanofibers (Fig. 2). Our nanofibers also exhibited biocompatibility by showing cell attachment and had an ultimate tensile strength of ~10-15 MPa.

Conclusions: For the first time, we have exhibited a method for fabricating a Janus-type nanofiber scaffold using CJS that showed continuous transition of the PCL:gelatin compositions at the fiber level and bulk level. Future studies include incorporation of growth factors on one side that can be used for tissue engineering heart valves or can also serve as a wound healing patch possessing environmental resistance on one side and therapeutic properties on the other.

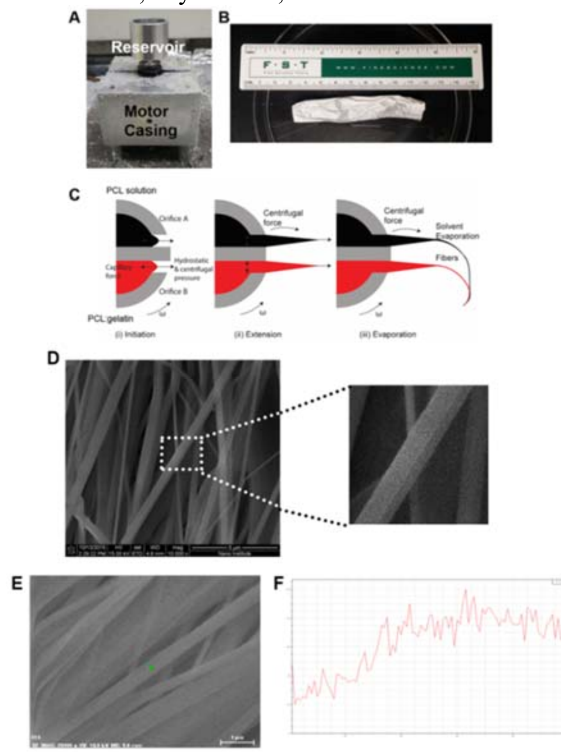

Figure 1. Biphasic Janus-type polymer nanofiber networks. (A) CJS system used for the fabrication process (B) Representative size of a nanofiber scaffold. (C) Schematic diagram of centrifugal jet spinning process. (D) SEM images of nanofiber. (E and F) SEM image and associated EDX spectra for nitrogen. The green arrow signifies the direction of scan for the EDX.

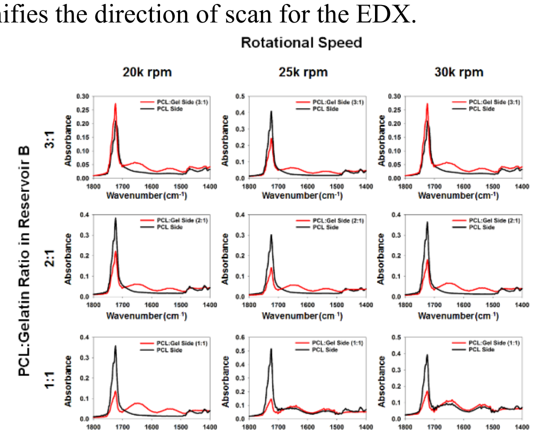

Figure 2. ATR-FTIR spectrographs shows the biphasic character of the PCL:gelatin nanofibers with respect to different ratios and rotational speeds.

References: Khang A, Ravishankar P, Krishnaswamy A, Anderson PK, Cone SG, Liu Z, Qian X, Balachandran K. Engineering anisotropic biphasic Janus-type polymer nanofiber scaffold networks via centrifugal jet spinning. J Biomed Mater Res Part B 2016. DOI: 10.1002/jbm.b.33791