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A comparative study of jet formation and nanofiber alignment in electrospinning and electrocentrifugal spinning systems

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ABSTRACT

Electrocentrifugal spinning is a recently developed spinning system whose performance is still under investigation by researchers. In this study the process of jet formation in electrocentrifugal spinning is explored and compared to the same process in electrospinning and centrifuge spinning. The results show that the incorporation of the electrical and the centrifugal forces in the electrocentrifugal spinning system leads to the formation of a more stable jet at lower viscosities. It is also shown that the electrocentrifugal spinning method is an efficient technique for the production of aligned nanofiber bundles with enhancement in the mechanical properties.

1. Introduction

Polymeric nanofibers enjoy excellent physical and mechanical characteristics embedded in their nature of decreased diameters down to submicron. Very large surface area to volume ratio of nanofibers offers different significant applications for them including nanocatalysis, tissue engineering scaffolds, protective clothing, filters, nanoelectronics, high performance fibrous instruments, nanobiosensors, drug delivery, wound dressing, composites, etc [1]. Different techniques have already been proposed to produce nanofibers such as drawing, template synthesis, gas jet spinning, island-in-the-sea, electrospinning and recently electrocentrifugal spinning. Among these methods, electrospinning seems to be the most versatile, applicable, high-potential and simplest technique. The formation of nanofiber via electrospinning is based on the continuous stretching of a viscoelastic jet derived from a polymer solution or melt by the electrostatic forces. The electrospinning technique may be considered as a variant of the electrospray process. Both of these techniques involve the use of a high voltage supply to induce the formation of a liquid jet. In electrospray small droplets or particles are formed as a result of the breakup of an electrified jet that is often produced from a low viscosity solution. In electrospinning a solid fiber is generated as the electrified jet is continuously elongated due to the electrostatic repulsions between the surface charges and the evaporation of the solvent [2]. Due to the unique features and applications, the process has recently been reviewed in a number of publications [3–11], but here we only intend to review the most recent activities in the area of alignment of nanofiber by this technique. The associated bending instability of the spinning jet causes the produced nanofibers to be deposited on the surface of the collector as randomly oriented nonwoven mat. However, in many applications, aligning the deposition of nanofibers in a specific direction is a requirement. For example, in the fabrication of electronic and photonic devices, well aligned and highly ordered architectures are often required. Even for applications as simple as fiber based reinforcement, it is also critical to control the alignment of fibers.

In recent years a number of approaches have been demonstrated to directly collect electrospun nanofibers as uniaxial aligned arrays [2]. These approaches include electrospinning which uses a collector consisting of two pieces of electrical conductors separated by a gap [12–17], collecting spun nanofibers on a rotating thin wheel with sharp edge [18], fabricating aligned yarn of nanofibers by rapidly oscillating a grounded frame within the jet [19,20], using a metal frame as a collector to generate parallel arrays of nanofibres [21,22], using magnetic field to produce aligned nanofibrous arrays [23,24], and using a rotating drum at a very high speed up to thousands of rpm [25,26]. In another approach, Deitzel et al. [27] used a multiple field technique which can straighten the

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