Morphology and Mechanical Property of Electrospun PA 6/66 Copolymer Filament Constructed of Nanofibers

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Abstract: A technique for spinning continuous filaments constructed of nano-scale fibers instead of non-woven obtained by general electrospinning was described in the paper. Polyamide 6/66 copolymer solution in 88% formic acid was used as the spinning material. The relationships between the fiber microstructures, filament mechanical properties and spinning parameters: spinneret tip to collector vertical distance (TD), rotation speed (RS) were investigated. Post-drawing was performed to the as-electrospun continuous filament. The research results revealed that increase of TD and RS could improve the fiber's uniaxial alignment and crystal structure, consequently the strength of the filament was enhanced. After being post-drawn, the stress and strain at break of the electrospun polyamide 6/66 copolymer filament was well improved.

Keywords: electrospinning, polyamide 6/66 copolymer, nanofiber filament, mechanical property morphology

1. Instruction

Electrospinning is a simple and inexpensive method for fabrication of sub-micro or nano-scale fibers, which was proposed at the beginning of 20th century. Zeleny J described the principle of electrospinning in 1917 [1], and in 1934 Formals elaborated the equipment and technique to electrospin chemical fibers in the USA patent 1975704 [2]. Then, in 1969 Taylor brought forward the concepts of Taylor cone and critical voltage, and obtained the voltage values at which Taylor cones formed [3]. A great number of researchers have been focusing on the electrospinning technique since the 90th of last century, and much more than 100 polymers were spun into nano-scale fiber nonwovens.

A typical electrospinning device usually includes a metallic capillary (a stainless needle) connected to a high voltage, and a collector grounded or charged to a negative voltage. When the electric field exceeds a critical value, the electrostatic force will overcome the surface tension of the polymer solution (or melt), causing a thin jet ejection from the needle tip. As this jet travels through the air, the solvent evaporates leaving behind a polymer fiber deposited on the collector. Generally, a porous nonwoven mat is formed by electrospinning, in which nano-scale fibers randomly orient. The nanofiber nonwovens are acceptable only for some applications such as filters, wound dressings, tissue scaffolds and sensors etc [4-6]. Meanwhile, obtaining continuously aligned nanofibers and high-volume production is very important for many areas such as fiber reinforcement and device manufacture. Several techniques have been developed to align electrospun nanofibers and some breakthroughs have been made. The primary principles to electrospin uniaxial align nanofiber bundles are changing the shape of a collector, appending an assistant electric field [7-8]. Consequently, a bigger mechanical force or electric force is loaded on fibers [9-10]. So far, a lot of methods have been achieved to obtain uniaxial fiber bundles, for example, a pair of spaced electrically charged conductive plates [4,7,9-17], rotating wheel [5,18-20], rotating disk collector [16][21-22], a tip collector [8,23], an assistant electric field [6][24], near-field electrospinning [25] and grounded collector electrode water bath [26-28].

Continuous spinnability, appropriate mechanical performances for textile process and stable

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morphologies are very important for electrospun fiber bundles (nanofiber filaments). In this paper, we described a new spinning technique to continuously electrospin nanofiber filaments for 6~10hours. The equipment includes these elements: typical electrospinning device, active solution collector, heating-drawing set and rotating mandrel. Polyamide 6/66 copolymer pellets were used as materials. The relationships between spinning parameters and microstructures, mechanical properties of the filaments were investigated. As-electrospun PA6/66 filaments were post-drawn. The functions of drawing ratio on the crystal structures, orientations and tensile properties were also discussed.

2. Experimental

2.1 Materials

Pure polyamide 6/66 copolymer pellets (Sigma Aldrich Inc.) were dissolved in 88% formic acid, and stirred to yield a 25wt% spinning solution. Pure peregal O was mixed with deionized water, and 0.5wt% bath solution was obtained. All reagents were used without further purification.

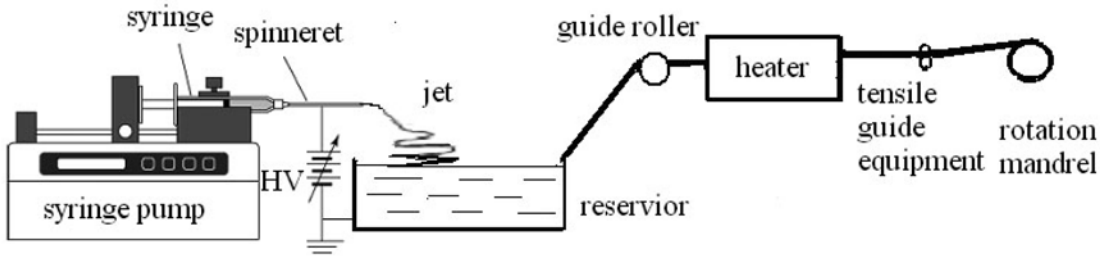

Figure 1 Schematic diagram of electrospinning device

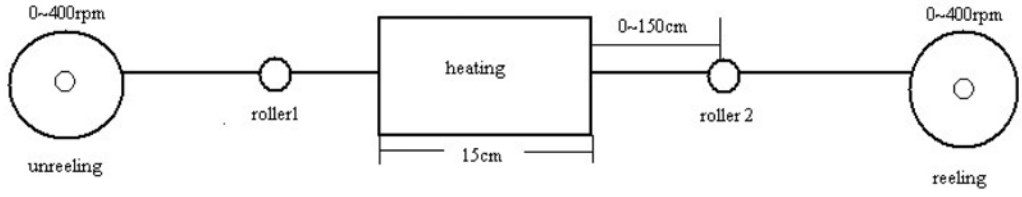

Figure 2 Sketch of post drawing of electrospun fiber bundles

2.2 Electrospinning nano-scale fiber filament and post drawing

As shown in Figure 1, spinning solution was drawn into a syringe with a stainless spinneret (ID 0.35mm). The spinneret was connected with a positive pole of high power supply (HV) by a wire. A circular reservoir with a diameter of 16 centimeters was full of peregal O aqueous solution. The horizontal distance from the tip of a spinneret to the left-wall of a reservoir was 2.5cm, and the vertical distance (TD) was varied. A grounded electrode was placed on the middle of the reservoir. A mandrel with diameter 11.4mm rotated on 0~400rpm, and temperature in the rotating region could be adjusted from room temperature to 400ºC.The flow rate of spinning solution was controlled by a micro syringe pump (Kd scientific 100, USA).

The nano-scale copolymer PA6/66 fiber filament was formed on the following steps: Firstly, 25wt% polyamide 6/66 copolymer solution in 88% formic acid at flow rate 0.06ml/h was spun into nano-scale fibers at an electric field (voltage 14kv, TD 4~12cm), and fibers deposited on the surface of 0.5wt% bath solution. Then a bundle of continuous fibers were obtained from the reservoir, and the fiber bundle was passed through a guide roller, heater (100ºC), and tensile guide equipment. Finally, continuous filament was reeled on the mandrel at 50~250 rpm. Figure 2 shows the method of post drawing electrospun fiber bundles. Both unreeling and reeling speeds are 0~400rpm. The temperature of heating region can be adjusted from room temperature to 300ºC.