Fabrication of Uniaxially Aligned Polypropylene Nanofibers via Handspinning

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Abstract

Spinnability of viscoelastic materials is well known phenomenon to produce spun-fibers in various areas. For example, “Natto” is a famous Japanese food having a high spinnability.¹ Furthermore, the formation of “Pele’s hair” can be also explained as a spinning process.² Generally, a spinnable liquid is a non-Newtonian fluid with viscoelasticity.

Electrospinning has become of great interest, not only because it can produce polymer fibers with diameters in the range of nano- to a few micro-meters using polymer solutions or melts, but also because it has the advantage of being a simple, convenient as well as being inexpensive methods as compared with conventional methods.³,⁴ A number of polymers including both synthetic and natural polymers, as well as biopolymers have been successfully spun into the fibers with diameters ranging from tens of nanometers to a few micrometers via electrospinning.⁵ On the other hand, solution electrospinning of polyolefins, including polyethylene and polypropylene, has been limited due to their high solvent resistance and very high electrical resistivity. Recently, we reported successful preparation of sPP nanofibers via solution electrospinning, which used mixed and polar solvents for providing the electrical property with polypropylene.⁶ However, such mixed solvent system had a few problems, for instance, not eco-friendly, harmful for human body, high-cost for manufacturing, unstable conditions of polymer solution, and so on. Moreover, such mixed solvent system is not appropriate for mass production. Specifically, the biomedical and pharmaceutical applications of the fibers electrospun from toxic solvents would be seriously limited.

In this study, we report new method for producing the nanofibers which can possibly overcome the limitations occurring in both solution and melt electrospinning, and report that a uniaxially aligned syndiotactic polypropylene (sPP) nanofibers can be successfully prepared from the sPP solutions and melts by using a novel handspinning.⁶ Unlike solution electrospinning, handspinning does not need to use high electric force and high energy, which are obviously high production costs and a big burden on the environment. Moreover, various solvents and polymers can be safely used on handspinning process. Indeed, the process of handspinning is very simple and straightforward, as seen in Fig.1.

Syndiotactic polypropylene (sPP) nanofibers could be successfully prepared by novel handspinning. As demonstrated by SEM analysis, the morphologies of handspun sPP nanofibers were strongly dependent upon the processing conditions, such as spinning method, solvent system. Compared to the normal electrospun sPP nanofibers, the handspun sPP nanofibers showed smoother morphologies(Fig. 2). Moreover, interestingly, the handspun sPP single nanofibers showed higher Young’s modulus and tensile strength, compared to electrospun sPP single nanofiber(Fig. 3 and Table 1). Furthermore, we tried to make bio-polymer and high chemical resistance polymer nanofiber via melt handspinning because the biomedical and pharmaceutical applications of these fibers electrospun from toxic solvents would be seriously limited.

References

Figures

**Fig. 1** (A) Simple and easy process of handspinning. Rapid pressing and pulling away process of polymer solution by using thumb and index fingers can produce the uniaxially aligned nanofibers. (B) Digital photo of uniaxially aligned sPP nanofibers, and typical SEM image (inset) of the corresponding handspun sPP nanofibers.

**Fig. 2** SEM images of handspun sPP nanofibers obtained from the single solvent system (A: cyclohexane), mixed solvent system (B: cyclohexane / acetone / DMF, 80 / 10 / 10 wt%), and (C) electrospun sPP nanofibers. PAD = 10 cm, TCD = 15 cm. The insets show the magnified SEM images.

**Fig. 3** The typical stress/strain curves for (A) the handspun and (B) the electrospun sPP single nanofibers.

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<thead>
<tr>
<th>Sample</th>
<th>Young's modulus [MPa]</th>
<th>Tensile strength [MPa]</th>
<th>Elongation at break [%]</th>
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<tbody>
<tr>
<td>Handspun nanofiber</td>
<td>3710 ±52</td>
<td>190 ± 12</td>
<td>35 ± 3.7</td>
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<tr>
<td>Electrospun nanofiber</td>
<td>478 ± 14</td>
<td>52 ± 4.3</td>
<td>81 ± 6.1</td>
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