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The Spinnability of PA6/CS-NPs Nanofiber Filaments via a One-step Multi-Needle Electrospinning Method with a Flowing Water Bath

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Abstract

Wet electrospinning is a convenient and versatile method to produce nanofibers. When adding an active agent into the bath solution, functional fibers may be fabricated in the fiber-forming process. In this paper, the spinnability of PA6/CS-NPs hybrid nanofiber filaments was studied which might obtain antibacterial activity. Three dispersants were selected, including span-80 and tween-80 (ST) (1/1, w/w), sodium polyacrylate (PAAS) and methyl cellulose (MC) to improve the dispersibility of the chitosan nanoparticles (CS-NPs) in the Peregal O aqueous solution. The mixture of ST was finally determined to be applied in the bath solution mainly because the agglomeration of CS-NPs could be largely reduced and the suspension of CS-NPs be maintained comparatively stable, and the continuous spinning time was longer than the others. When ST was added into the bath solution to fabricate the fibers, by varying the compositions of the bath solution, including concentrations of the CS-NPs and ST, the morphologies of PA6/CS-NPs fibers were investigated. When the composition of the bath solution was 0.2 wt.% ST and 0.4 wt.% CS-NPs, the maximum number of CS-NPs could be observed on the surface of the nanofibers. Compared to the pure PA6 nanofiber filaments, the mechanical properties of the PA6/CS-NPs hybrid nanofiber filaments would be weakened.

Keywords: Electrospinning; Chitosan nanoparticles; Dispersibility; Spinnability

1 Introduction

It is well known that electrospinning is a versatile approach to produce ultrafine fibers with diameters ranging from several micrometers down to a few nanometers from polymer solutions or melt using electro-static forces [1]. Nanofibers have generated great interest in the field of materials science due to their unique properties and fascinating applications in many areas [2], such as electronic and optical nanodevices [3, 4], tissue engineering [5], chemical and biological sensors [6, 7], drug delivery systems [8]. Membranes and filaments are the two forms of products

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prepared by electrospinning. Compared to the membranes, filaments which are assembled by a liquid bath have better nanofiber alignment degrees and mechanical strength [9].

Functional nanofibers can be prepared by two strategies generally [10]. One is that combined with the post-processing methods, the functional fibers can be obtained after the electrospinning process. And the other depends on fabricating the hybrid nanofibers during the electrospinning process. Comparing these two methods, the first method can make active agents to be adhered on the surface of the fibers, which take full advantages of the properties of active agents and large-surface area nanofibers together [11].

Chitosan is the most essential derivative of chitin which is the second most abundant biopolymer in the world [12]. As a natural cationic polysaccharide, chitosan is composed essentially of β (1→4)-linked glucosamine units together with some proportion of N-acetylglucosamine units [13]. Because chitosan exhibits outstanding properties such as biocompatibility, biodegradability, non-toxic, and antimicrobial [14], it can be used in many fields such as filtration, wound dressing tissue engineering, and enzyme immobilization [15-17]. Chitosan nanoparticles (CS-NPs) has been developed recently. When the particle size of chitosan reaches the nanometer level, the physical and chemical properties of CS-NPs are improved. Yang et al. [18] prepared CS-NPs and applied this material to wool fabric finishing treatment. Compared with ordinary chitosan, CS-NPs-treated wool fabric possessed better anti-bacterial and shrink-proofing properties.

Nanoparticles tend to aggregate due to their high specific surface area, and high surface free energy and consequently limited properties of nanoparticles. In order to improve the dispersibility and reduce the aggregation of the nanoparticles in the aqueous solution, the proper dispersant should be introduced. There are many kinds of dispersant that can be divided into anionic surfactants, cationic surfactants and non-ionic surfactants [19-21]. As for chitosan which is a natural cationic polysaccharide, the anionic and non-ionic surfactants can be chosen to improve the stability of CS-NPs dispersion aqueous liquid.

In this paper, the spinnability of PA6/CS-NPs hybrid nanofiber filaments was studied by a one-step multi-needle electrospinning method with a liquid bath circling system. What was noteworthy was that CS-NPs were dispersed in the Peregal O aqueous solution rather dissolved in the spinning solution by formic acid. And the mean size of the CS-NPs was about 600 nm, which would easily tend to agglomerate in the Peregal O aqueous solution. By choosing the proper dispersant which aimed to make CS-NPs homogeneously suspend and reduce the CS-NPs aggregation in the Peregal O aqueous solution, continuous and uniform nanofiber filaments could be fabricated. And antibacterial nanofiber filaments could be obtained in the fiber-forming process. This study demonstrated the possibility to prepare functional nanofiber filaments by one-step.

2 Material and Methods

2.1 Materials

Polyamide-6 (PA6) pellets were purchased from Macklin. Chitosan nanoparticles (CS-NPs) (powder, 96.4% of deacetylation degree) were purchased from Shandong Laizhou Bio-products Company. Formic acid (HCOOH, 88%), Span-80 and Tween-80 (ST) were obtained from Sinopharm Chemical Reagent Co., Ltd. Peregal O was obtained from Shandong Yousuo Chemical Technol-