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Characterization of PVA-Chitosan Nanofibers Prepared by Electrospinning

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Abstract

PVA/Chitosan nanocomposite fibers were prepared by electrospinning method. The weight ratio of PVA:Chitosan was fixed at 80:20 in 2% Acetic acid. The concentration of the PVA/Chitosan solution was varied from 3 to 5 wt%. The viscosity of precursor solution was determined by Ubbelohde viscometer. The results revealed that the mixture solution viscosity is directly proportional to its concentration. The morphology and diameter of PVA/Chitosan nanocomposite fibers were characterized by scanning electron microscopy and atomic force microscopy. The diameter of as-prepared PVA/Chitosan nanocomposite fiber was approximately 100 nm. The suitable concentration condition of the solution for fiber formation is 5wt% due to the maximum fiber yield. Fourier Transform Infrared Spectroscopic measurement exhibited the existence of relevant functional groups of both PVA and Chitosan in the composites.

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Keywords: Chitosan; PVA, Nanofibers; Electrospinning

1. Introduction

Chitosan (CS) is derived from chitin and has recently attracted increasing interest both in research and development aspects. Chitin was a basic element of D-glucosamine and can be extracted from shellfish such as shrimp, lobster and crabs. Generally, Chitin has excellent biocompatibility, biodegradable properties, non-toxicity and ease of solubility in organic acids. According to its distinguished properties, Chitin can be applied for practical related technologies such as textile materials, starting materials for plant growth enhancer and nanofibers[1]. Poly (vinyl alcohol) (PVA) is typically non-toxic and water-soluble synthetic polymer. It is also biocompatible, can be degraded by method and yields comparably high fiberforming. According to compatible properties to CS, it is

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believed that the composite of PVA and CS, especially in form of nanostructures, can lead to the novel functional biocompatible materials for specific biomedical applications. Among growth processing techniques, electrospinning is the most effective technique for preparation of various kinds of nanofibers because it can produce relatively consistent nanofibers with required diameters ranging from few nanometers up to few hundred nanometers.

For instance, Homa Homayoni *et al.*, reported on the synthesis of chitosan nanofibers by electrospinning with the details of processing optimization[2]. Paul Akangah *et al.*, successfully synthesized Nylon-66 nano-fibers by electrospin technique and investigated the effect of its interleaving on impact damage resistance of epoxy/carbon fiber composite laminates[3]. Simon C. Baker *et al.*, employed this technique to synthesize polystyrene fiber scaffolds that can be applied routinely for three-dimensional cell culture experimentation [4]. Xuejun Kang *et al.*, accomplishedly prepared electrospun polymer nanofibers as a solid-phase extraction sorbent applied for evaluation of directly extracted trazodone from human plasma[5].

In the present work, conventional electrospinning method was employed to synthesize PVA/CS nanocomposite fibers. The viscosity of precursor solution was determined by Ubbelohde viscometer. The precursor concentration and growth conditions were investigated. The morphology and diameter of PVA/CS nanocomposite fibers were characterized by scanning electron microscopy (SEM) and atomic force microscopy (AFM). The functional groups of PVA/CS nanocomposite fibers were characterized by Fourier Transform infrared spectroscopy .

2. Experimental

Fig. 1 illustrates a schematic chart of the preparation of PVA/CS nanocomposite fibers. The precursor sol for PVA and CS was prepared from (PVA) Polyvinyl alcohol (96% hydrolyzed typical average M_w 85,000–124,000 SIGMA ALDRICH) and CS (from shrimp shells $\geq 75\%$ (deacetylated) SIGMA ALDRICH). PVA/CS solution was dissolved in acetic acid. The weight ratio of PVA:CS was fixed at 80:20 in 2% acetic acid. The concentration of the PVA/CS precursor was varied from 3 to 5 wt% and mixed under magnetic stirring for 1.5 h at 75 °C. PVA/CS nanocomposite fibers were prepared by electrospinning method. The applied voltage was 21-25 kV and the electrospinning distance was fixed at 10 cm. The viscosity of precursor solution was determined by Ubbelohde viscometer. The characteristic morphology and diameter of PVA/CS nanocomposite fibers were characterized by scanning electron microscopy (SEM) and atomic force microscopy (AFM).

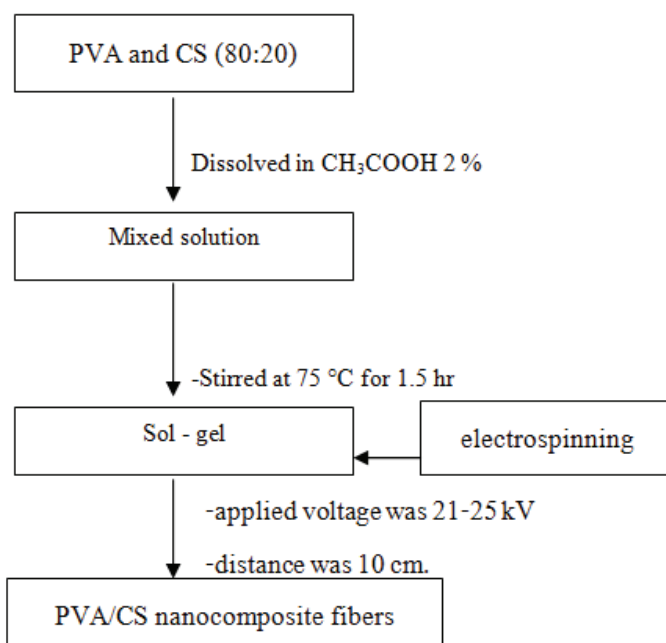


Fig. 1 Schematic chart of the preparation of PVA/CS nanocomposite fibers by electrospinning method

3. Results and Discussion

The specific viscosity (η_{sp}) of PVA/CS precursor was determined by Ubbelohde viscometer. The specific viscosity is calculated by the following equation,

$$\eta_{sp} = \eta_r - 1, \quad (1)$$

where η_r is relative viscosity. Fig. 1 shows the dependence of the precursor viscosity on its concentration. It is found that its viscosity increases linearly with increasing concentration. This result is essential for the optimization on the formation of nanofiber of this composite material.

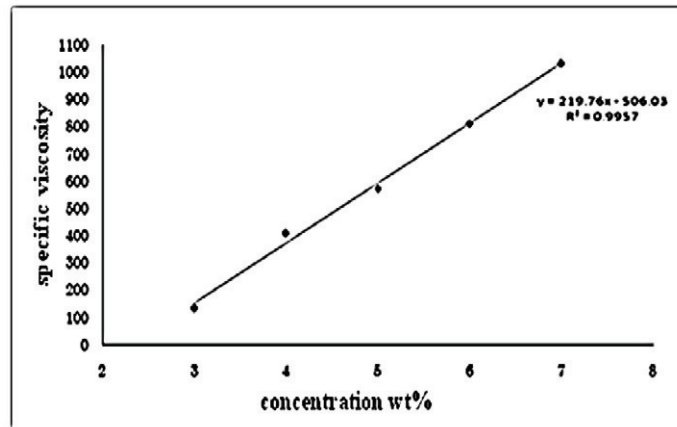


Fig. 2 The specific viscosity of PVA/CS precursor.

Fig. 3 shows SEM images of PVA/CS nanocomposite fibers prepared from the precursor with different concentration. The images of as-obtained nanofibers using 3 wt%, 4 wt%, and 5 wt% PVA/CS concentration are illustrated in Fig. 3(a), 3(b) and 3(c), respectively. The composite systems consist of nanofiber and micro-bead structure. All images reveal that as-synthesized nanofibers prepared at various conditions have good uniformity with regular diameter of about 100 nm implying that the electrospun nanofiber diameter is insignificantly affected by the precursor concentration. As the concentration increases, the numbers of micro-bead structure considerably decrease and the uniformity of well-defined nanofiber is enhanced. These SEM results suggest that the suitable concentration condition of the solution for fiber formation is 5wt% due to the maximum fiber yield. The higher concentration, on the other hand, can deteriorate the nanofiber yield because of improper solution viscosity to maintain the fiber formation [6].

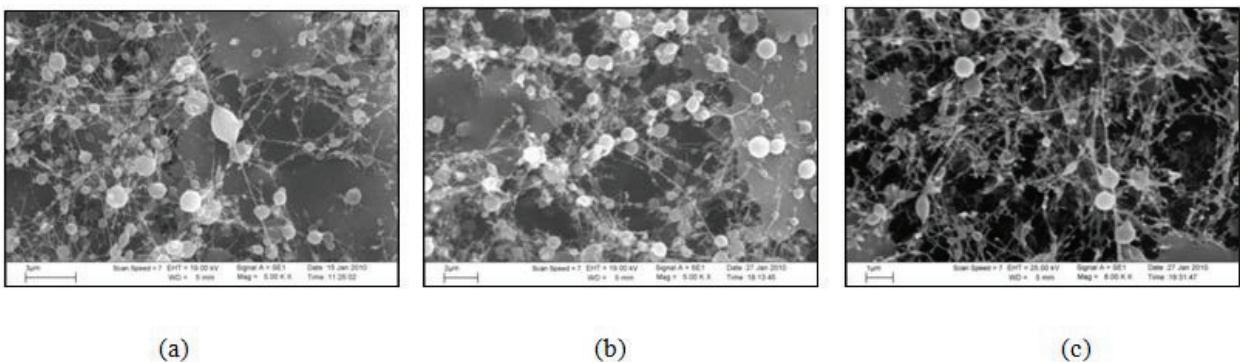


Fig. 3 SEM images of as-produced PVA/CS nanocomposite fibers prepared from PVA/CS precursor concentration of (a) 3 wt%, (b) 4 wt% and (c) 5 wt%.

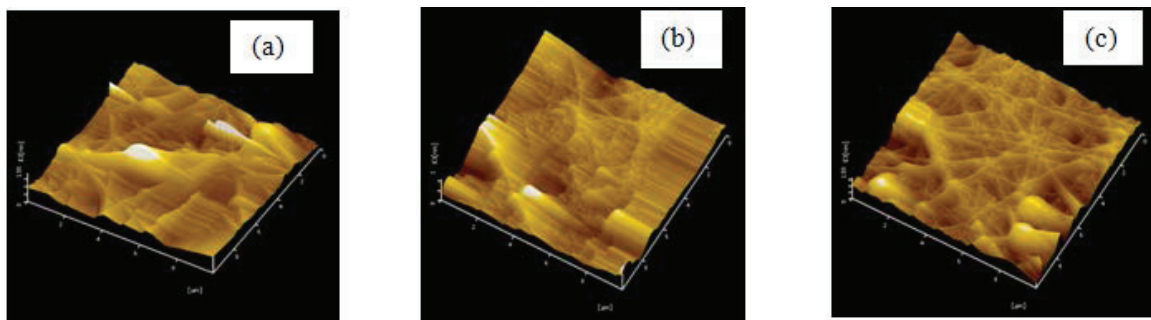


Fig. 4 AFM images of as-produced PVA/CS nanocomposite fibers prepared from PVA/CS precursor concentration of (a) 3 wt%, (b) 4 wt% and (c) 5 wt%.

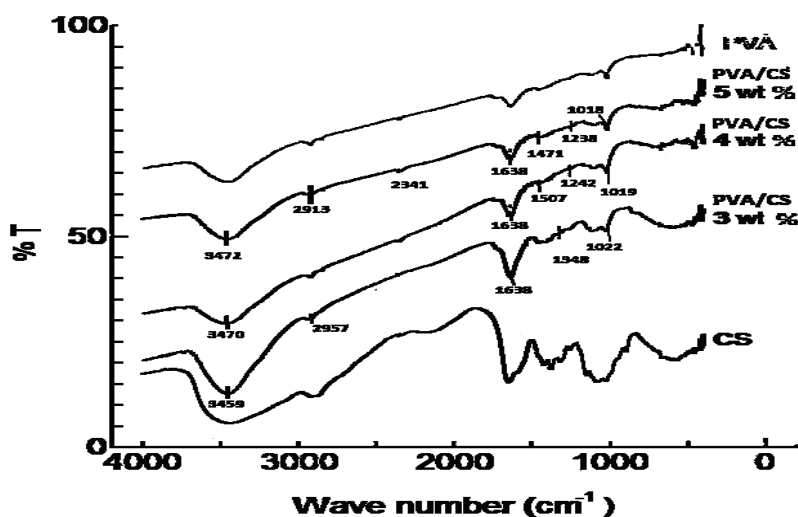


Fig. 5 FTIR spectra of PVA/CS nanocomposite fibers prepared at various precursor concentration.

The surface morphology of PVA/CS nanocomposite fibers were additionally characterized by atomic force microscopy. The weight ratio of PVA:CS was fixed at 80:20 in 2% Acetic acid. The electrospinning distance was 10 cm. The AFM images of as-produced nanofibers using 3 wt%, 4 wt%, and 5 wt% PVA/CS concentration are exhibited in Fig. 4(a), 4(b) and 4(c), respectively. The results indicate that the nanofiber of PVA/CS nanocomposite has blend fibers with different concentration of the PVA/CS solution. The blend fibers structures was decrease when increasing concentration of the solution. The AFM results are agreeable to SEM results. Furthermore, the fiber system prepared from 5 wt% PVA/CS concentration shows the dense matrix of uniform fibers with significant improved surface roughness. Both SEM and AFM results can guide to the acknowledgment of optimized condition to synthesize this kind of this nanocomposite fiber system.

The FTIR measurement of the composited was carried out in order to characterize the functional groups participated on the formation of PVA/CS nanocomposite fibers. Figure.5 shows FT-IR spectra of PVA/CS nanocomposite fibers with different weight ratios. The CS exhibited characteristic broad bands of OH group at $3400\text{--}3500\text{ cm}^{-1}$ [7].The bands of NH_2 group and O-C-NH_2 group can be observed at 1638 cm^{-1} . The broad bands of CH_3 group and $\text{CH}_3\text{-O}$ group can be observed at $1000\text{--}1200\text{ cm}^{-1}$ [8]. The FT-IR spectra of PVA showed the characteristic broad band at $2900\text{--}3000\text{ cm}^{-1}$ for CH_2 group and CH_3 group, respectively.[ref]. Fourier Transform Infrared Spectroscopic measurement exhibited the existence of relevant functional groups of both PVA and CS in the composites.

4. Conclusion

In this study, PVA/CS nanocomposite fibers were prepared by electrospinning method. The weight ratio of PVA:CS was fixed at 80:20 in 2% Acetic acid. The viscosity of precursor solution was determined by Ubbelohde viscometer. The results revealed that the mixture solution viscosity is directly proportional to its concentration. The morphology and diameter of PVA/CS nanocomposite fibers characterized by SEM and AFM indicated that the diameter of as-prepared PVA/CS nanocomposite fiber was approximately 100 nm. The morphology changed gradually from the more beads structure to the uniform fiber-structure with increasing concentration of the solution from 3% to 5 wt%. The suitable concentration condition of the solution for fiber formation is determined at 5wt% due to the maximum fiber yield. Furthermore the Fourier Transform Infrared analysis demonstrated the existence of relevant functional groups of both PVA and CS in the composites.

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