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Effect of Ultrasonic Vibration Power on Bubble-electrospun Nanofibers

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ABSTRACT

Biodegradable poly (vinyl alcohol) (PVA) polymer solutions with various concentrations are processed by ultrasonic vibration and bubble-electrospun to prepare nanofibers. It is shown that the ultrasonic vibration power has a significant impact on the viscosity and electrical conductivity of PVA solution, especially the morphology of the obtained nanofibers. Besides, when the concentration of spinning solution is kept at 11 %, the diameters of the nanofibers are measured. The novel approach can be used to improve solution spin ability and fiber fineness.

INTRODUCTION

Electrospinning whatever solution or melt has some bottlenecks which make it difficult to reduce the diameters of fibers to nanoscales, increase efficiency and output significantly, also keep process continuous. In recent years, multijet electrospinning [1], solution blow spinning [2] and magneto-electrospinning [3] could solve some of these existing problems, but meanwhile, cause other adverse effects.

Bubble-electrospinning [4], which mimics the spider spinning, is a potential technology for improving solution spin ability and increasing mass-production of nanofibers. Ultrasonic vibration can remarkably change some physical and chemical

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properties of polymer solutions. Besides, much finer fibers were. In addition, much finer fibers were produced than without the application of vibration technology[5].

In this work, poly (vinyl alcohol) (PVA) nanofibers are prepared by bubble electro spinning combined with ultrasonic vibration. In a certain time, the influence of ultrasonic vibration power on the properties of PVA solution is discussed experimentally.

EXPERIMENTAL PART

PVA (Mw=77,000 g/mol) was dissolved into distilled water at 80-90 ℃ for 3 h with three concentrations of 8 %, 11 %, and 14 % (g/ml) under magnetic stirrer. The prepared solution was treated by ultrasonic vibration before bubble electrospinning. The spinning device used was demonstrated schematically in the literature [5]. The applied voltage was kept at 25 kV, and the collecting distance was set at 10 cm. The morphology of nanofiber membranes was characterized by Scanning Electron Microscope instrument. The fiber diameters were determined via Image J software. At least 50 nanofibers in different SEM images were analyzed for each sample.

RESULTS AND DISCUSSION

The influence of ultrasonic vibration power on the 8 % solution is shown in Table 1. It is obvious that the increase of the ultrasonic vibration power results in a dramatically decrease of the viscosity and increase of the electrical conductivity.

Figure 1 shows SEM images of PVA membranes fabricated by bubble-electrospinning at the concentration of 8 %. There were a few beads for the nanofibers fabricated by the polymer solution without ultrasonic vibration (Figure 1(a)). However, the beads were still found as the increase of ultrasonic vibration power (Figure 1(b), 1(c) and 1(d)). It should be ascribed to polymer degradation resulting from ultrasonic vibration [6].

Table 2 exhibits the effect of ultrasonic vibration power on the 11 % solution. The change trend of the viscosity and electrical conductivity is similar to that of Table 1.

Figure 2 shows the SEM micrographs and diameter distribution histograms of bubble-electrospun PVA nanofibers at the concentration of 11 %. Obviously, ultrasonic vibration did not appreciably affect the morphology of the PVA fibers. The smooth fibers were obtained in all cases. Additionally, the fiber diameters from measurement were 270, 256, 225 and 203 nm, respectively.

TABLE I. THE EFFECT OF ULTRASONIC VIBRATION POWER ON THE VISCOSITY AND CONDUCTIVITY OF PVA SOLUTION WITH A CONCENTRATION OF 8%.

Power (w)	Viscosity (mpa.s)	Conductivity (μs/cm)
0	200	955
195	180.5	1090
390	163	1136
585	142	1328

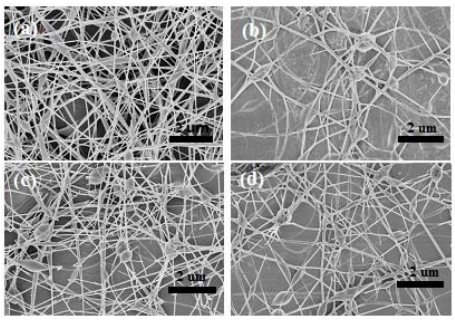

Figure 1. SEM images of PVA membranes fabricated by bubble-electrospinning under the ultrasonic vibration power of (a) 0, (b)195, (c) 390, and (d) 585 w.

PVA solution with a concentration of 14 % was also treated by ultrasonic vibration, and the data are not shown here. We found that the viscosity with a sharp increase will be out of measurement on test bench if ultrasonic vibration power is set larger than 390 w. It is probably that the heat generated from ultrasonic vibration leads to a huge number of solvent evaporation. So the nanofibers are difficult to be obtained.

Figure 3 exhibits the SEM micrographs of bubble-electrospun PVA nanofibers under a certain spinning conditions. The fiber junctions caused by higher viscosity appeared without ultrasonic vibration (Figure 3(a)). When ultrasonic vibration power was set at 195 w, it gave rise to the excellent morphology of nanofibers (Figure 3(b)).

CONCLUSION

The effect of ultrasonic vibration on the bubble-electrospun PVA nanofibers was systematically studied. At a certain spinning condition, the increase of the ultrasonic vibration power results in a dramatically decrease of the viscosity and increase of the electrical conductivity. Moreover, PVA Nano fibrous membranes with excellent morphology can be fabricated at a proper concentration. The ultrasonic vibration which will make the distribution of nanoparticles as additives into the bubble-elctrospun solution uniform and improve spin ability, can be applied to future development of functional nanofibers.

TABLE II. THE EFFECT OF ULTRASONIC VIBRATION POWER ON THE VISCOSITY AND CONDUCTIVITY OF PVA SOLUTION WITH A CONCENTRATION OF 11%.

Power (w)	Viscosity (mpa.s)	Conductivity (μs/cm)
0	1412.5	962
195	817.5	1070
390	960	1058
585	767.5	1415

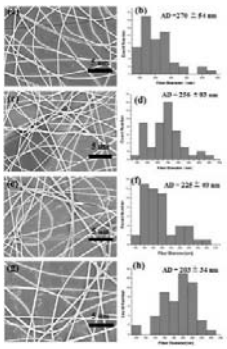

Figure 2. SEM images and diameter distribution histograms of PVA nanofibers under the ultrasonic vibration power of 0 ((a), (b)), 195 ((c), (d)), 390 ((e),(f)), and 585 ((g), (h)) w.

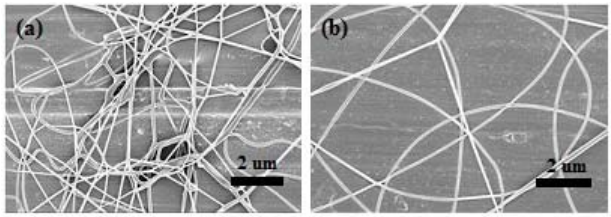

Figure 3. SEM images of PVA nanofibers fabricated by bubble electro spinning under the ultrasonic vibration power of (a) 0, (b) 195 w.

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