

EFFECT OF ETHANOL POST-TREATMENT ON THE BUBBLE-ELECTROSPUN POLY(VINYL ALCOHOL) NANOFIBER

by

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Poly(vinyl alcohol) nanofibers were prepared by bubble electrospinning. After the ethanol post-treatment, poly(vinyl alcohol) nanofibers showed enhanced hydrophobicity with water contact angle change from 0 to 78.9°, and the break strength of poly(vinyl alcohol) nanofibers was dramatically improved from 8.23 MPa to 17.36 MPa. The facile strategy with improved hydrophobicity and mechanical properties of poly(vinyl alcohol) nanofibers will provide potential benefits for applications of this material, especially in filtration field.

Key words: *bubble electrospinning, poly(vinyl alcohol), ethanol treatment*

Introduction

Electrospinning, as an emerging technique, has been aroused intensive interests of researches for fabricating macro/nano fibers. Recent studies have focused on using this technique to fabricate nanofibers for high performance application, such as tissue engineering, electrodes and membrane filtration [1]. Different materials were dissolved to electrospinning for liquid separation, such as polystyrene, poly(vinylidene fluoride), and nylon 6 [2]. All these materials need chemical solvent to dissolve completely. Most of the solvents are toxic, leading to bad effect on environment and human beings health. Poly(vinyl alcohol) (PVA) is a material with biodegradability, lower cost and water-processable, and has been successfully fabricated for gas separation [3]. However, PVA is a strong hydrophilic material and has poor moisture barrier properties, which limit its application of gas separation and potential liquid separation [4].

Based on this, PVA nanofibers were prepared by bubble electrospinning in the present study. After ethanol treatment, morphology change of PVA nanofibers were observed by scanning electron microscopy (SEM). In addition, the wetting ability and mechanical properties of electrospun PVA nanofiber mat were also investigated to know the effect of ethanol treatment on PVA nanofiber properties.

Experimental

The PVA 1750±50 (AR, Co., Ltd. China) was dissolved in deionized water at 90 °C for 2 hours to prepare 8 wt.% solutions. A high electric potential of 20 kV was applied, and

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the electrospun nanofibers were collected on flat aluminum foil which was placed at a distance of 25 cm. Then the as-spun nanofibers were immersed in ethanol (99.8% AR, Co., Ltd. China) with 3 hours, and dried in air. The morphology of nanofibers was observed using an SEM (Hitachi S-4800, Japan) at 20 °C, 60 RH. Water contact angle was measured by an optical contact-angle meter system (Kruss DSA 100, Germany). The mechanical properties of PVA nanofiber mats (10 mm × 40 mm) were obtained using a universal texting machine (Instron 3365, Instron, Norwood, Mass., USA) at 25 ± 0.5 °C, $60 \pm 5\%$ relative humidity. The thickness of the mats was measured using a micrometer. At least 5 measurements for each sample were performed in the testing.

Results and discussion

As shown in fig. 1, cylindrical and smooth PVA nanofibers were obtained, with diameter of about 440 nm. The PVA nanofibers were interspersed, showing loose structure which may contribute to poor mechanical strength with weak bonding at fiber junctions [5]. However, after ethanol treatment, it exhibited bigger diameter as well as tight structure. The PVA nanofiber showed swelled morphology, and fusion also occurred among some of the fiber junctions, as indicated by the arrows (fig. 1). This occurs because that ethanol can swell the nanofibers and slightly dissolve the nanofibers to facilitate fusion. As a result, swelled and fused nanofibers were obtained.

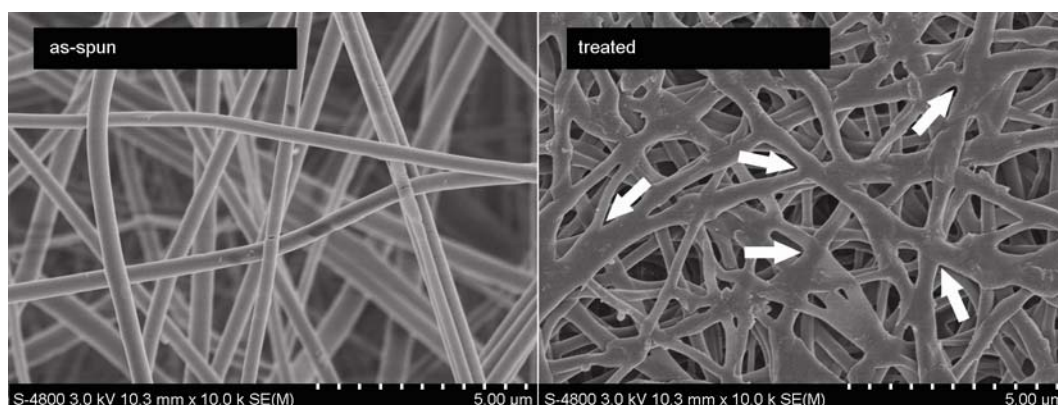


Figure 1. Morphology of as-spun and treated PVA nanofiber

The PVA nanofibers with different surface morphology after ethanol-treated might show different wetting property, so as-spun and treated nanofiber mat were immersed in water with one hour and one month. Significantly different wetting behavior was shown in fig. 2. Immediately the as-spun PVA nanofiber mat contacted water, shrinkage occurred, which is due to the dissolution of hydrophilic group, fig. 2(b). However, the treated PVA nanofiber mat exhibited no obvious change in surface morphology and shape, fig. 2(b). After one hour ethanol treated, PVA nanofibers swelled and some of them fused together, leading smaller and less pores, fig. 2(c). And further swell and fusion of PVA nanofiber occurred after one month later, with no obvious change in fiber morphology and diameter, fig. 2(d).

Water contact angle (WCA) is the most direct reflection of material wetting property. Figure 3 shows the WCA of PVA nanofiber mat before and after ethanol treatment. It can be seen that WCA of as-spun and treated PVA nanofiber mat were 0° and 78.9°, respectively.

Figure 2. Morphology of PVA nanofiber; (a) as-spun and treated nanofiber, (b) as-spun and treated nanofiber immersed in water, and (c) and (d) treated nanofiber immersed in water with one hour and one month later

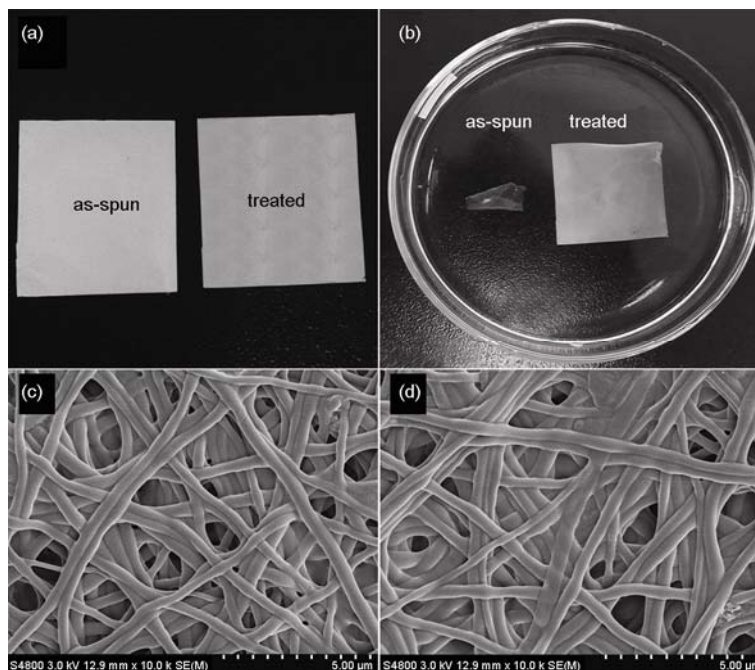


Figure 3. The WCA of as-spun and treated PVA nanofiber mat



The PVA is a strong hydrophilic material, and regenerated PVA nanofibers were dominant amorphous structure, showing 0° of WCA at room temperature. After treatment, PVA nanofiber swelled and fused together, the increased physical junctions made it tight structure and difficult for water enter the inner of nanofiber mat, leading higher hydrophobicity with 78.9° of WCA.

To further evaluate the effect of ethanol treatment, mechanical property of PVA nanofiber was investigated. As shown in fig. 4, the strength and strain at break of PVA nanofiber before and after treatment were 8 MPa, 180%, and 18 Mpa, 60%, respectively. The mechanical property results can be attributed to ethanol induced fusion at fiber junction points (fig. 1). In other words, the ethanol made

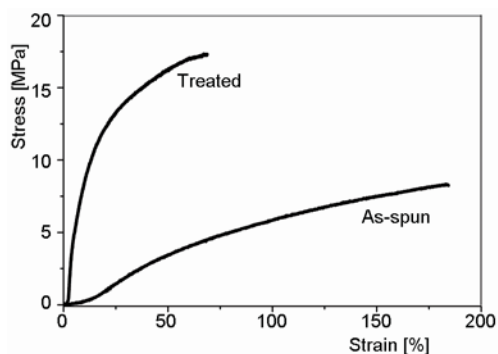


Figure 4. Mechanical property of as-spun and treated PVA nanofiber

PVA nanofibers swollen and fused finally with increased physical fiber junction points, which may result in stronger intermolecular forces and more interaction of nanofiber, showing improved ultimate tensile strength of PVA nanofibers.

Conclusions

With ethanol treatment, PVA nanofiber mat exhibited improved hydrophobicity and mechanical properties, which resulted from the swell of nanofiber and fusion at fiber junction points. The enhanced hydrophobicity and mechanical property will benefit PVA in air separation and potential application in liquid separation.

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