

Fabrication of Water-Stable Electrospun Polyacrylic Acid-Based Nanofibrous Mats for Removal of Copper (II) Ions in Aqueous Solution

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ABSTRACT: Polyacrylic acid (PAA) is an important polymer material for metal ion complexation and for nanocomposite materials syntheses. Generating ultrafine, uniform, and stable PAA nanofibers is of great scientific and technological interest for various applications. In this study, we systematically investigated the influence of processing parameters on the morphology and stability of the electrospun ultrafine PAA nanofibers. We show that a higher concentration (up to 25 wt %) favored the formation of uniform PAA nanofibers, whereas at the concentration of 10 wt %, only bead structures were produced. Increasing the applied voltage (up to 22.5 kV) resulted in more uniform PAA nanofibers. In addition, longer collection distance (20 cm) was beneficial for the

evaporation of solvent and for decreasing the adhesion between nanofibers, thus leading to the nanofibrous mats with high porosity. Finally, the PAA nanofibers could be rendered water insoluble by heating the electrospun composite PAA/polyvinyl alcohol (PVA) nanofibers at 145°C for 30 min. The resulting nanofibrous mats exhibited excellent performance to remove Cu(II) ions in aqueous solution. The formed nanofibers may find various applications in ultrafiltration, separation, and environmental sciences. © 2010 Wiley Periodicals, Inc. *J Appl Polym Sci* 116: 2409–2417, 2010

Key words: fibers; stabilization; separation techniques; polyacrylic acid; copper ions

INTRODUCTION

Electrospinning technology is emerging as a simple and low-cost method for fabricating various polymeric nanofibers and nanostructured inorganic/polymer composite materials with outstanding properties such as small diameters in the range of nano-

meters to a few microns, high aspect ratio, and high specific surface area.¹ The unique properties of nanofibers or nanostructured composite materials make them widely useful in ultrafiltration, wound dressing materials, tissue engineering scaffolds, catalytic films, sensors, etc.^{2–7}

Polyacrylic acid (PAA) is an important polyelectrolyte material, which has been widely used as metal ion complexing agents,⁸ used as stabilizers for nanoparticle synthesis,⁹ and used as a layer component for polyelectrolyte multilayer construction.^{10,11} Most importantly, polyelectrolyte multilayers containing PAA layer components can be used as a nanoreactor system for generating a range of composite nanoparticulate films.^{12–15} For instance, our previous work showed that multilayers of PAA and polyallylamine hydrochloride assembled onto glass beads can be used as a nanoreactor for an *in situ* synthesis of zero-valent iron nanoparticles for environmental applications.¹⁶ It is expected that PAA nanofibers formed through an electrospinning process are used as a template or a nanoreactor system for generating a range of nanoparticle-containing nanofibers for various applications.

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To fabricate uniform ultrafine PAA nanofibers, one has to optimize the preparation conditions during the electrospinning process. The fiber formation greatly depends on the solution properties of the polymers and the operating parameters such as the applied voltage, the collection distance, and the flow rate of the solution.^{17,18} Kim et al. investigated the effect of ionic strength on the morphology of PAA nanofibers. It is suggested that the characteristic morphology change of PAA nanofiber may be caused by the chain conformation and conductivity changes of PAA solutions with an ionic strength.¹⁹ Li and Hsieh discussed the effect of solution concentration, electrospinning voltage, and solvent on the morphology, size and structure of PAA nanofibers.²⁰ Results showed that the fiber diameters increased with increasing solution concentration and electrospinning voltage, and the aqueous solution allowed the generation of more homogeneous nanofibers than the DMF solvent. Although the factors affecting the formation and morphology of PAA nanofibers have been studied in literature,^{21,22} there are few reports related to a systematic investigation of the effects of processing parameters and solution properties on the morphology of PAA nanofibers with relatively low molecular weight. The use of low-molecular weight PAA may be useful for generating nanofibers with different properties for different applications. For example, in our previous work,¹⁶ we were able to use PAA with low molecular weight to form multilayers for subsequent formation of nanoparticles.

In this study, PAA nanofibers were prepared from electrospinning, and the influence of the preparation parameters during the electrospinning process such as PAA concentration, applied voltage, and collection distance on the formation of PAA nanofibers was systematically investigated. In addition, to render the fibrous mats water insoluble, we also attempted to fabricate the composite PAA/polyvinyl alcohol (PVA) nanofibers and crosslink PAA and PVA via a heat treatment. Finally, the formed water-stable PAA/PVA nanofibrous mats were used to complex copper (II) ions. We show that the nanofibrous mats display excellent performance in removing Cu(II) ions in aqueous solution. To our knowledge, this is the first study related to the use of electrospun PAA-based nanofibrous mats for removal of toxic heavy metal ions. Findings from this study suggest that the fabricated nanofibrous mats can be potentially used to remove toxic heavy metal ions. The nanofibrous mats may also be used as a nanoreactor system for generating a range of nanoparticles inside each individual nanofibers as the PAA polymers can bind to metal ions for subsequent nanoparticle syntheses,^{16,23} thereby offering many interesting applications.

EXPERIMENTAL

Materials

PAA (average $M_w = 240,000$, 25 wt % in water) was obtained from Aldrich. PVA (88% hydrolyzed, average $M_w = 88,000$) was from J&K Chemical. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ was purchased from Shanghai Kechuang Chemicals Co., Ltd. Water used in all experiments was purified using a Milli-Q Plus 185 water purification system (Millipore, Bedford, MA) with resistivity higher than 18 M Ω cm. The PAA and PVA polymers were used as received. Both polymers were dissolved or diluted in water before use.

Electrospinning

The experimental set-up²⁴ consisted of a 10-mL syringe, a stainless steel needle with an inner diameter of 0.8 mm, a high voltage power supplier (Institute of Beijing High Voltage Technology, Beijing, China), and a collector, which was positioned vertically. A clamp was used to connect the high voltage power supplier (positive voltage ranging from 14 to 25 kV) with the needle. The collector was covered with aluminum foil and grounded directly. The polymer jets emerged from the Taylor Cone under a high electrical field formed the ultrafine fibers, which were collected on the aluminum foil. Subsequently, the aluminum foil was removed from the collector, and the samples were air dried for at least 24 h before characterization. The electrospinning experiments were performed at room temperature.

Electrospinning was performed with either pure PAA or PAA/PVA blend solutions. PAA solutions (in water) with concentrations of 10 wt %, 15 wt %, 20 wt %, and 25 wt % were prepared by simply diluting the 25 wt % commercial stock PAA solution. PVA solution was prepared by dissolving PVA powder into water while gently stirring at 80°C for 3 h, and then cooled down to room temperature. Measured PVA and PAA solution were mixed to achieve a mass ratio of 1 : 1 at constant total polymer concentrations of 8.5 wt % and 10 wt %, respectively. The mixed solution was stirred for 30 min before use in order to make the solution homogenous. A polymer solution (10 mL) was loaded into the syringe. The distance of tip-to-collector was in the range of 15–25 cm. The flow rate was controlled using a syringe pump.

Crosslinking of PAA/PVA composite nanofibrous mats

Freshly prepared PAA/PVA nanofibrous mats were crosslinked upon heating treatment at 145°C for

30 min in the oven and cooled down to room temperature.

Characterization

The morphologies of the electrospun pure PAA or PAA/PVA composite nanofibrous mats were observed using a scanning electron microscope (SEM) (JSM-5600LV, JEOL Ltd., Japan) with an operating voltage of 10 kV. Prior to SEM experiment, samples were sputter-coated with 10-nm Pt films. Fourier transform infrared (FTIR) spectra were recorded using a Nicolet 5700 FTIR spectrometer (Thermo Nicolet Corporation, US) at a wavenumber range of 4000–500 cm^{-1} at room temperature. The fiber mats were cut into round pieces with a diameter of 20 mm and then put onto the sample holder before measurements. The apparent density and porosity of electrospun fibrous mats before and after treatment were calculated using eq. (1) and 2,²⁵

$$\begin{aligned} \text{apparent density (g/cm}^3\text{)} \\ = \frac{\text{mat mass (g)}}{\text{mat thickness (cm)} \times \text{mat area (cm}^2\text{)}} \quad (1) \end{aligned}$$

mat porosity

$$= \left(1 - \frac{\text{mat apparent density (g/cm}^3\text{)}}{\text{bulk density of mixture (g/cm}^3\text{)}} \right) \times 100\% \quad (2)$$

where the thickness of the fibrous mats was measured by a micrometer, and the bulk density of mixture was calculated according to their weight ratio in the mixture. The swelling ratio of the fibrous membranes was calculated according to eq. (3),

$$\text{Swelling ratio} = (W_s - W_0)/W_0 \quad (3)$$

where W_0 is the dry weight of the fibrous mat, W_s is the weight of the fibrous mat immersed in water (26°C) at different time intervals. Potentiometric titration was performed manually using a pHS-3C pH meter under the protection of nitrogen atmosphere at room temperature. Measured PAA/PVA nanofibrous mats were added to 20 mL distilled water to give a final concentration of 1 mg/mL. And, then the charges available on the nanofibers were determined by potentiometric titration with standard NaOH (0.1N) solution.

Copper (II) ion removal experiment

Cupric sulphate was selected as a model species to prepare an aqueous solution of Cu(II) ions for investigating the removal capability of water-stable PAA/PVA nanofibrous mats. The solution of Cu(II) ions

with a concentration of 50 mg/L was prepared by dissolving $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in water. The pH value of the solution was adjusted to 5.0 with 0.1M NaOH, which was beneficial for the adsorption of Cu(II) ions according to literature report.²⁶ In batch experiments, each water-stable PAA/PVA nanofibrous mat with identical weight was added into a 20-mL vial filled with 10 mL Cu(II) ion solution (50 mg/L) to reach a final concentration of 2 mg/mL. The nanofibrous mat samples were withdrawn after a given time interval and the concentration of Cu(II) ions were analyzed using inductively coupled plasma atomic emission spectroscopy (ICP-AES) (Prodigy, Leeman, US). To test the absorption selectivity of the Cu(II) ions, the crosslinked PAA/PVA nanofibrous mats were exposed to an aqueous solution containing both Cu(II) and Ca(II) ions with a similar concentration (50 mg/L). At a given time interval, the mat samples were withdrawn and the solution was analyzed using ICP-AES to determine the concentration of Cu(II) and Ca(II) ions. The effect of the ionic strength on the absorption capability of the PAA/PVA fibrous mats was also investigated by exposing the mats into the Cu(II) solution containing sodium chloride with different concentrations.

RESULTS AND DISCUSSION

Electrospinning of pure PAA solution

Electrospinning of pure PAA solution at a series of concentrations produced a stable polymer jet under proper spinning conditions, but yielded different morphologies of nanofibrous mats. We systematically examined the effect of PAA concentration, the applied voltage, and the tip-to-collector distance on the morphology of the PAA nanofibers.

Figure 1 shows the SEM images of electrospun pure PAA nanofibers at the concentrations of 10 wt %, 15 wt %, 20 wt %, and 25 wt % at an applied voltage of 18.8 kV. It is clear that at the concentration of 10 wt %, only beads were produced [Fig. 1(a)]. With the increase of the solution concentration, some fiberlike products were formed, with a large number of beads still existing [Fig. 1(b,c)]. When the concentration was increased up to 25 wt %, the fiber structure with an average diameter of 614 ± 127 nm was clearly observed. Distinct adhesion between the nanofibers appears to be dominant, resulting in a rough mat. It appears that the polymer concentration is one of the most critical parameters to control the quality of nanofibers. The concentration is directly related to the viscosity, surface tension, and conductivity of the polymer solution. Lower concentration results in lower viscosity and higher surface tension, which favors the formation of bead structures, whereas increasing the concentration could result in

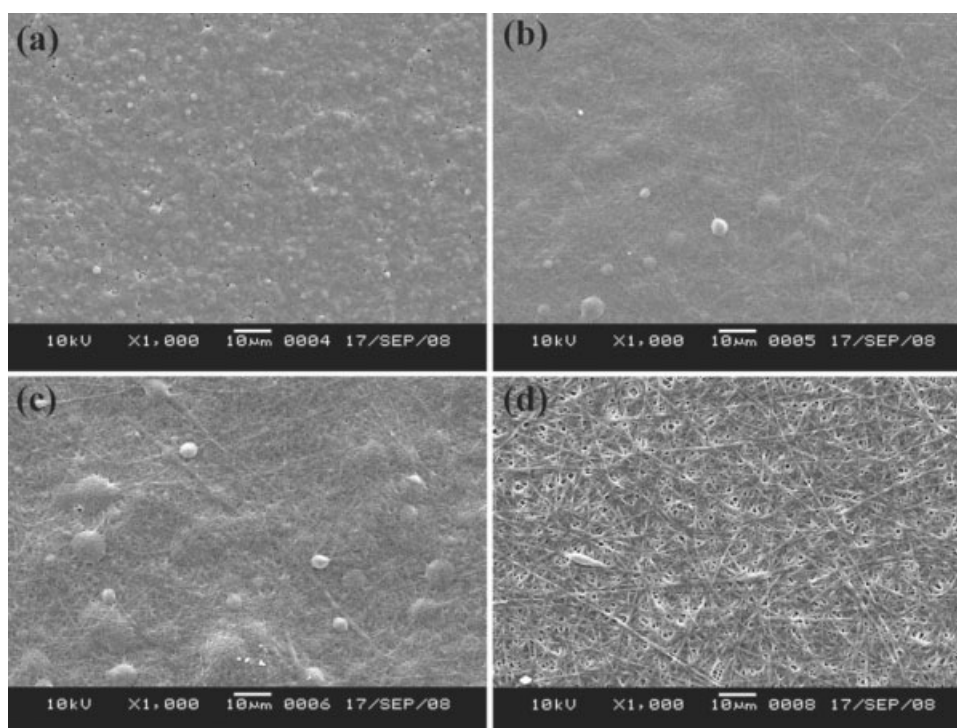


Figure 1 SEM images of electrospun PAA nanofibers formed from different concentrations: (a) 10 wt %, (b) 15 wt %, (c) 20 wt %, and (d) 25 wt %.

increased solution viscosity, which is essential for the formation of fiber structures.²⁷ It should be noted that solution viscosity is a primary parameter determining the quality of the electrospun polymer nanofibers. Literature data show that using a PAA with a higher M_w (450,000), one could fabricate uniform PAA nanofibers at a concentration of 8 wt % in water.²⁰

Applied voltage is another factor influencing the morphology of PAA nanofibers. When the PAA concentration (25%) and the collection distance (20 cm) are kept constant, some spindle-like structures were formed along the fibers at the applied voltage of 18.8 kV [Fig. 1(d)]. However, at a higher voltage (22.5 kV), the spindle-like structure disappeared (Fig. 2). This is because with the increase of applied voltage, more ionized solution could be produced, resulting in an increase of solution charge density. Hence, a stronger electrostatic force applied to the electric polymer jet entails the fibers with a stronger stretching force, resulting in the formation of uniform fiber structures.²⁸ However, it is worthwhile to note that the increase of voltage should be limited in a given range because a certain higher voltage would result in an unstable electrospinning.²⁸

The process of ultrafine fiber formation is also a process of the fiber solidification and solvent evaporation. Therefore, changing the collection distance may significantly affect the rate of fiber solidification and solvent evaporation. Consequently the porosity

of the fibrous mats may be very different. In general, the nanofibers randomly deposit onto the collector and form a circular mat according to the shape of the capillary needle. A small circular area with deep color called “wet spot” can be found in the center of the mats. The area or size of the “wet spot” directly reflects the degree of the fiber adhesion. Larger “wet spot” suggests a lower porosity of the nanofiber mat. Herein, we added a dye Red BB (final concentration = 0.1 wt %) into the PAA solution before

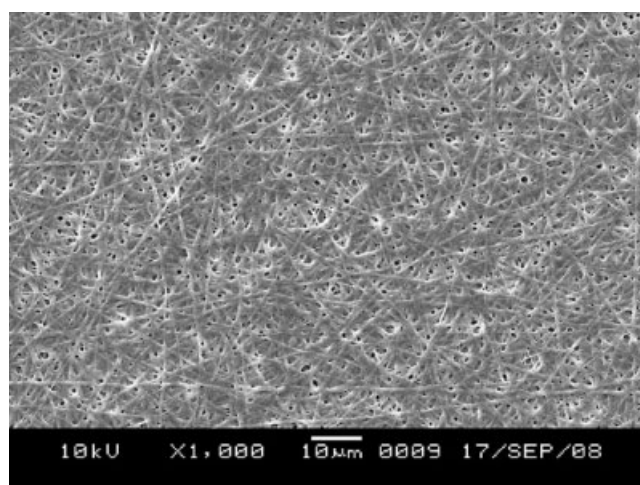


Figure 2 A typical SEM image of PAA nanofibers fabricated at a voltage of 22.5 kV. The PAA concentration was 25 wt %, and the collection distance was 17 cm.

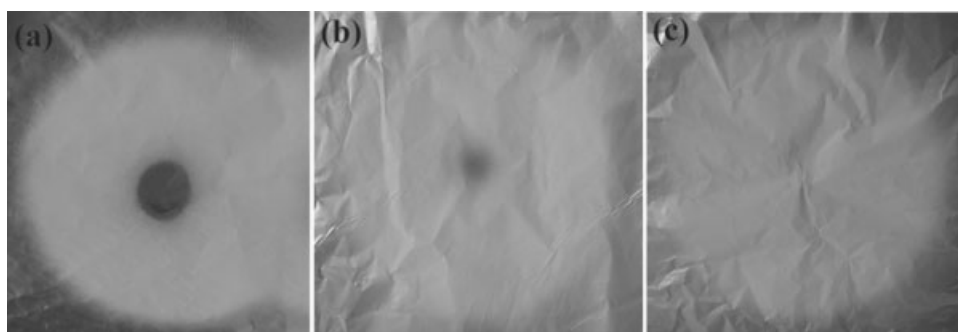


Figure 3 Digital photos of PAA nanofibrous mats fabricated at a distance of (a) 15 cm, (b) 17 cm, and (c) 20 cm.

electrospinning in order to make the “wet spot” more visible. Figure 3 shows the digital photos of nanofibrous mats collected with different collection distances. When the collection distance was 15 cm, a deep red color area in the centre of the mat was observed with some enriched liquid [Fig. 3(a)]. And the red color was beginning to fade with the increase of collection distance [Fig. 3(b,c)]. This is because under the stable electrospinning condition, longer collection distance is beneficial for the evaporation of solvent and the decrease of the adhesion between nanofibers, thus endowing the nanofibrous mats with high porosity. At the collection distance of 20 cm, the nanofibers got better solidified, and the red-color disappeared basically. Figure 4 shows the SEM images of PAA nanofibers with a collection distance of 15 cm, 17 cm, and 20 cm, respectively. More pores can be observed at a larger collection distance. This result is consistent with the observation in Figure 3.

Electrospinning of PAA/PVA blend solution

PVA nanofibers have been successfully fabricated by electrospinning.^{29,30} Compared with a PAA solution with a similar concentration, an aqueous PVA solution was more viscous. It is expected that mixing PVA with PAA may significantly promote the spinnability of PAA.³¹ Literature data show that the highest viscosities of PAA and PVA mixture solution could be achieved by mixing them at a weight ratio of 1 : 1 compared with other weight ratios due to the possibly maximized hydrogen bonding interac-

tion between the two polymers.²² Herein, PAA and PVA were mixed at a weight ratio of 1 : 1 to prepare homogeneous solutions with a total polymer concentrations of 8.5 wt % and 10 wt %, respectively. The morphologies of electrospun PAA/PVA nanofibers were shown in Figure 5. We can see that continuous nanofibers were obtained under the applied voltage (16.6 kV) and the collection distance (20 cm). However, there was some adhesion phenomenon between the nanofibers for the case of 8.5 wt % total polymer concentration [Fig. 5(a)], whereas smooth and uniform nanofibers were produced at the total polymer concentration of 10 wt % [Fig. 5(b)]. This further confirms that the viscosity of polymer solution might be a key parameter affecting the morphology of electrospun nanofibers. In addition, the diameter of the PAA/PVA nanofibers increases with the increase of the polymer concentration. At the 8.5 wt % concentration, the diameter of the fibers is 134 ± 39 nm; while the diameter of the fibers increases up to 170 ± 27 nm when the polymer concentration is increased to 10 wt %.

Crosslinking of PAA/PVA composite nanofibrous mats

As both PAA and PVA are water-soluble polymers, the electrospun PAA/PVA nanofibers could be dissolved in water immediately [Fig. 6(a)]. To retain their unique fiber structure in water, the PAA/PVA nanofibrous mats were treated at 145°C for 30 min to form intermolecular crosslinking between the carboxyl groups of the PAA and the hydroxyl groups of the

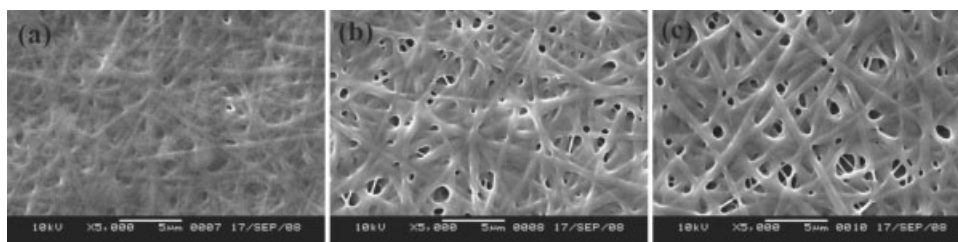


Figure 4 SEM images of PAA nanofibrous mats fabricated at a distance of (a) 15 cm, (b) 17 cm, and (c) 20 cm.

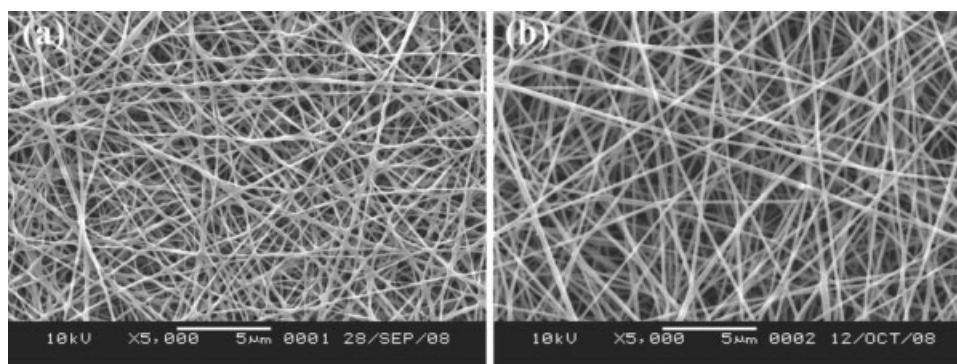


Figure 5 SEM micrographs of PAA/PVA nanofibers fabricated at a total polymer concentration of (a) 8.5 wt % and (b) 10 wt %.

PVA.³² The nanofibrous mats thus obtained became water-insoluble and kept excellent porous fiber structure even after immersion in water for a week [Fig. 6(b)]. In contrast, without heating treatment to crosslink PAA and PVA, nothing was left after immersing the PAA/PVA nanofibrous mats collected on the aluminum foil into water for only 10 min [Fig. 6(a)].

We have tried to use FTIR to verify the crosslinking of PAA and PVA in the PAA/PVA fibrous mats (Fig. 7). It is clear that the FTIR spectra of PAA/PVA nanofibers before and after heat treatment are nearly identical. No ester-bound adsorption peak was detected and a strong adsorption peak at 1710 cm^{-1} ascribed to carboxyl group was still left, even though the esterification was the proper explanation for the outstanding property of water insolubility theoretically. We assume that the FTIR technique may not be sensitive enough to detect the ester-bond formation. This result is consistent with the literature data.³² To confirm if the PVA polymer in the PAA/PVA nanofibers could be self-crosslinked upon heating treatment, we fabricated pure PVA nanofibers and attempted to crosslink PVA under similar conditions to those used to crosslink PAA/PVA nanofibers as described in Experimental Section. We found that PVA nanofibers after treatment were not stable

in water, further proving that PVA polymers are not able to be crosslinked under similar conditions.

Porosity is one of the most important parameters to evaluate the property of electrospun nanofibrous mats. Knowing the bulk densities of PAA and PVA polymers, along with the calculated apparent density of the nanofibers, we were able to calculate the porosities of PAA/PVA and crosslinked PAA/PVA nanofibrous mats according to literature report.²⁵ The porosity of PAA/PVA nanofibrous mats (86.6%) without any treatment decreased to 69.6% after heat-induced crosslinking and fiber contraction, thus forming the dense fibrous mats.

Furthermore, the used two polymers of PVA and PAA are miscible after formation of the nanofibers. This has been proved by our earlier study.²³ In that study, crosslinked PAA/PVA nanofibers were used as nanoreactors to complex Fe(III) ions through the binding with the carboxyl groups of PAA polymers for the formation of zero-valent iron nanoparticles (ZVI NPs). The formed ZVI NPs were uniformly distributed in the nanofibers, suggesting that the PVA and PAA polymers are miscible after the formation of electrospun nanofibers.

For environmental applications, it is important to know the swellability of the nanofibrous

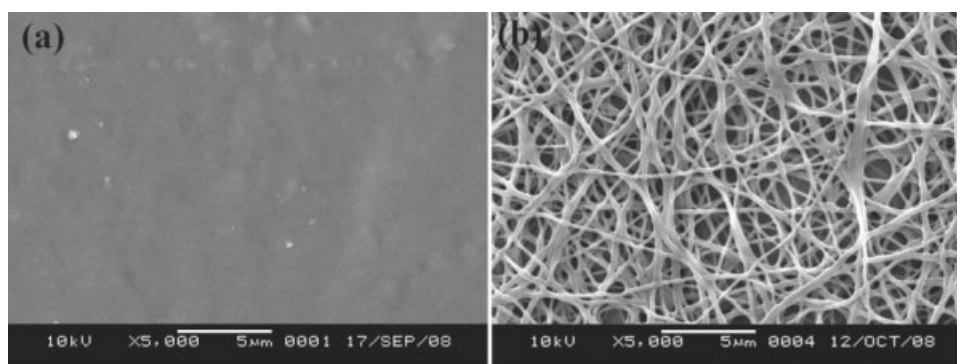


Figure 6 SEM images of (a) non-crosslinked PAA/PVA nanofibers after immersion in water for 10 min, and (b) crosslinked PAA/PVA nanofibers after immersion in water for a week.

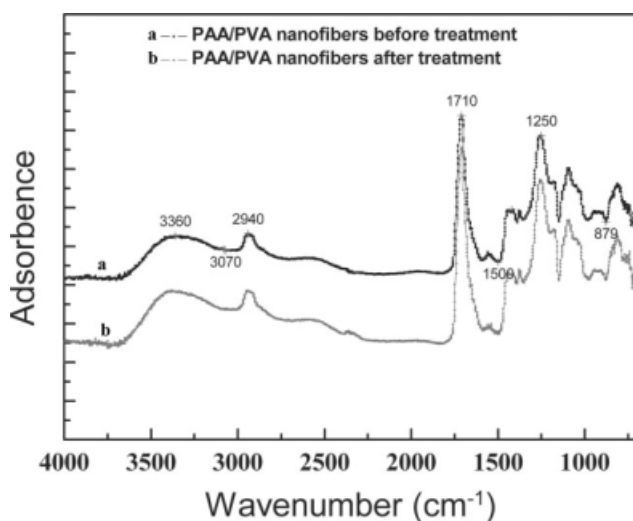


Figure 7 FTIR spectrum of PAA/PVA nanofibers before (Curve a) and after (Curve b) heat treatment.

membranes. The swelling ratio of the crosslinked PAA/PVA fibrous mats was calculated according to eq. (3). The weight of the fibrous mat after immersion in water was monitored at different time intervals (5 min, 10 min, 20 min, 30 min, 40 min, 1 h, 2 h, 6h) until no further weight increase. We showed that the weight of the mat did not change after 1 h immersion in water. The swelling ratio of the crosslinked PAA/PVA fibrous mat was found to be 9.69.

The Cu(II) removal capability of the crosslinked PAA/PVA nanofibrous mats (see below) could be significantly related to the available charges of the mats, namely the available free carboxyl groups of the mats. The density of the free carboxyl groups was determined by potentiometric titration using standard NaOH solution (0.1N). We showed that the initial pH value of the mat solution (6.63) was increased to 7.02 after addition of 30 μ L NaOH solution. Hence, the available charges on the nanofibers were determined to be 0.146 mmol/g.

Cu(II) ion removal experiments

As an example of potential environmental applications, the water-stable PAA/PVA nanofibrous mats were used to remove heavy metal ions in water. As

a commonly used heavy metal, copper is found harmful if discharged into natural water resources. Therefore, Cu(II) was selected as a model heavy

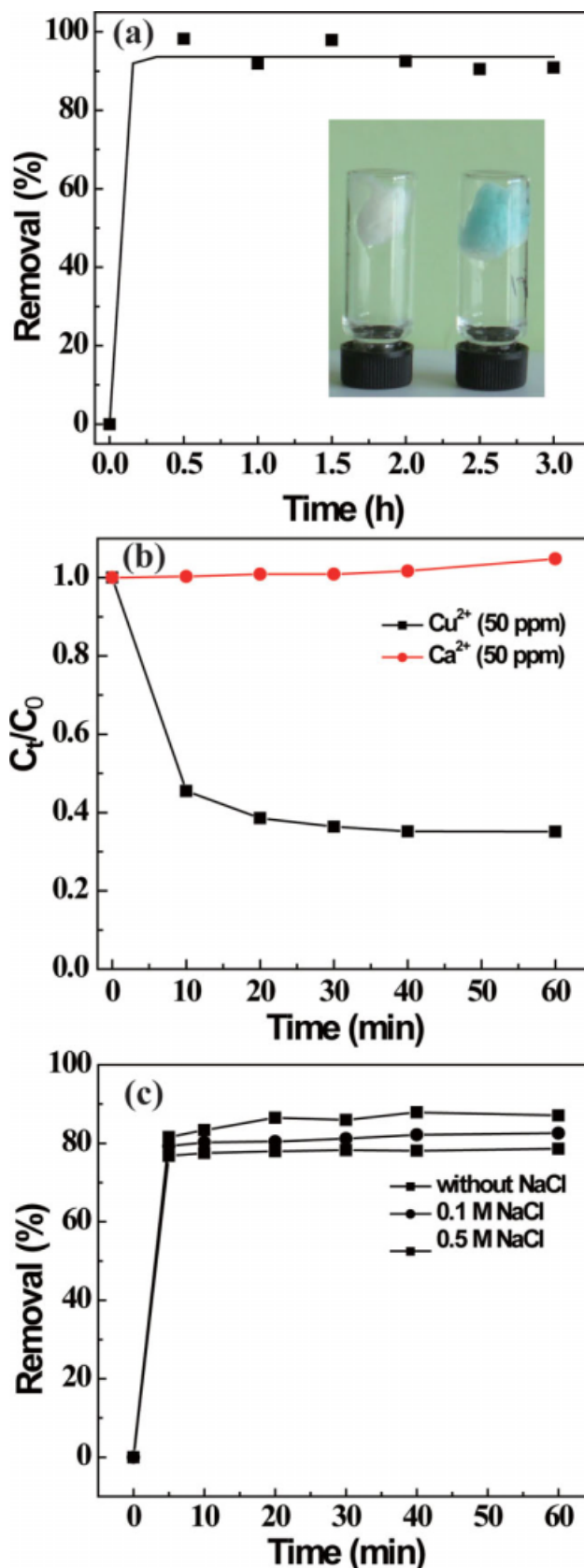


Figure 8 (a) Removal percentage of Cu(II) ions as a function of exposure time. Inset shows a digital image of water-stable PAA/PVA nanofibrous mats before (left panel) and after (right panel) complexation with Cu(II) ions. (b) Selective absorption of Cu(II) ions by crosslinked PAA/PVA fibrous mats in the presence of Ca(II) ions as a function of exposure time. (c) Removal percentage of Cu(II) ions in aqueous solution with different NaCl concentrations as a function of exposure time. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

metal ion contaminant for investigating the removal capability of water-stable PAA/PVA nanofibrous mats. The PAA/PVA nanofibrous mats were able to remove about 91% of Cu(II) ions at room temperature [Fig. 8(a)]. The uptake of Cu(II) ions rapidly reached up to 98.2% in the initial 0.5 h, then decreased a little and ultimately kept stable removal percentage at 91%. This is presumably due to the dynamic equilibrium of adsorption and desorption between the Cu(II) ions and PAA/PVA nanofibrous mats. The white color of PAA/PVA nanofibrous mats changed to light blue after complexation with Cu(II) ions for 3 h, further supporting the successful removal of Cu(II) ions in aqueous solution [Fig. 8(a), inset]. The ion removal capacity of the mats was calculated to be 0.142 mmol/g (moles of ion removed per gram of mat). According to the results shown in Figure 8(a), the contact time was fixed at 60 min for the rest of the batch experiments to make sure that the equilibrium was reached. The excellent adsorption capability of PAA/PVA nanofibrous mats is attributed to the strong complexation capability of free carboxyl group of PAA with Cu(II) ions, in agreement with literature.^{26,33} In addition, the crosslinked PAA/PVA nanofibrous mats displayed higher selectivity toward the absorption of Cu(II) in the presence of both Cu(II) and Ca(II) ions with a similar concentration [Fig. 8(b)]. Furthermore, the dependence of the Cu(II) absorption capability of the crosslinked PAA/PVA mats on the ionic strength was also investigated. Under the selected ionic strengths ([NaCl] = 0, 0.1, and 0.5M), we showed that the absorption capability of the crosslinked PAA/PVA fibrous mats was not significantly affected [Fig. 8(c)]. With the increase of NaCl concentration, the Cu(II) ion removal percentage was slightly decreased.

It is interesting to note that the ion removal kinetics could be affected by the swelling of the crosslinked PAA/PVA fibrous mat. To test this hypothesis, we immersed the fibrous mat into water for 1 h to achieve its maximum swellability. Then the swelled mat was used to remove Cu(II) ions under similar conditions. We showed that both dry and wet mats displayed approximately similar Cu(II) ion removal kinetics.

We note that the selected fiber mat and Cu(II) ion concentrations are not optimized in this study. The removal efficiency of Cu(II) ions using PAA/PVA nanofibrous mats may be affected by the initial mass of the fibrous mats, the initial Cu(II) ion concentration, and pH of Cu(II) ion solution. Further detailed studies are necessary to achieve a complete understanding on the factors influencing the Cu(II) ion removal using PAA-based electrospun nanofibrous mats. When compared with other materials (e.g., PAA/PVA films) used for ion removal, the high sur-

face area-to-volume ratio of the PAA-based fiber materials allows for maximum interaction with the ions to be removed, thereby significantly improving the efficiency of the environmental remediation process.

CONCLUSION

In summary, PAA nanofibers electrospinning from PAA polymer with relatively low molecular weight under various processing parameters were systematically investigated. The results showed that at higher concentration (up to 25 wt%) more uniform nanofibers were fabricated, whereas at the concentration of 10 wt % only droplets were formed due to the lack of enough chain entanglement. Higher positive voltage (up to 22.5 kV) and longer collection distance (20 cm) were beneficial for the electrospinning of uniform, porous PAA nanofibrous mats. Furthermore, addition of PVA (a highly viscous polymer) could significantly improve the spinnability of PAA. Smooth and uniform ultrafine PAA/PVA fibers were produced at a total polymer concentration of 10 wt %. Water-stable PAA/PVA nanofibers with porosity of 69.6% could be obtained by thermal treatment at 145°C for 30 min. Finally, we show that the fabricated water-stable PAA/PVA nanofibrous mats are able to quickly remove Cu(II) ions, a model of heavy metal contaminant in aqueous environment and the removal percentage approaches to 91% within 3 h. We anticipate that the water-stable PAA/PVA nanofibrous mats can be used for removal of other toxic heavy metal ions in aqueous solution. In addition, the nanofibrous mats could also be used as a nanoreactor system for our future development of various composite nanoparticulate porous fibrous mats for a range of applications in ultrafiltration, separation, and environmental sciences. Research work along this line is currently underway in our laboratory.

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