Research Article

Electrospun Nanoporous Poly(butylenes succinate-co-butylene terephthalate) Nonwoven Mats

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A traditional Chinese drug “Yunnan Baiyao” is used as an additive in poly(butylenes succinate-co-butylene terephthalate) (PBST) solution, which is a kind of biodegradable aliphatic-aromatic copolyesters, to produce microspheres with nanoporosity by electrospinning; the tunable size of nanoporosity can be controlled by changing the voltage applied in the electrospinning process.

1. Introduction

The performance and applications of nanomaterials strongly depend on their morphological and structural properties [1, 2]. An obvious phenomenon is the remarkably large surface-to-volume ratio of nanomaterials, and porous nanofibers can result in extraordinary increase of the ratio [3–9], which is very much suitable for biomedical applications [10, 11], such as drug release. To this end, electrospinning technology is used to fabricate nanoporous materials using a Chinese traditional drugs called “Yunnan Baiyao” as an additive [7].

2. Biocompatible Materials

Materials for biomedical applications should have not only good mechanical properties, but also excellent biocompatibility and cytocompatibility. Therefore, biocompatible polymers are electrospun to nonwoven mats. Sometimes, surface or volume modification is needed to ensure the property of biomaterials. Biodegradable polymers including poly(lactic-co-glycolic acid) (PLGA) and PCL, and water soluble biomaterials such as poly(ethylene oxide) (PEO) and polyvinyl alcohol (PVA), can be easily electrospun into nanofibers.

In this paper, poly(butylenes succinate-co-butylene terephthalate) (PBST), a kind of aliphatic-aromatic copolyesters, is chosen to be the base material for electrospinning.

It shares desirable biodegradability and good mechanical properties [12]. A kind of Chinese traditional drugs called “Yunnan Baiyao,” which is a highly valued and important traditional Chinese drug, is used as an additive. There are a wide variety of therapeutic uses of “Yunnan Baiyao,” including the promotion of blood circulation, removal of blood stasis, anti-inflammatory action, hemostasis, induction of blood clotting, relief of swelling, and alleviation of pain, it can also be used for the treatment of traumatic injury, spitting blood, hemoptysis, surgical bleeding, suppurative and pyogenic infections, soft tissue bruise, closed fracture, infective diseases on skin and so forth. It also has potential applications in wound dressings [7].

3. Experimental

3.1. Materials. Poly(butylenes succinate-co-butylene terephthalate) (PBST) with a molecular weight of 20,000 g/mol was supplied by Shanghai Institute of Organic Chemistry. PBST pellets were dissolved in a mixed solvent of isopropylalcohol and chloroform with a weight ratio 9 : 1. The solvents were bought from Shanghai Chemical Reagent Co., Ltd., China. “Yunnan Baiyao,” however, a traditional Chinese drug, was produced by Yunnan Baiyao Group Co. Ltd., China. All materials were used without any further purification.

FIGURE 1: SEM image of the electrospun porous microspheres. The voltage is 20 KV, the diameter of micropores varies from 600 nm to 800 nm.

FIGURE 2: SEM image of the electrospun porous microspheres. The voltage is 25 KV, the diameter of micropores varies from 250 nm to 500 nm.

PBST and “Yunnan Baiyao” were dissolved in the mixed solvent with the weight ratio 1:9:90 (“Yunnan Baiyao”: PBST: mixed solvent).

3.2. Electrospinning Process. The electrospinning setup includes a high voltage power supply (up to 50 kV), a syringe, a syringe pump, a flat metal needle, and a grounded collector. The collection distance was 12 cm, environment temperature was 27°C, and relative humidity was 60%. In the electrospinning process, a charged polymer solution is extruded toward a grounded collector plate. In sufficiently high electric field, the polymer stream is whipped around, leading to the formation of a nonwoven mat of submicrometer-diameter fibers. The diameter of the orifice is 0.7 mm, the voltage is adjusted to 10-30 KV, and the flow rate is adjusted artificially.

4. Results and Discussion

The morphology of the electrospun nonwoven mats was investigated by a scanning electron microscope (SEM). The films were collected on an SEM disk and coated with gold before photographing. SEM micrographs are illustrated in Figures 1, 2, and 3.

FIGURE 3: SEM image of the electrospun porous microspheres. The voltage is 35 KV, the diameter of micropores varies from 100 nm to 200 nm.

FIGURE 4: Macromolecular chains are compacted during the electrospinning.

4.1. Electrospinning Dilation. According to the continuity of the charged flow,

$$\frac{1}{4}\pi d^2 u \rho = Q, \quad (1)$$

where d is the diameter of the jet, u the velocity, ρ the density of the solution, and Q flow rate, the radius of the jet decreases with the increase of the velocity of the incompressible

FIGURE 5: Relationship between the size of microspheres and the applied voltage.

charged jet. When the velocity exceed, a critical value u_{cr} , electrospinning dilation, see Figure 4 or [13], happens which leads to microspheres with nanoporosity as illustrated in Figure 5. It is obvious that the size of nanoporosity can be controlled by changing the applied voltage.

4.2. Nanoeffect. According to the size effect of mechanical properties, electrospun fibers on the nanoscale possess higher strength and Young modulus. Such fibers are possibly applied in tissue engineering like connective tissue which provides structural and mechanical support for the body and works in conjunction with muscle tissue for coordinated and reflexive movements by acting as the lever arm [10].

5. Conclusion

In conclusion we suggested a general strategy for the synthesis of microspheres with nanoporosity by electrospinning, the porous sizes having uniform but tunable diameters can be controlled by changing the voltage applied in the electrospinning process. The flexibility and adaptation provided by the method have made the method a strong candidate for producing nanoporous materials for biomedical applications, such as tissue engineering, drug release, and the bubble electrospinning [13–16], can be used for volume production of nanoporous materials.

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