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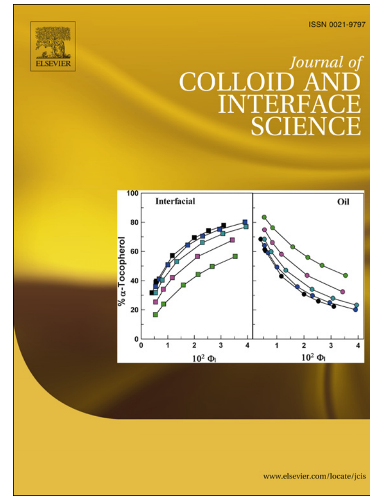

Porous bead-on-string poly(lactic acid) fibrous membranes for air filtration

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Porous bead-on-string poly(lactic acid) fibrous membranes for air filtration

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Abstract

Porous bead-on-string poly(lactic acid) (PLA) nanofibrous membranes (NMs) were fabricated by electrospinning, and the formation mechanism of the membranes was determined in this study. The PLA fibrous morphology, including the fiber diameter, bead size, number of beads, and surface structure of the beads, could be closely controlled by regulating the solvent compositions and the concentrations of the PLA solutions. The filtration performance, which was evaluated by measuring the penetration of sodium chloride (NaCl) aerosol particles with an average diameter of 260 nm, indicated that the filtration efficiency and pressure drop for the resultant PLA membranes could be manipulated by modifying the morphology of the fibers. Moderate bead size and quantity contribute to the low pressure drop, and small fiber diameters and nanopores on the beads were conducive to high filtration efficiency. Furthermore, the NM formed from a 5 wt% solution and a solvent mixture containing dichloromethane (DCM)/N, N-dimethylacetamide (DMAC) in a 10/1 ratio of PLA by weight exhibited excellent filtration efficiency (99.997%) and a low pressure drop (165.3Pa), which are promising characteristics for the membranes' application as filters for respiratory protection, indoor air purification, and other filtration applications.
Keywords: electrospinning, porous bead-on-string fiber, poly(lactic acid), filtration performance

1. Introduction

In recent decades, increasing attention has been devoted to air quality, which has seriously deteriorated due to rapid industrialization [1]. Air pollution, especially which due to fine particulates suspended in air with diameters smaller than 2.5 μm, is one of the primary causes of respiratory disease and pneumonopathy [2]. According to previous studies, conventional non-woven fibrous media have been widely used in different air filtration applications, such as glass fibers and the melt-blown fibers used as the core filtration medium in indoor air filters and N95 respirators. However, the filtration efficiency of these materials with respect to fine particles is relatively low due to the materials' micro-sized fiber diameter [3]. It is well documented that filtration media with smaller fiber diameters exhibit higher filtration efficiency [4]. Nanofibers, which have diameters on the nanoscale, large specific surface areas, and high length to diameter ratios, are considered promising materials for air filtration media [5, 6].

Electrospinning is an efficient and versatile technique for preparing fibrous membranes with nano- and sub-micron fiber diameters [4, 7, 8]. Electrospun mats exhibit very high porosity, small pore size, and good interconnected pore structure, which facilitates the transport of air molecules and the capture of particles in the air [5, 9, 10]. Based on these characteristics, many types of electrospun fibrous membranes, such as ultrafine Nylon 6 fibers, polyethylene oxide nanofibers, and ultrafine polyacrylonitrile fibers, have been fabricated as air filtration media [7, 11, 12]. The abovementioned nanofibers usually possess circular cross-sections, smooth surfaces, and very small diameters, which contribute to the high capture efficiency of particles. However, these nanofibers tend to pack compactly, generating fibrous membranes with a high packing density; thus, these materials are not conducive to air flow penetration.

Previous studies have shown that the morphological properties of fibers, including the fiber diameter and the surface structure, and the packing density (volume fraction) of fibrous membranes have a dramatic effect on fibers' filtration performance [3, 13, 14]. The morphology of a polymer nanofiber can be controlled by varying the polymer solution