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Preparation of poly (tetrafluoroethylene) nanofiber film by electro-blown spinning method

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ABSTRACT

As a kind of high-performance fiber, PTFE fiber has been widely used in many fields because of its unique characteristics. In this study, pure PTFE nanofiber film was prepared effectively through electro-blown spinning (EBS) under dual forces of high speed air flow and static electric method followed by a thermal treatment process. The effects of PTFE/PVA ratio, the amount of boric acid (BA), air pressure, applied voltage and sintered temperature were discussed to obtain the PTFE nanofibers with different diameters, and the film had been characterized by SEM, TG, XRD and XPS, respectively. The results showed that pure PTFE nanofiber film with good morphology could be large scale prepared through the EBS process. Moreover, this novel EBS method may realize the industrialized production of high performance polymer fibers.

1. Introduction

Poly (tetrafluoroethylene) (PTFE) is a fluorocarbon polymer with unique characteristics such as outstanding chemical resistance, excellent thermal stability and strong hydrophobicity. As a kind of high-performance fibers, PTFE fiber is widely used in various fields including electronic information, industrial high-performance filters, membrane distillation [1] and wastewater treatment [2]. Moreover, PTFE nanofiber with larger specific surface area has better performance when compared with PTFE common fiber.

PTFE fiber is difficult to be manufactured using conventional solution-spinning and melt-spinning methods because of insoluble and non-melting properties. At present, it's usually prepared by membrane-splitting and paste-extrusion method, but lots of lubricants are used in the preparation process resulting in considerable environmental pollution and the fiber prepared with large diameter leads to the lacking of better performance [3]. PTFE nanofiber film with large length to diameter ratio, high specific surface area and compact structure has been successfully prepared using electrospinning method by some researchers [4,5]. This process is simple and cost-effective, but the low productivity and industrialization difficulty become a bottleneck which restricting its development.

In recent years, electro-blown spinning (EBS) technology as a new method of preparing nano/submicro-fibers has attracted widespread attention because of its good fiber morphology and high productivity [6,7]. EBS has also been successfully employed by our coworkers to produce inorganic fibers [8,9]. The solution jets are quick stretching under dual forces of high speed air flow and static electric, and then nanofibers are obtained with the solidification of polymer and evaporation of solvents. Herein, in this paper, EBS was used as an effective way to prepare PTFE nanofiber film, and different parameters were discussed showing their direct effects on the morphologies and the diameters of the nanofibers.

2. Materials and methods

2.1. Materials

All materials were purchased commercially and were used without further purification, which including Poly (tetrafluoroethylene) (PTFE) emulsion (60 wt%, Jiangsu Transfar Technology co., LTD.), polyvinyl alcohol (PVA, 1788), Boric Acid (BA, analytical grade). The water used in this work was distilled water.

2.2. Fabrication of PTFE nanofiber films

BA powder was dissolved in distilled water in a vial by stirring for 2 h at room temperature to prepare BA solution (4 wt%). PVA powder was dissolved in distilled water in a beaker by stirring for 6 h at 90 °C to prepare PVA solution (10 wt%). The PTFE emulsion

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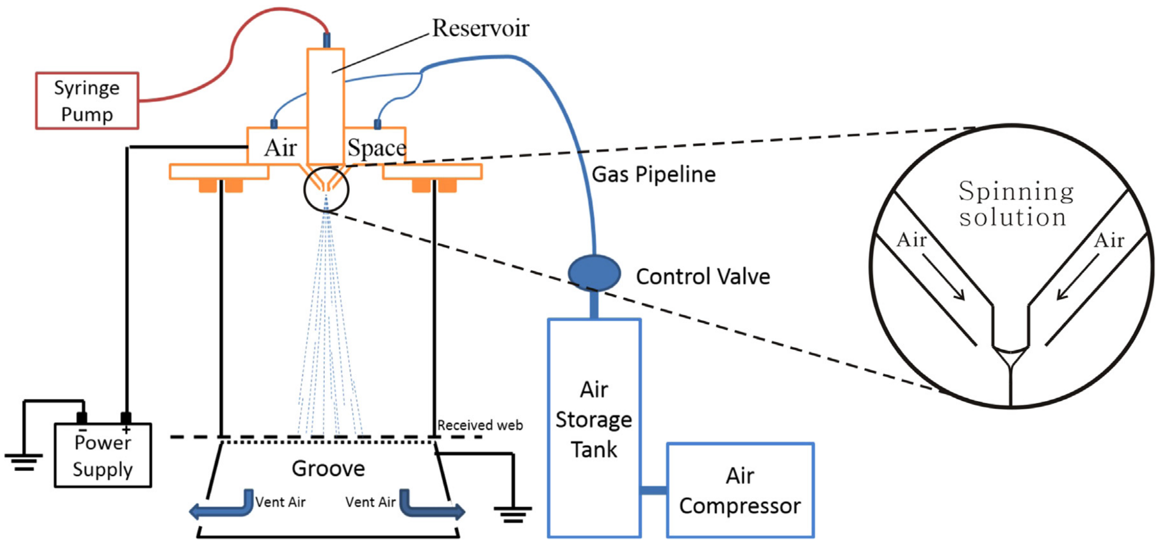

Fig. 1. The schematic of self-made EBS equipment.

and amount of BA solution were added to PVA solution with different mass ratios and followed by continuous stirring for at least 8 h to form spinning solution at room temperature.

The schematic of self-made EBS equipment was shown in Fig. 1. It was composed of air system, feeding system, high voltage power supply and grounding metal collector. Spinning solution was contained in reservoir, loaded into a 0.8 mm inner flat stainless co-axial needle and delivered with a syringe pump. The co-axial needle was used to attenuate the filaments which the inner was for the solution and the outer was for the air flow, and its partial enlarged schematic was shown in Fig. 1. The high pressure air produced by air compressor was stored in the air storage tank. The air flow rate using in the spinning process was controlled by the control valve. The distance between the tip of the spinneret and the collector was maintained at 1000 mm. The solution jets were stretched by high speed air flow and static electricity. After the solidification of polymer and evaporation of solvents, the as-spun PTFE/PVA/BA composite nanofiber film was deposited on a web collector. The film was dried for at least 8 h at 70 °C and subsequently sintered to 390 °C for 20 min at a heating rate of 10 °C/min in air atmosphere to obtain the pure PTFE nanofiber film. The different air pressures and voltages were applied to spin fibers with different diameters.

3. Results and discussion

The microstructure and surface morphologies of the films were observed by field emission scanning electron microscope (FE-SEM; S-4800, Hitachico., Japan) after 2 min gold coating (E1045, Hitachi ion sputter, Japan). Fig. 2a1 showed the SEM of PTFE/PVA/BA composite nanofiber film obtained through EBS method, and the average diameter was 502.55 nm (Fig. 2a2). As-spun fibers with smooth surface were randomly arranged and formed a clear fiber film. Fig. 2a3 showed the pure PTFE nanofiber film obtained with sintered treatment, and the diameter distribution of the fiber was shown in Fig. 2a4 which had good continuity and the average diameter was 585.26 nm. After sintering, the PVA in fibers was decomposed, but the PTFE in fibers was left and melted in the fiber intersections resulting in bonding and formed a connected fiber mesh structure (Fig. 2a3). The output of fibers weight by EBS process (5–9 g/h) is about several times and even more when

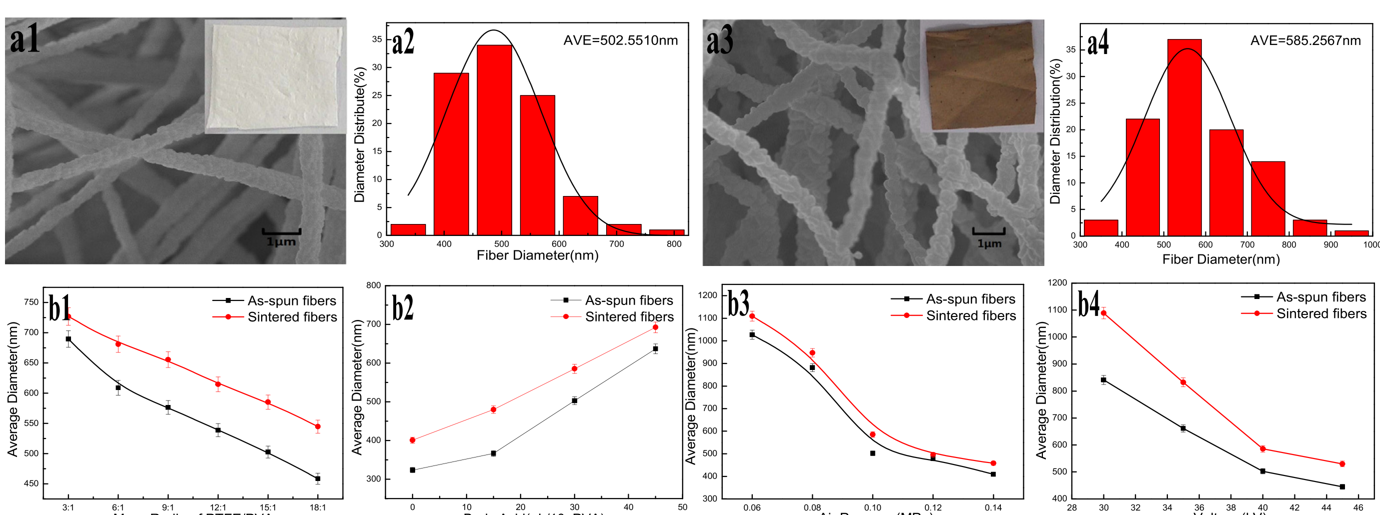

Fig. 2. (a1) SEM image (inset was Digital images) and (a2) fiber diameter distribution of PTFE/PVA/BA composite nanofiber film; (a3) SEM image (inset was Digital images) and (a4) fiber diameter distribution of PTFE nanofiber films; effects of different parameters on fibers average diameters: (b1) mass ratio of PTFE/PVA; (b2) the amount of BA; (b3) air pressure; (b4) voltage.