



Research paper

Preparation and performance of novel polyvinylpyrrolidone/polyethylene glycol phase change materials composite fibers by centrifugal spinning

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ABSTRACT

Currently, phase change materials (PCMs) composite fibers are typically prepared by electrospinning. However, electrospinning exhibits safety concerns and a low production rate, which limit its practical applications as a cost-effective fiber fabrication approach. Therefore, a novel, and simple centrifugal spinning technology is employed to extrude fibers from composite solutions using a high-speed rotary and perforated spinneret. The composite fibers based on polyvinylpyrrolidone (PVP) and polyethylene glycol (PEG) were prepared by centrifugal spinning. The SEM of PVP/PEG composite fibers indicated that the fibrous morphology is well preserved. The DSC and TGA indicated that PVP/PEG composite fibers exhibit good thermal properties.

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1. Introduction

With the continuous increase in the world's energy crisis, there is an increasing interest toward the research of renewable energy sources [1,2]. PCMs with a high-energy storage density and small temperature variation from storage to retrieval can function as renewable, clean energy storage materials for storing thermal energy [1,3,4]. According to the chemical composition, PCMs can be categorized into inorganic PCMs, organic PCMs, and their blends [1,3]. As compared to inorganic PCMs, organic PCMs, such as PEG, exhibit advantages of cost-effectiveness, moderate phase-change enthalpies, high latent heat density, wide melting temperatures for convenient, suitable phase transition temperatures, and stable physical and chemical properties for long-term usage, which have been widely used in solar engineering, solar heating systems, building energy conservation, air-conditioning systems, and waste heat recovery [5–7]. However, PCMs exhibit risk of leakage during phase transition [8–10]. Recently, shape-stabilized composite PCMs based on PCMs and a support matrix have been developed

[1,9,11–15]. Shape-stabilized composite PCMs with desirable dimensions, exhibiting attractive advantages of direct use without additional encapsulation, cost-effectiveness, and facile preparation, could overcome the leakage perfect [4,11].

Previously, several studies have reported the preparation of composite fibers by electrospinning [8,9,11–13,15–17]. Electrospinning is popular and versatile, but it demonstrates several problems for producing composite fibers [14,18]. First, electrospinning with a low production rate considerably hampers the mass production of composite fibers. Second, electrospinning is sensitive to the solution conductivity and environmental factors. Finally, the application of a high-voltage electric field and the inevitable use of solvents lead to potentially increasing production costs and safety concerns [15,19]. Therefore, advanced technologies should be developed to overcome the disadvantages of electrospinning. Centrifugal spinning is a simple, convenient, and versatile technique, which demonstrates significant potential for generating composite fibers. Moreover, theoretically, almost any soluble polymer, such as polymer blends and nanoparticle polymers, with a sufficiently high molecular weight could be subjected to centrifugal spinning [14,18]. PVP is a versatile polymer widely used in several industrial areas because of its excellent thermal, chemical resistance, and mechanical properties. Hence, it is suitable and competent to act as a support matrix for composite fibers.

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In this study, novel PVP/PEG composite fibers, where PEG and PVP act as the PCMs and support matrix, respectively, were successfully prepared by centrifugal spinning.

2. Experimental

2.1. Materials

PEG, with an average molecular weight of 6000, ethanol (AR, 99.7%) and PVP ($M_w = 1,300,000 \text{ g mol}^{-1}$) were purchased from Sinopharm Chemical Reagent Co., Ltd.

2.2. Centrifugal spinning process

A PVP and PEG powder mixture with different mass ratios (PVP: PEG = 50:50, 40:60, 30:70) was prepared by grinding. Solutions including 12 wt% PVP were prepared by dissolving the PVP and PEG powder mixture in ethanol at 25 °C under magnetic stirring for 24 h. Fig. 1 shows the schematic of the centrifugal spinning system. Centrifugal spinning was performed at 25 °C in air using a homemade apparatus. The centrifugal spinning system was powered by a DC motor, and the rotational speed was controlled by a speed controller. The cylindrical spinneret has a height of 2 cm

and a radius of 1.5 cm, with a nozzle diameter of 0.5 mm and a wall thickness of 3 mm. The distance between the nozzle tip and collection device was 20 cm. In this study, the rotational speed of the DC motor was controlled at 2000 rpm. All of the spinning operations were conducted at 25 °C. The large-scale production of PVP/PEG composite fibers is possible because of the relatively high evaporation rate of ethanol. The prepared composite fibers with different mass ratios of PVP: PEG = 50:50, 40:60, 30:70 are hereafter referred to as PVP/PEG (50/50), PVP/PEG (40/60), and PVP/PEG (30/70), respectively.

2.3. Measurements

The morphologies of PVP/PEG composite fibers were observed by scanning electron microscopy (SEM, JSM-IT300). Thermal analysis was performed on a differential scanning calorimeter (DSC, Q200) under nitrogen with heating and cooling rates of 5 °C/min, ranging from 0 °C to 100 °C. Thermogravimetric analysis (TGA, Q50) and differential thermogravimetric (DTG) measurements were conducted to investigate the thermal stability and decomposition properties of the samples. The TGA data were recorded in a temperature range from room temperature to 600 °C at a heating/cooling rate of 10 °C/min.

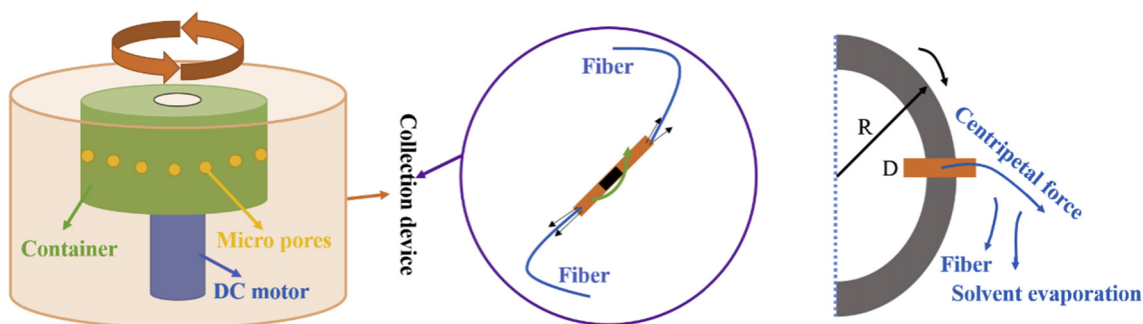


Fig. 1. Schematic of the centrifugal spinning system.

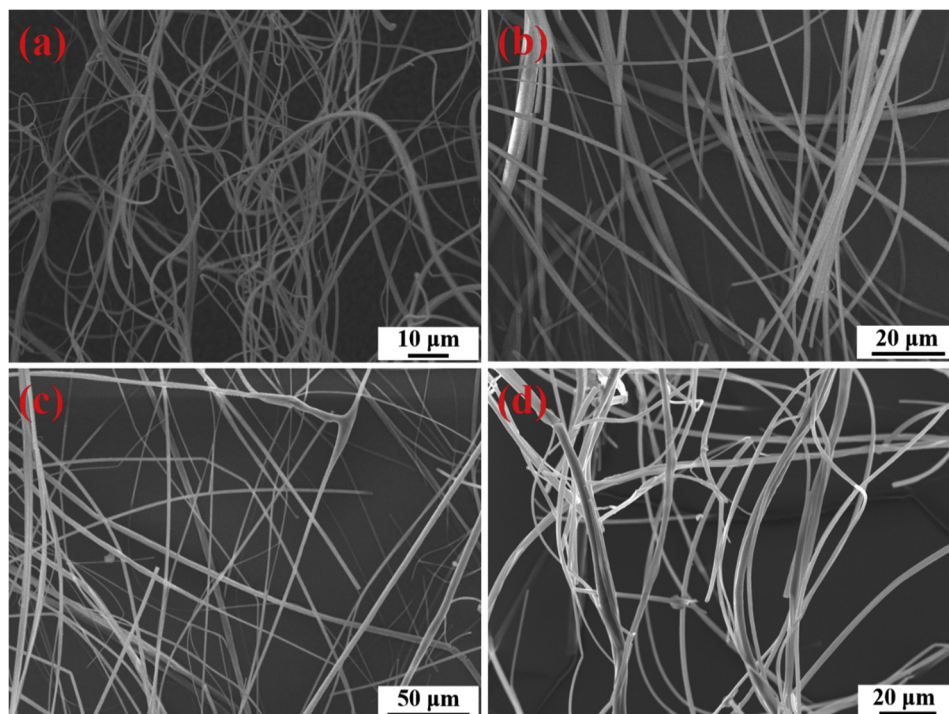


Fig. 2. Morphology and microstructure of the centrifugal spinning composite fibers: (a) PVP, (b) PVP/PEG (50/50), (c) PVP/PEG (40/60), (d) PVP/PEG (30/70).

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