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Preparation of temperature-response fibers with cholesteric liquid crystal dispersion

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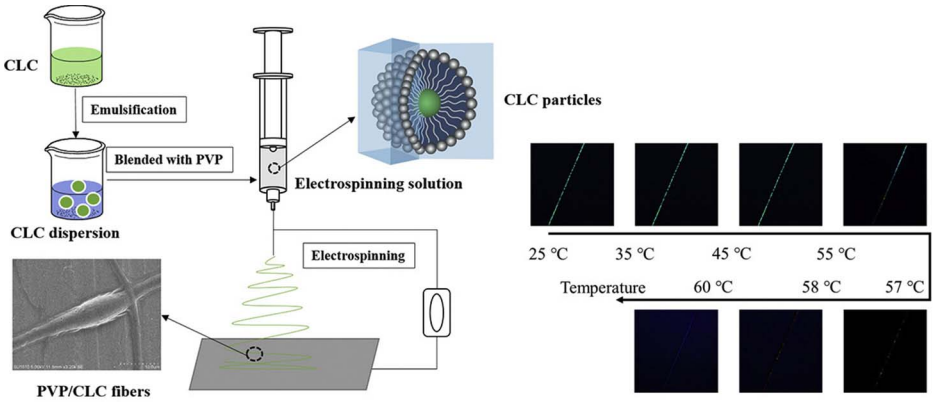
GRAPHICAL ABSTRACT



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ABSTRACT

Cholesteric liquid crystal (CLC) dispersion was prepared using the mixed emulsifiers composed of Tween 20 and Span 80. The effects of preparation parameters on mean particle size and particle size distribution of CLC dispersion were investigated, demonstrating that the CLC mixture was better dispersed and stabilized above the phase transition temperature, and keeping the HLB at 11.7, emulsifier amount at 1.0%, dispersing speed at 5000 rpm for 60 min, the CLC particle in the dispersion were spherical and had a reversible thermochromic property. This dispersion was then used in the preparation of temperature-response PVP/CLC fibers in a water-based system by electrospinning. Polarized optical microscopy and scanning electron microscopy image reveal that CLC particles were incorporated into the PVP/CLC fibers, protecting the CLC from leaking out. The PVP/CLC fibers exhibited an optical temperature response in the temperature range from 25 to 60 °C.

1. Introduction

Cholesteric liquid crystal (CLC) draws much attention due to its visible chromatic response property, which has advantages of quick response, reversibility and adjustable color range [1,2]. When incorporated into fibers, CLC could endow fibers with novel responsive ability to external physical, chemical, or electrical stimuli [3,4], which expends the application range of CLC from sensors to smart textures.

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Electrospinning has been widely adopted to fabricate functional materials by incorporating functional additives into electrospun fibers [5–12], which also applies to polymer/LC electrospun fibers [13,14]. Lagerwall et al. [15] utilized coaxial electrospinning to produce the polymer/LC fibers. In their work, the inner liquid crystal fluid and the outer polymer fluid were placed separately and the two fluids were immiscible. Though coaxial electrospinning has remarkable advantage in fabricating core-shell structure fiber, its preparation technology is very difficult to control. Meanwhile, West et al. [16] reported forming core-shell polymer/LC fibers by electrospinning a homogeneous solution of LCs and polymer. A high voltage is applied to the homogenous solution forming an ultrafine jet that is ejected from the charged solution and then transformed into polymer/LC fibers by phase separation. One key point for this method is to find a suitable solvent to dissolve both liquid crystal and polymers. However, most solvents satisfying this criterion are potentially hazardous chemicals such as acetone and chloroform.

Water-soluble polyvinylpyrrolidone (PVP) makes great applied contribution because of its outstanding solubility and good biocompatibility, especially in the fields associated with people's health such as pharmaceuticals, cosmetic and food [17,18]. And the introduction of CLC inside PVP fibers is a promising strategy to produce temperature-response PVP fibers, which hold enormous untapped potential in medical inspection and sensor fields. However, CLC can't be directly applied to PVP fibers by solution electrospinning, since CLC are hydrophobic which has poor compatibility with water soluble polymer. In order to overcome this problem, emulsifiers can be used to convert CLC from hydrophobic into hydrophilic surface, further improving the compatibility of PVP and CLC [19,20].

Therefore, to prepare temperature-response fibers, CLC was first emulsified using mixed emulsifiers to obtain CLC dispersions. The parameters affecting the CLC dispersion were studied and the optimum conditions for preparing the CLC dispersion were identified. Then the CLC dispersion was added into the PVP solution to prepare the PVP/CLC fibers. The morphology and thermochromic property of the PVP/CLC fibers were investigated.

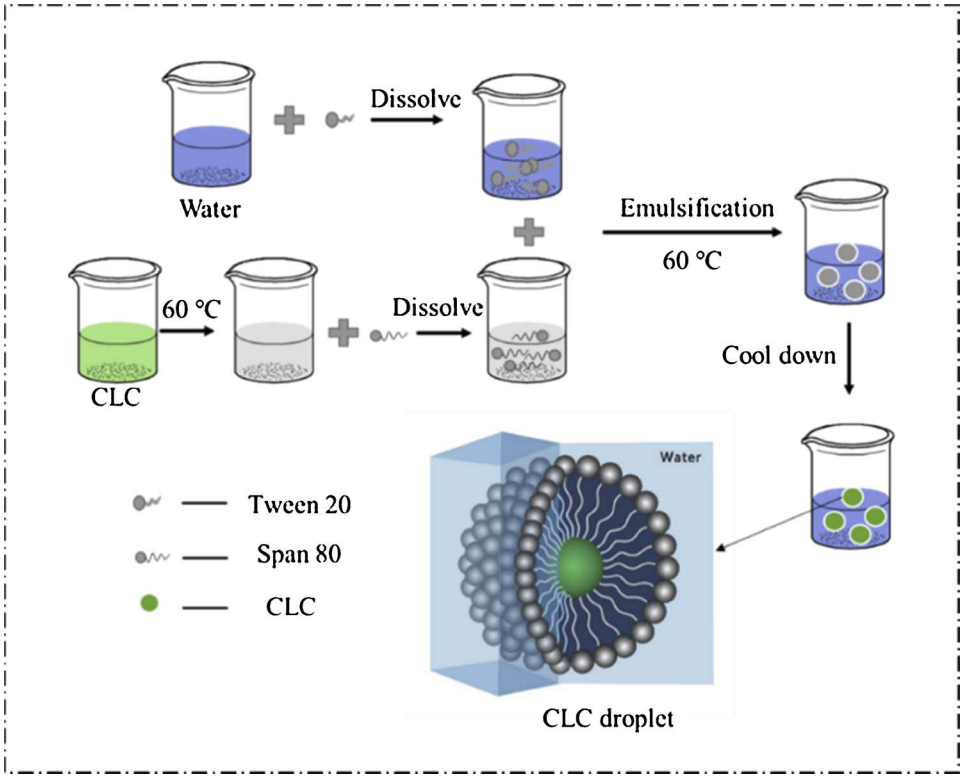
2. Experimental

2.1. Materials

Cholesteryl nonanoate (CPE, purity > 95%) was obtained from Alfa Aesar Co., Ltd, USA. Cholesterol oleyl carbonate (COC, purity > 95%) and Cholesteryl chloride (CC, purity > 95%) were supplied by Tokyo chemical industry Co., Ltd, Japan. Tween 20 and Span 80 were analytical grade and purchased from Sinopharm Chemical Reagent Co., Ltd, China. Polyvinyl pyrrolidone (PVP, Mn = 1,300,000) was analytical grade and supplied by Boai NKY Pharmaceuticals Ltd, China. All chemicals were used as received.

2.2. Preparation of CLC dispersion

The preparation procedure of the CLC dispersion is illustrated in Scheme 1. A CLC mixture containing COC, CPE and CC was prepared in proportions: 38 wt%, 38 wt% and 24 wt%, respectively. Tween 20 was dissolved in deionized water (18.2 MΩ cm) to make aqueous emulsifier solutions. The CLC mixture was homogenized at 60 °C and mixed with Span 80, then dispersed as spherical droplets into the aqueous emulsifier solution at the same temperature by high-speed emulsification (IKA, Germany) to make 10% CLC dispersion. Finally, the solution was allowed to cool down to room temperature.



Scheme 1. Schematic of the preparation procedure of CLC dispersion.