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Preparation and characterization of PLLA/nHA nonwoven mats via laser melt electrospinning

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ABSTRACT

Laser melt electrospinning is a novel technology to fabricate tissue engineering (TE) scaffolds, and this solvent-free process is far safer than common solution electrospinning. In this paper, the electrospun poly(L-lactide)/nano-hydroxyapatite (PLLA/nHA) composite fiber scaffolds were prepared by this method. The scanning electron microscopy (SEM) indicated that the fibers with diameters ranging from 4 to 7 μm were obtained, and the nHA particles were well-dispersed in the PLLA fibers matrix. The energy dispersion spectroscopy (EDS) and X-ray diffraction (XRD) analysis results demonstrated the existence of nHA in the PLLA fibers. With the modification of incorporating HA nanocrystalline particles, the hydrophilicity of the electrospun PLLA/nHA mats surface can be improved.

1. Introduction

As a biodegradable and bioabsorbable polymer, poly(L-lactide) (PLLA) has been widely used in biomedical fields with some modifications in biocompatibility and mechanical properties [1]. Hydroxyapatite (HA), a major inorganic component of natural bone, has been used as a bone grafting material with little inflammatory response due to its excellent biocompatibility and osteoconductivity. However, the brittleness of HA limits its applications [2,3]. According to reports [1–5], the mixing of HA powder with polymers not only enhanced the mechanical properties and the protein adsorption capacity of the materials, but also improved the brittleness of HA ceramics [2]. So, polymer/ceramic composite scaffolds can combine positive properties of organic and inorganic materials.

Electrospinning technology is considered to be an attractive approach for the fabrication of tissue engineering (TE) scaffolds. The scaffolds can mimic the nano-scales geometry and topology of extracellular matrix (ECM) structures, which can support cell adhesion, proliferation, and migration [6]. While the toxicity of the solvent used for electrospinning is highly critical for any in vivo TE applications. One way to avoid the toxicity of residual solvents for TE applications is the use of melt electrospinning [7–9]. Several researchers have performed experiments using melt electrospinning in recent years [10–17]. However, the thermal degradation of the polymer is serious during melt electrospinning process due to long melting time. Laser melt electrospinning is a novel method to prepare polymer nano or micro fibers. The rapid and uniform CO_2 laser heating can minimize the polymer degradation. The current work is aimed at the preparation of PLLA/nHA composites mats by this laser melt electrospinning method, the dispersion and hydrophilicity of the electrospun PLLA/nHA fiber mats were also investigated.

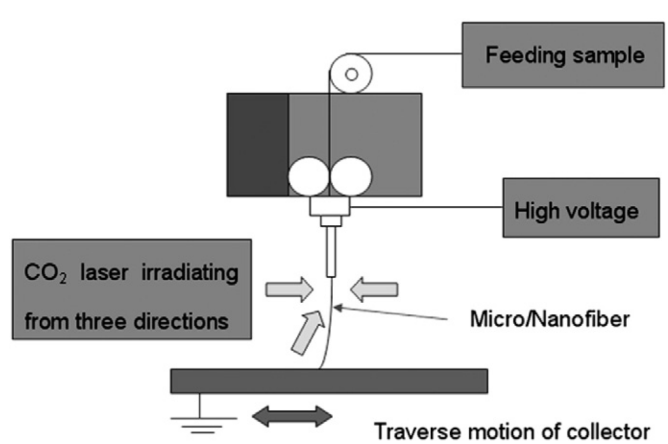

Fig. 1. Schematic diagram of the Laser melt-electrospinning system developed in this work [18].

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2. Experimental

2.1. Materials

The PLLA commercial pellets with molecular weight of ca. 60,000 g/mol were purchased from Nature Works LLC. (7000D, USA). The nHA powder with mean particle size of ca.100 nm was purchased from Aladdin Chemistry Co., Ltd. (China).

2.2. Preparation

The PLLA resin was dried under vacuum at 60 °C for 12 h to remove water, and nHA powder was dried at 100 °C for 12 h in the oven prior to use. The PLLA/nHA mixtures with various nHA contents (1, 3, 5, 7, and 9 wt.%) were put into a microcompounder (Haake MinilabII, Thermo Fisher Scientific, Germany) at a fixed temperature of 190 °C, and the speed of the screws was 50 rpm. The extruder was run for 10 min before the mixtures were extruded through an orifice. The PLLA/nHA rod-like samples, ca. 0.5 mm in diameter, were prepared for the following laser melt electrospinning tests.

Fig. 1 shows a schematic diagram of the laser melt electrospinning system (Katotech Co., LTD., Japan) in our present study. A rod-like PLLA or PLLA/nHA sample was fed to the laser irradiating part with the feed rate of 5 mm/min. The end of the rod was melted by the irradiation of laser beams from three directions with an Onizca PIN-30R laser apparatus (Tokyo, Japan). The diameter of needle was ca.

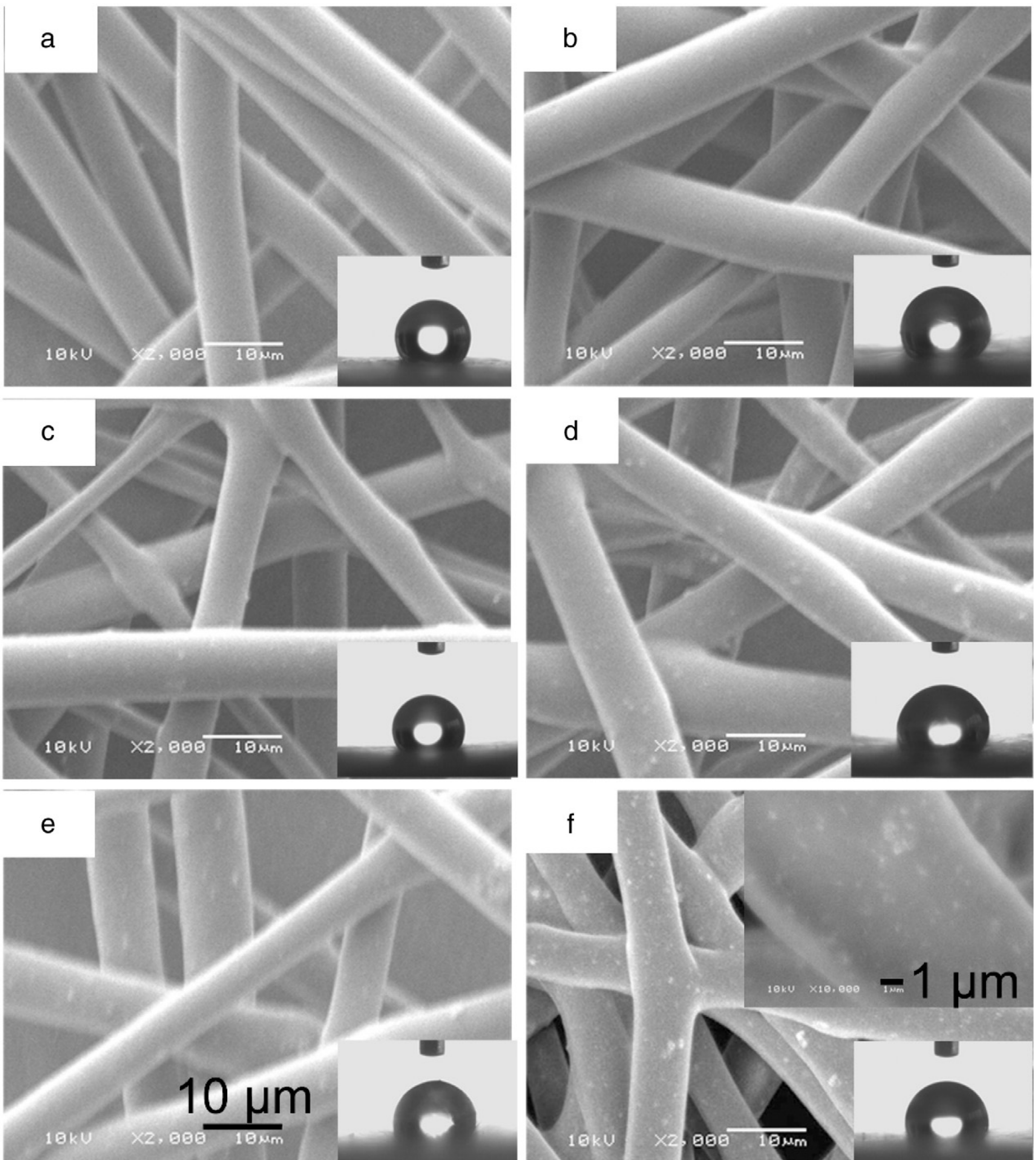

Fig. 2. Representative SEM images of melt electrospun PLLA/nHA fibers on the HA wt.% of (a) 0, (b) 1, (c) 3, (d) 5, (e) 7, and (f) 9 (the inserted images at the bottom right corner are WCA of the fibers mats).