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Preparation and properties of poly(lactic acid) melt spun fiber aligned and disordered scaffolds

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ABSTRACT

Aligned structure of extracellular matrix (ECM) plays a positive role in the surrounding environment and phenotype, it's necessary to simulate aligned structure of tissue and natural cell environment by aligned scaffolds. In this paper, aligned and disordered scaffolds were prepared by poly(lactic acid) (PLA) melt spun fiber and polyurethane (PU) adhesive. It can be found that PLA melt spun fiber aligned scaffold has smaller thickness, weight, pore diameter, porosity and strain while larger alignment degree and stress than disordered scaffold. This research provides a new method to prepare PLA melt spun fiber aligned scaffold could be potentially used to simulate ECM in tissue engineering.

1. Introduction

Aligned structure of ECM plays a positive role in the surrounding environment and phenotype, it can provide mechanical support and biochemical signals, and affect cytoskeleton structure, chromatin organization and gene transcription [1]. The dynamic interaction between cells and aligned ECM can control normal tissue development and function, and promote organization forming and wound healing [2]. Aligned scaffolds can simulate aligned structure of tissue and natural environment [3] and control the function of normal tissue [2], which have a wide range of applications in biomedical aspects, i.e., vascular, nerve and bone tissue engineering [4].

Some aligned scaffolds were prepared by electrospun nanofibers. Yang et al. [5] used electrospun device to manufacture nano/micro fibrous aligned and disordered scaffolds. Li et al. [6] applied two pieces of conductive silicon as a receiving device to produce nanofiber aligned and disordered scaffolds. Ospina-Orejarena et al. [7] and Gomez-Pachon et al. [8] prepared PLA electrospun nanofiber aligned scaffold to evaluate macrophage cell adhesion and elastic properties, respectively. Aligned scaffold prepared by electrospun nanofibers has some advantages, i.e., smaller fiber diameter, larger porosities and more convenience, while it has worse mechanical properties and inferior bonding effect among fibers.

PLA had good biodegradability and biocompatibility can be widely used in tissue engineering, i.e., tendons, ligaments, cardiovascular, blood vessels, skin, nerves, drug delivery and medical equipment, etc. [9,10]. Most PLA fibers used in tissue engineering are electrospun nanofibers [11] rather than melt spun fibers. PU can be made for functional biomaterials [12], i.e., implantable medical devices [13] and bone formation [14], etc. Here, for the first time, PLA melt spun fiber aligned and disordered scaffolds were prepared to compare surface and cross-sectional morphology, physical and mechanical properties.

2. Materials and methods

PLA melt spun fibers (filaments) with 54.77 °C glass transition temperature and 173.89 °C melt temperature were manufactured by Donghua University (Shanghai, China). The fineness of PLA multifilament is 9.18 tex/72 fiber and diameter of every PLA fiber in multifilament is 12.41 ± 0.89 μm.

PU adhesive, purchased from Hefei Huayue new materials technology Co., Ltd. (Hefei, China) with 40% original content, was used to prepare 5% PU contents.

Steel plates bought from Hangzhou Great Wall Mechanical and Electrical market was used for hot pressing. Size of every steel plate is 15.6 × 4.6 × 0.7 cm (length × width × thickness), weight is 0.41 kg and pressure is 559.9 Pa.

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PLA melt spun fibers with constant 1000 numbers were parallel winded by YG086 electronic yarn measuring instrument under the condition of 100 r/min rotating speed and 100 cN tension. The brush was fully immersed in 5% PU about 2 s firstly and taken out for brushing lightly on the surface of parallel PLA fibers (Fig. 1(a)), and this process was repeated for one time to achieve better bonding effect. Wet aligned scaffold was cured under 1119.8 Pa at 60 °C for 1 h in DHG-9240A Electro-thermostatic blast oven.

Parallel PLA melt spun fibers with constant 1000 numbers were cut into staple fibers with 2 cm length and arranged in a homodisperse and disordered state by hand (Fig. 1(b)). The brush was fully immersed in 5% PU about 2 s firstly and taken out for brushing lightly on the surface of PLA staple fibers, and this process was repeated for one time to achieve better bonding effect. PLA disordered staple fibers bonded by 5% PU adhesive were cured under 1119.8 Pa at 60 °C for 1 h in DHG-9240A Electro-thermostatic blast oven.

ETD-2000 sputtering apparatus was used to gold plating small samples 50 s for two times. Then S-4800 scanning electron microscope (SEM, Hitachi) was used to observe surface morphology. In order to observe cross-sectional morphology, samples were frozen in liquid nitrogen about 3 min, then were cut by a blade along longitudinal direction. A small piece of samples was used to observe cross-sectional morphology by SEM.

Image J software was applied to measure distance between two adjacent fibers, which could be considered as surface pore diameter from surface SEM and internal pore diameter from cross-sectional SEM. The angle of alignment degree could be measured by Image J software from SEM images between horizontal direction and fiber direction.

Liquid displacement method mentioned in Nazarov et al. [15] was applied to measure and calculate porosity of scaffolds.

The thickness was measured by a Vernier caliper at five different positions.

BS 224S electronic balance manufactured by Dolly scientific instrument Co., Ltd. (Beijing, China) was employed to measure weight.

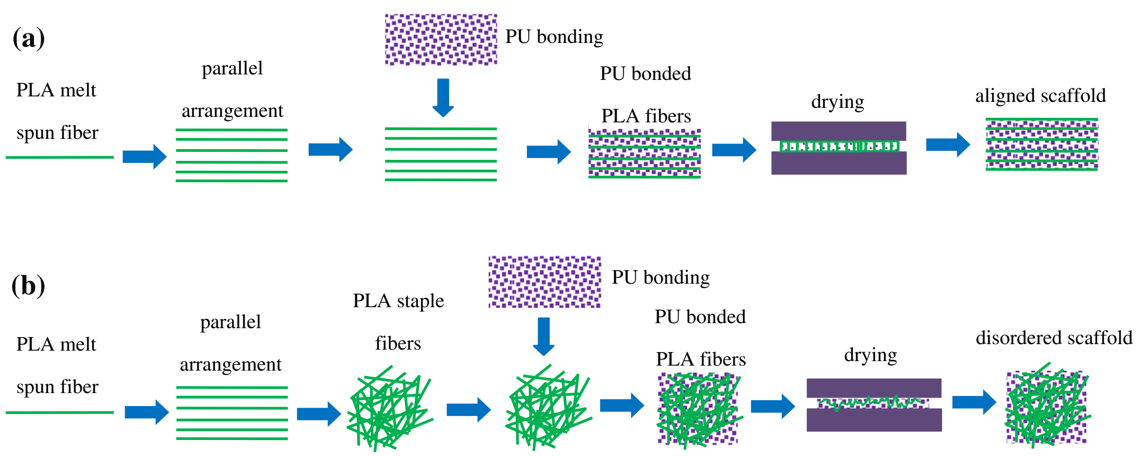

Fig. 1. Schematic of processes used to prepare PU bonded PLA melt spun fiber aligned scaffold (a) and disordered scaffold (b).

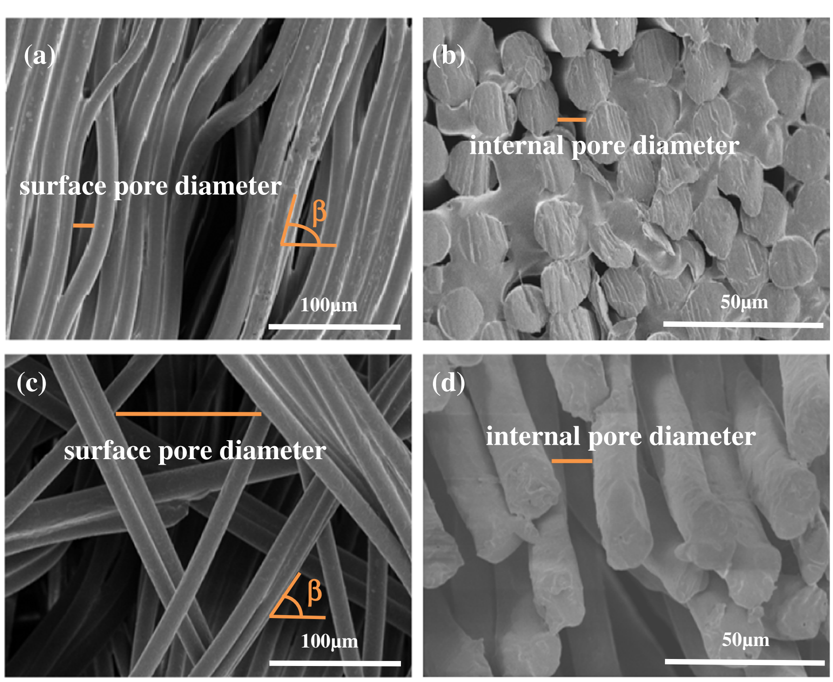

Fig. 2. Surface and cross-sectional morphology of aligned scaffolds (a) and (b), disordered scaffold (c) and (d) β is angle of alignment degree.

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