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In vitro degradation behaviour of non-porous ultra-fine poly(glycolic acid)/poly(L-lactic acid) fibres and porous ultra-fine poly(glycolic acid) fibres

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Abstract

The in vitro degradation behaviour of non-porous ultra-fine poly(glycolic acid)/poly(L-lactic acid) (PGA/PLA) fibres and porous ultra-fine PGA fibres was investigated. The non-porous ultra-fine PGA/PLA fibres were prepared by electrospinning of a PGA/PLA solution in 1,1,1,3,3,3-hexafluoro-2-propanol and the porous ultra-fine PGA fibres were obtained from them via selective removal of PLA with chloroform. Since PLA has a lower degradation rate than PGA, the degradation rates of the ultra-fine PGA/PLA fibres decreased with increasing content of PLA. The porous ultra-fine PGA fibres were degraded in vitro in the order of non-porous PGA > P-PGA/PLA(90/10) > P-PGA/PLA(70/30) > P-PGA/PLA(50/50) > P-PGA/PLA(30/70) due to autocatalytic hydrolysis.

Keywords: Poly(glycolic acid); Poly(L-lactic acid); Electrospinning; Porous ultra-fine fibre; Biodegradability

1. Introduction

Electrospinning is a unique technique for preparation of non-woven mats of ultra-fine fibres, exhibiting high specific surface area and high porosity [1]. Interestingly, it is possible to electrospin porous ultra-fine fibres by using highly volatile solvents [2]. A porous structure can be generated by phase separation resulting from the evaporation of solvents during the electrospinning process. The polymer-rich phase forms the fibre matrix and the solvent-rich phase the pores. However, the rapid evaporation of solvents induces the blockage of a spinning tip and prevents continuous electrospinning. Porous ultra-fine fibres can also be prepared via the electrospinning of immiscible polymer pairs, followed by removal of one component from the phase-separated composite fibres via selective dissolution, thermal degradation or photo degradation [3–7]. It was suggested that these porous ultra-fine fibres have potential applications in nanofiltration and functional nanotubes [8–10].

Poly(glycolic acid) (PGA), poly(L-lactic acid) (PLA), and poly(lactic-*co*-glycolic acid) (PLGA) have been widely used in biomedical fields because they have good biodegradability, biocompatibility, and mechanical properties [11–13]. Recently, the electrospinning of these polymers has attracted a great deal of attention

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due to their potential applications in drug delivery, surgical implantation, enzyme immobilization, tissue regeneration, prevention of post-operative induced adhesion, etc. [14–21]. In our previous study [7], porous ultra-fine PGA fibres were prepared via a selective dissolution technique. Ultra-fine PGA/PLA fibres were first prepared by electrospinning a PGA/PLA solution in 1,1,1,3,3,3-hexafluoro-2-propanol (HFIP) and then most of PLA was removed with chloroform. PGA and PLA were immiscible and that a co-continuous phase morphology was developed during the electrospinning process.

In this study, in vitro degradation behaviour of the non-porous ultra-fine PGA/PLA fibres and the resulting porous ultra-fine PGA fibres were investigated. It was reported that ultra-fine PGA, PLA, and PLGA fibres were degraded in the order of PGA > PLGA ≫ PLA [22]. The average diameters of the ultra-fine PGA, PLA, and PLGA fibres were 310, 290, and 760 nm, respectively. For biomedical applications, a suitable degradation rate is one of the most important requirements for matrix materials. It is expected that porous ultra-fine PGA fibres will show different biodegradability according to their porosity.

2. Experimental

2.1. Materials

PGA (M_w = 14,000–20,000) and PLA (M_w = 450,000) were purchased from Purac Co. and Boehringer Ingelheim, respectively. HFIP and chloroform were purchased from Aldrich Co. and used as received.

2.2. Electrospinning of PGA/PLA blend solutions

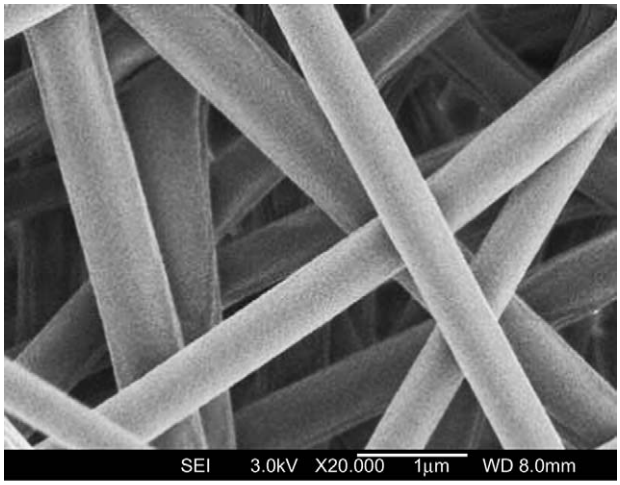
In order to prepare PGA/PLA blend solutions, 8 wt% of PGA and 5 wt% of PLA solutions in HFIP were prepared and mixed at predetermined ratios (PGA/PLA = 90/10, 70/30, 50/50, 30/70 w/w). The electrospinning setup used in this study consisted of a syringe and needle (ID = 0.495 mm), an aluminium collecting plate, and a high voltage supply (Chungpa EMT). All the PGA/PLA solutions were electrospun at a positive voltage of 17 kV and a working distance of 7 cm (the distance between the needle tip and the collecting plate). The mass flow rate of the PGA/PLA solutions was 4 mL/h.

2.3. Preparation of porous ultra-fine PGA fibres

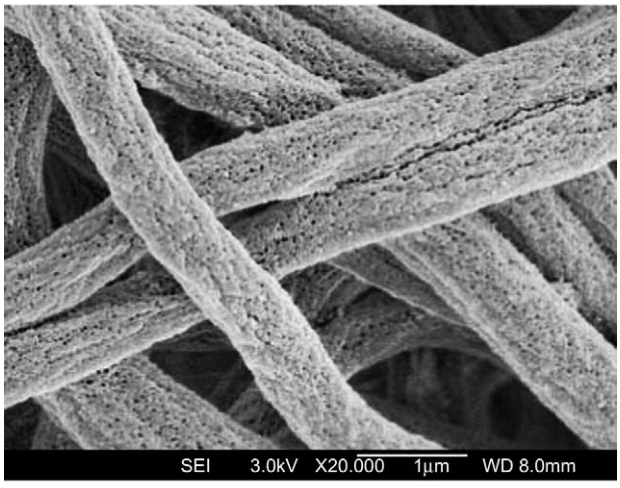
Porous ultra-fine PGA fibres were prepared from non-porous ultra-fine PGA/PLA fibres via selective dissolution of PLA with chloroform. The porous ultra-fine PGA fibres obtained from the non-porous ultra-fine PGA/PLA fibres are referred to as P-PGA/PLA fibres. For example, porous ultra-fine PGA fibres obtained from ultra-fine PGA/PLA(90/10) fibres are referred to as P-PGA/PLA(90/10) fibres.

2.4. In vitro degradation

Ultra-fine fibre mats were cut into a rectangular shape with dimensions of 40 × 40 × 0.1 mm, placed in closed bottles containing 50 mL of phosphate buffer solution (PBS, pH 7.3), and then incubated in vitro at 37 °C for different periods of time. After each degradation period, the samples were washed, dried in a vacuum oven at 25 °C for 24 h, and then weighed. The weight-loss percentages of the samples were calculated from the dried weights obtained before and after degradation.



(a)



(b)

Fig. 1. SEM images of (a) ultra-fine PGA/PLA(50/50) fibres and (b) P-PGA/PLA(50/50) fibres.