Surface modification of poly(l-lactide) electrospun fibers with nanocrystal hydroxyapatite for engineered scaffold applications

Nguyen Dang Luong a, b, Doo Sung Lee a, Young-Kwan Lee c, Jae-Do Nam a, b

a Department of Polymer Science and Engineering, Sungkyunkwan University, Suwon, South Korea
b Department of Periodontology, Yongdong Severance Hospital, College of Dentistry, Yonsei University
c Department of Chemical Engineering, Sungkyunkwan University, Suwon, South Korea

Received 29 June 2006; accepted 14 November 2007
Available online 22 November 2007

Abstract

The hydrophobicity of the poly(l-lactide) (PLLA) surface was modified by incorporating hydroxyapatite (HAp) nanocrystalline particles during the electrospinning process for the engineered scaffold applications. The HAp nanocrystals were synthesized with 30 nm in diameter and 100–120 nm in length, which subsequently formed micrometer-sized agglomerates in the range of 2.5 µm. The synthesized HAp agglomerates were electrospun in the PLLA solution, and the HAp nanocrystals were desirably exposed on the surface of the electrospun PLLA fibers to give higher surface energy and lower contact angles with water. The surface-exposed hydrophilic HAp nanocrystals substantially increased the precipitation of various salts on the HAp/PLLA fiber surfaces in a buffer solution due to the hydrophilic nature and ionic affinity of HAp. Finally, the developed HAp/PLLA fibers desirably sustained the fibrous structural integrity during the accelerated-aging test in water, which was not the case with the pristine PLLA fibers.

Keywords: Electrospinning; Hydroxyapatite; Nanocomposite; PLLA; Surface modification

1. Introduction

Biodegradability and ability to induce and promote the new bone formation by osteogenic cells at grafted sites are the prerequisites of graft materials in the field of the bone regeneration like implant dentistry and periodontology [1]. The critical properties of bone-graft materials to be used in the load-bearing sites are the degree of strength retention over time, and the structural and mechanical equivalence to the bone with the proper biodegradation rates [2]. Engineered scaffold structures usually in the form of porous structures need to provide a mechanical modulus ranging from 10 to 1,500 MPa for hard tissue and 0.4 to 350 MPa for soft tissue applications [3], which correspond to the mechanical properties of human tissues [4]. Polymeric porous scaffold structures have been fabricated using traditional polymer-processing techniques such as porogen leaching or gas forming [5]. However, the maximum compressive moduli of those processes and material systems are in the range of ca. 0.4 MPa, which is well below the requirements for hard tissue or most soft tissue applications [6]. Recently, a nanocomposite technology has been adopted to reinforce the polymer scaffold structure, for example, by using nano-sized reinforcing entities like montmorillonite (MMT) [7]. When a small amount of MMT platelets (5.79 vol.%) is added to PLLA polymers, the tensile modulus of the MMT/PLLA composite system was reported to increase up to 170.1 MPa [7a].

HAp represents a family of bone grafting materials which have been focused on in the last decades because it contains biocompatibility with little inflammatory response when implanted within connective and bone tissues [8]. In addition, as with the MMT/PLLA scaffold systems [7], the HAp particles can act as reinforcing entities when incorporated in biodegradable polymers, which can ultimately give a mechanically-robust engineered scaffolds. Excellent biocompatibility and promising bioactivity of HAp stem from the similar compositions to the bone and tooth minerals [9]. A polymer-based HAp implant system prepared by an image-based design with orthogonal channels (40% porosity) was reported to provide a compressive modulus and strength of 1400±400 MPa and 30±8 MPa, respectively.