Materials Letters 168 (2016) 56–61

Contents lists available at ScienceDirect

Materials Letters

journal homepage: www.elsevier.com/locate/matlet

Highly dispersed nanoscale hydroxyapatite on cellulose nanofibers for bone regeneration

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ARTICLE INFO

Article history:
Received 23 October 2015
Received in revised form
3 December 2015
Accepted 3 January 2016
Available online 4 January 2016

Keywords:
Electrospinning
Cellulose nanofibers
Hydroxyapatite
Bone regeneration
Nanocomposites

ABSTRACT

A successful method for fabrication of electrospun hydroxyapatite (HAp) coated cellulose nanofiber scaffold (HAp/CMC) for tissue engineering is reported. The cellulose acetate nanofibers (CANFs) were deacetylated to produce cellulose nanofibers (CNFs) which were subsequently converted to sodium carboxy methyl cellulose (Na-CMC). The Na-CMC nanofibers mat was then coated with HAp for bone regeneration applications. The FTIR results confirmed conversion of CANFs to CNFs and CNFs to Na-CMC. HAp nanocrystal growth was observed in SEM images, with crystal becoming minute and numerous upon increasing HCO_3^- in the simulated body fluid (SBF) solution. The proliferation of osteoblastic MC3T3-E1cells on HAp-coated CMC nanofiber mat was observed to increase with seeding time. The results confirm suitability of the HAp/CMC nanofiber mat for bone regeneration.

1. Introduction

Bone defects from diseases, tumor and trauma [1] require orthopedic treatments/surgeries, which do not always heal the problem. In many cases defects from bone tumor removal and hereditary syndromes need allogeneic/autogenic implants [2]. Tremendous work has been done to produce bone substitutes from natural/synthetic polymers [3]. The primary requirements for substitutes are biocompatibility, nontoxicity, bio-activity, should be osteogenetic and possess bone-resemblance [1]. Biodegradable polymers, for this purpose, possess higher suitability owing to their natural biodegradation which does not require another surgical treatment for their removal after bone tissues are regenerated. For this purpose carboxymethyl cellulose due to its natural biodegradability and biocompatibility is a promising contestant [4,5]. HAp is also highly biocompatible with human-body-cells and possesses bone formation and growth characteristics. It is capable of forming chemical bonds directly with human-living-cells [6,7] which endows its application as a synthetic allograft [8]. Particularly in osteogenesis and osteoconduction, HAp has chemical similarity with the nonorganic constituents of bone matrix [$CA_{10}(OH)_2(PO_4)_6$] [9], thus has been investigated and used as bone substitute [10–12]. Its potential applications include drug delivery [13] and anti-cancer growth [14], macromolecular-filtration [15], heavy-metal removal [16], catalyst in VOCs [17] and bone regeneration [18]. Osteo-conductivity, osteo-inductivity, slower biodegradability and biocompatibility are the key advantages of synthesized HAp [9,19]. For to investigate CMC/HAp behavior as bone regenerative scaffold, CMC nanofibers prepared from electrospun cellulose acetate by deacetylation [20–23] followed by carboxymethylation, were coated with HAp. The CA was electrospun and then deacetylated to produce cellulose, which was further treated with NaOH and then Na_2CO_3/$ClCH_2CO_2H$ mixture to produce CMC.

2. Materials and methods

2.1. Materials

Cellulose acetate (CA, M_n: 30,000) was purchased from Sigma-Aldrich, Japan and acetone, *N*,*N*-dimethylformamide (DMF), NaOH, Na_2CO_3, $ClCH_2CO_2H$, NaCl, $CaCl_2$, Na_2HPO_4, and $NaHCO_3$ from Wako Pure Chemicals, Japan. All chemicals were used without further purification. The 23 wt% CA solution was prepared by dissolving in acetone: DMF solvents (4:6, w:w) at room temperature, afterwards electrospun to prepare its non-woven mat

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http://dx.doi.org/10.1016/j.matlet.2016.01.010

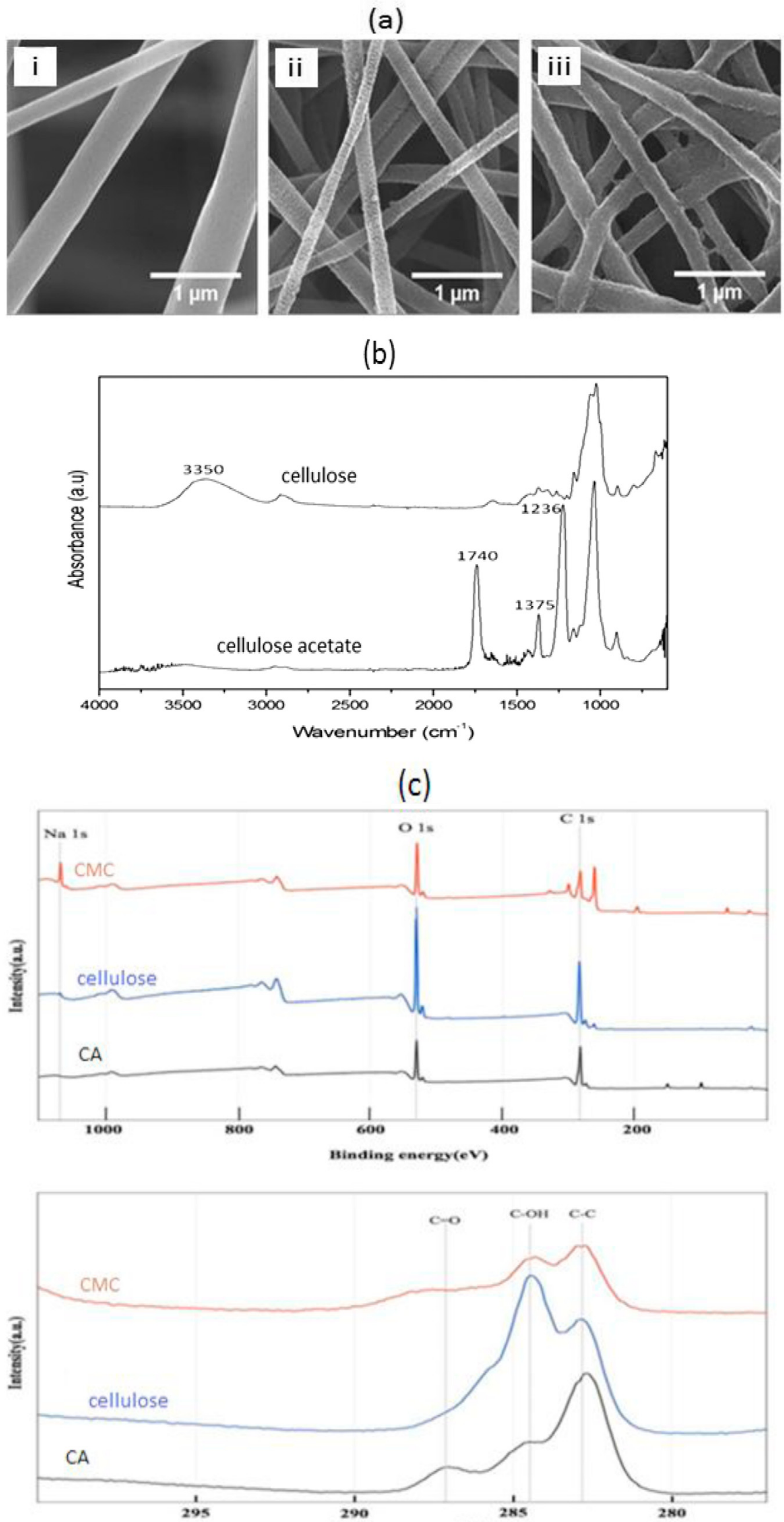

Fig. 1. (a) FE-SEM images of (i) CA (ii) cellulose (iii) CMC nanofibers, (b) FTIR spectra of CA and cellulose nanofibers, and (c) XPS spectra of CA, cellulose and CMC nanofibers.