Materials and Design 32 (2011) 4882–4889

Contents lists available at ScienceDirect

Materials and Design

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

Nanostructured titanium-45S5 Bioglass scaffold composites for medical applications

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ARTICLE INFO

Article history:
Received 27 April 2011
Accepted 2 June 2011
Available online 12 June 2011

Keywords:
A. Nano-materials
C. Mechanical alloying
F. Microstructure
G. X-ray analysis

ABSTRACT

Titanium–10 wt.% 45S5 Bioglass scaffold nanocomposites were synthesized by the combination of mechanical alloying and by a "space-holder" sintering process. The porous structure and corrosion properties were investigated. *In vitro* biocompatibility of these materials was evaluated and compared with a conventional microcrystalline titanium, where normal human osteoblast (NHOst) cells from Cambrex (CC-2538) were cultured on the disks of the materials and cell growth was examined. The morphology of the cell cultures obtained on Ti–10 wt.% 45S5 Bioglass nanocomposite was similar to those obtained on the microcrystalline titanium. On the other hand, on porous scaffold, the cells adhered with their whole surface to the insert penetrating the porous structure, while on the polished surface, more spherical cells were observed with a smaller surface of adhesion. The present study has demonstrated that titanium–10 wt.% 45S5 Bioglass scaffold nanocomposite is a promising biomaterial for bone tissue engineering.

1. Introduction

Titanium (Ti) and its alloys possess favorable properties, such as relatively low modulus, low density and high strength [1]. Apart from that, these alloys are generally regarded to have good biocompatibility and high corrosion resistance, but cannot directly bond to the bone. In addition, metal implants may loose and even separate from surrounding tissues after implantation. Additionally, these alloys have relatively poor tribological properties because of their low hardness [2].

Over the past years, nanoscale metallic and ceramic materials, also called nanomaterials have attracted enormous amounts of interest from researchers [3–5]. Nanomaterials demonstrate novel properties compared to conventional (microcrystalline) materials due to their nanoscale features.

One of the methods that allow the change of biological properties of Ti alloys is to produce a nanocomposite, which will exhibit the favorable mechanical properties of titanium and excellent biocompatibility and bioactivity of ceramic [6–9]. The most common ceramics, used in medicine are hydroxyapatite (HA), 45S5 Bioglass or Al_2O_3 [10]. Till now, it has been show, that implants made from Ti-based bionanomaterials improved considerably the prosthesis ultimate strength and their biocompatibility [11]. The process permits the control of microstructural properties such as the size of pore openings, surfaces properties, and the nature of the base metal/alloy. Pore sizes larger than 150 μm are generally preferred because they provide a suitable environment for bone reorganisation and vascularisation. For example, Ti-based nanocomposites reinforced with 10–20 wt.% HA or 45S5 Bioglass particles were fabricated by the optimal technical condition of hot pressing technique [7,8]. Our results of *in vitro* studies show that these bionanocomposites have excellent biocompatibility and could integrate with bone.

Various methodologies are being used in an effort to improve the interfacial properties between the biological tissues and the existing implants, e.g., Ti and Ti-based alloy [12]. The electrochemical technique, a more simple and fast method, can be used as a potential alternative for producing porous Ti-based metals for medical implants [13,14]. Good corrosion resistance of the titanium is provided by the passive titanium oxide film on the surface. This layer is important for the good biocompatibility. The native oxide has thickness of few nanometers. In the case of anodic oxidation the oxide thickness can be multiplied up to micrometer range. The structure and thickness of the grown oxide depends on the electrochemical etching conditions, for example: current density, voltage, electrolyte composition.

There are a large variety of fabrication techniques for metal foams or similar porous metal structures [15]. Usually liquid phase and powder metallurgical processes are used for producing metal foams. Wen et al. have successfully fabricated Ti foams with a porosity of 78% [16]. These foams have unique open-cellular structure and achieve low Young's modulus (5.3 GPa), but the compressive strength is not sufficient for the human cortical bone.

Sintering a mixture of Ti powder and space-holder particles (e.g. ammonium hydrogen carbonate – CH_4HCO_3) produced porous Ti with a porosity of 70% which exhibited a plateau stress of 53 MPa

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doi:10.1016/j.matdes.2011.06.005