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Synthesis and characterization of titanium-45S5 Bioglass nanocomposites

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ABSTRACT

Titanium-45S5 Bioglass nanocomposites were synthesized by the combination of mechanical alloying and powder metallurgy process. The structure, mechanical and corrosion properties of these materials were investigated. Microhardness test showed that the obtained material exhibits Vicker's microhardness as high as 770 $HV_{0.2}$ for Ti-20 wt.% 45S5 Bioglass, which is more than three times higher than that of a conventional microcrystalline titanium (225 $HV_{0.2}$). Additionally, titanium-10 wt.% of 45S5 Bioglass nanocomposites ($i_c = 1.20 \times 10^{-7}$ A/cm^2, $E_c = -0.42$ V vs. SCE) were more corrosion resistant than microcrystalline titanium ($i_c = 2.27 \times 10^{-6}$ A/cm^2, $E_c = -0.36$ V vs. SCE). *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. Mechanical alloying and powder metallurgy process for the fabrication of titanium-45S5 Bioglass nanocomposites with a unique microstructure, higher hardness, lower Young's modulus and better corrosion resistance, in comparison to microcrystalline titanium, were developed. On the other hand, Ti-10 wt.% 45S5 Bioglass composites posses higher fracture toughness compared to 45S5 Bioglass. The proper modification of chemical composition and microstructure of Ti-bioceramic nanocomposites can expand the use of titanium in the biomedical fields.

1. Introduction

Titanium and titanium alloys are common in dental implant applications because of their desirable properties, such as relatively low Young's modulus, good fatigue strength, corrosion resistance, biocompatibility as well as formability and machinability. However, titanium and its alloys cannot meet all of the clinical requirements. Current research focuses on improving the mechanical performance and biocompatibility of Ti-based systems through variations in alloy composition, surface treatment and microstructure [1–7].

One of the methods that allows the change of biological properties of Ti alloys is the modification of its chemical composition [2]. Current goals in the development of new Ti-based biomaterials are: (i) to avoid potentially toxic elements, such as vanadium, to further improve biocompatibility; (ii) to produce titanium alloys with a high fatigue strength but a low Young's modulus compared to cortical bone (E = 10–25 GPa), (iii) to minimize stress shielding and improve fracture healing. Ti–6Al–7Nb, which has been developed for surgical implants, is also attractive for dental applications [8].

Surface modification technologies, such as grist blast, chemical etching, and plasma spraying are often utilized to improve the osseointegration ability of titanium dental implants [4–6]. Additionally, to enhance the physicochemical and mechanical performance of implant materials through microstructure control, the top-down approaches known as mechanical alloying (MA) and severe plastic deformation (SPD) techniques were applied [7,9–15]. Recent studies proved clearly that nanostructuring of titanium can considerably improve not only the mechanical properties, but also the biocompatibility [15]. This approach also has the benefit of enhancing the biological response of the CP titanium surface [16].

Till now, a number of SPD methods for producing bulk ultra fine grain metals/alloys have been developed [13–15]. Valiev and coworkers apply a process known as equal channel angular pressing (ECAP), which is a viable processing route to grain refinement and property improvement [13]. Their study reports of nanostructured titanium, produced as long-sized rods with superior mechanical and biomedical properties and which demonstrates its applicability for dental implants. It turns out that the extreme grain refinement of the bulk of the metal down to nanoscale transpires to

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