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Osteoconductive Nanocomposite Coating of Apatite-Wollastonite and Chitosan

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ABSTRACT

Here, we show the importance of the marine biomaterial chitin and its derivative, chitosan, in bioimplant applications. Titanium and titanium alloys have shown high potential for load bearing in bioimplant applications. However, after their application, a bond with living bone often does not develop or the integration of the implants with bone tissue takes several months. Moreover, the surface of any material implanted in living body changes over time. Titanium ions may be released from the implant surface, following corrosion and wear. Therefore, the metallic implants coated with bioactive materials are able to induce a biological bonding with both soft and hard tissues. Chitin, an important marine biomaterial, and its derivative, chitosan, is an excellent bioactive material compatible with human biological environment and has good flexural strength and osteoconductive properties. Apatite-wollastonite (AW) has been regarded as a promising biomaterial due to its high biocompatibility, good bioaffinity and osteoconductivity and its crystallographic and chemical similarity with human bone and teeth. However, coating them at ambient temperatures onto titanium implants have proven difficult. We will discuss a new technique that we have developed using electrophoresis to coat a chitosan-AW composite onto a titanium substrate and demonstrated its useful mechanical and biochemical properties and its bioactivity.

Keywords: Electrophoretic deposition, chitosan, apatite-wollastonite, titanium implants

INTRODUCTION

Titanium and titanium alloys are proven to be potentially very suitable materials for load bearing in bioimplant applications due to their biocompatibility, high corrosion resistance and reliable mechanical properties. Nevertheless, from the biochemical point of view, they are considered nearly inert materials (Hench, 1991; Stoch *et al.*, 1994; Flavio *et al.*, 1999) because they do not bond with the bone through chemical or biological interaction, but simply by a morphological connection to the bone. This insufficient adhesion to the bone, due to the lack of a specific biological response from the living tissues, can progressively form a non-adherent fibrous capsule around the implant and this can lead to clinical failure. However, metallic implants, coated with bioactive materials, are able to induce a biological bonding with both soft and hard tissues.

Glass-ceramics containing apatite and wollastonite crystals (AW) have been found to have the highest mechanical strength among bioceramics and they have also been shown to display the ability to directly bond to living bone by forming an apatite layer on their surface in the body environment (Osborn and Newesely, 1980). Although ceramic coatings have been shown to improve bone attachment and integration of implants, long-term stability of coating is still a challenging issue. Thus, attention has been directed towards the potential use of ceramic-

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polymer composites in the recent years so as to improve the biocompatibility and mechanical strength of implant materials.

Chitin, an important marine biomaterial and its derivative, chitosan are excellent bioactive materials found to be compatible with human biological environment. Chitosan is a principal constituent in the shells of crabs, lobsters and other crustacean species. It has been used in a number of biomedical applications such as drug encapsulation, fat absorbers, and wound dressing materials. Chitosan/Wollastonite composite scaffolds have earlier been used for tissue engineering (Zhao *et al.*, 2004).

Different coating techniques have been used to produce coating on metallic substrates including plasma spray, sol-gel, enamelling, slurry dipping, electrophoretic deposition and sputter coating. In particular, the sputtering and plasma spray techniques could present some problems related to difficulty in coating complex shapes and the eventual compositional modifications due to the high temperature (Liu and Ding, 2002). Electrophoretic deposition has been known as an efficient technique used in assembling fine particles because of its simplicity, low equipment cost, the possibility of deposition on substrates of complex shape, high purity and micro-structural homogeneity of deposits.

In this work, the researchers developed nano-composite coatings which could help in surface modification of titanium implants, thereby improving its performance. The approach used in achieving the optimal nano-composite coating makes use of a simple, cost-effective electrophoretic deposition technique. The various parameters of operation were optimized and these included pH, surface of titanium and approach of coating. The coated titanium implants, using electrophoretic deposition and characterized by different techniques and its biocompatibility, were also studied.

Electrophoretic Deposition and pH Optimization

The prepared coating had lamellar structure with alternating layers of ceramic and polymer. The advantage of using polymer, as the innermost layer, is to achieve stronger interaction of the coat with the metal substrate.

pH optimization was performed over a range of 1-6.5 pH value, using a fixed current density and the final pH was set as 1.6.pH. At this pH, a uniform, crack free coat was obtained.

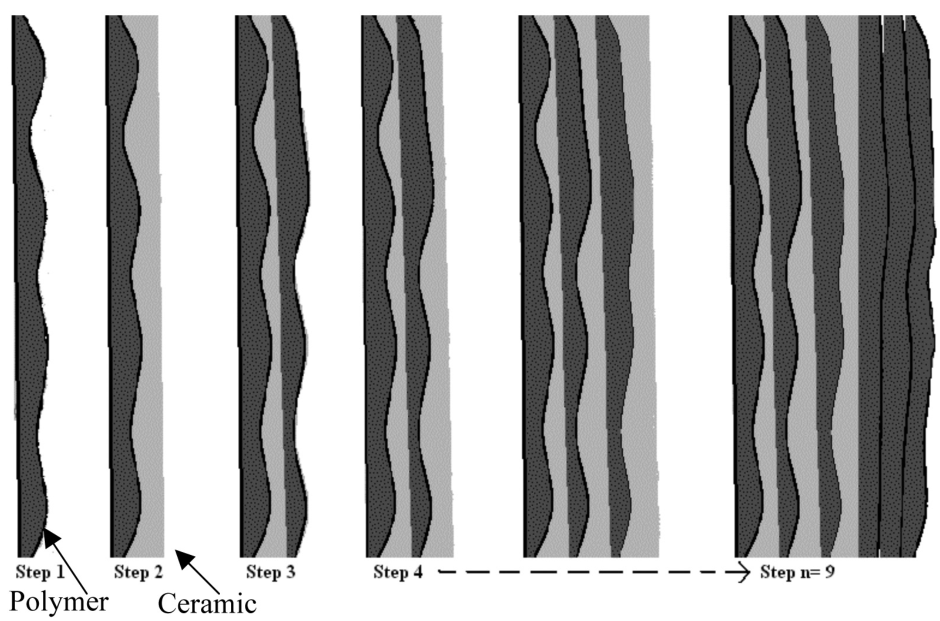


Fig. 1: Coating pattern used to coat titanium substrate

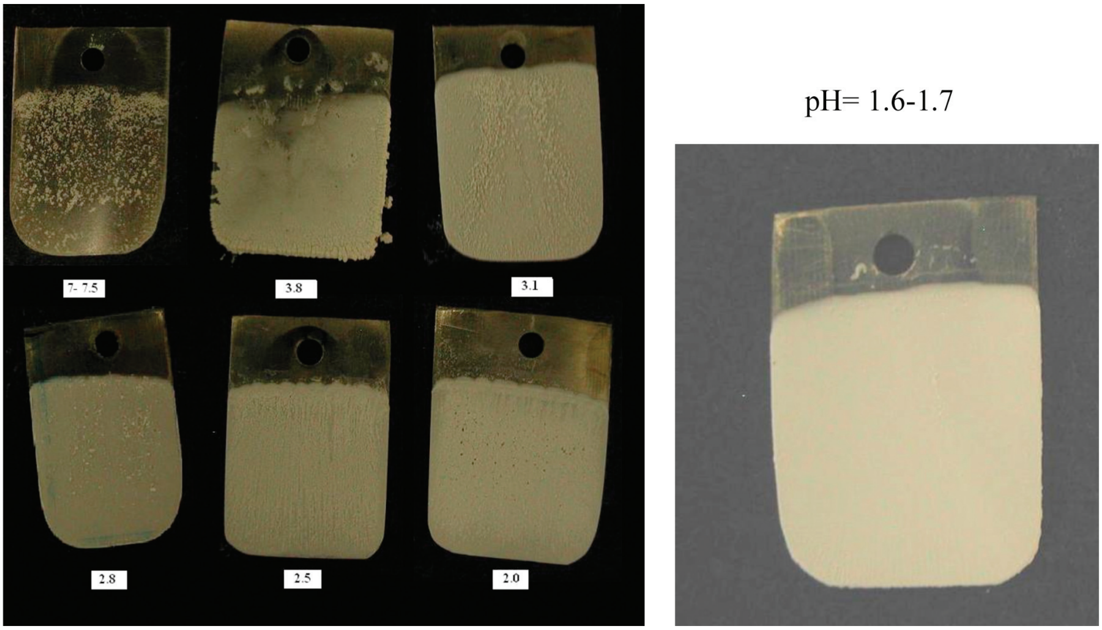


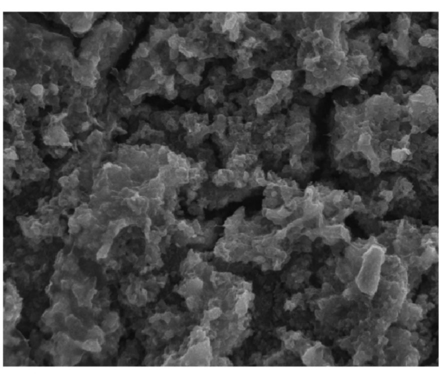
Fig. 2: Coats shown at various pH levels

Particles do not have a definite morphology and are irregularly shaped. The coat contains interstices and pores; the thickness of the coat is found to be approximately 40 µm. The XRD pattern indicates the presence of Wollastonite phase with retention of substantial crystallinity of 65%.

The samples show significantly increased apatite gwowth on their surface till the 21st day.

Cell culturing experiments were carried out and the result showed that the coating has osteoconductive potential and promises to improve the performance of metal implants, apart from its good bioactivity.

Characterization Studies



Bar= 20 microns

Fig. 3: ESEM micrograph showing particle morphology

Bar= 100 microns

Fig. 4: ESEM micrograph showing the thickness of coating

Bioactivity Studies

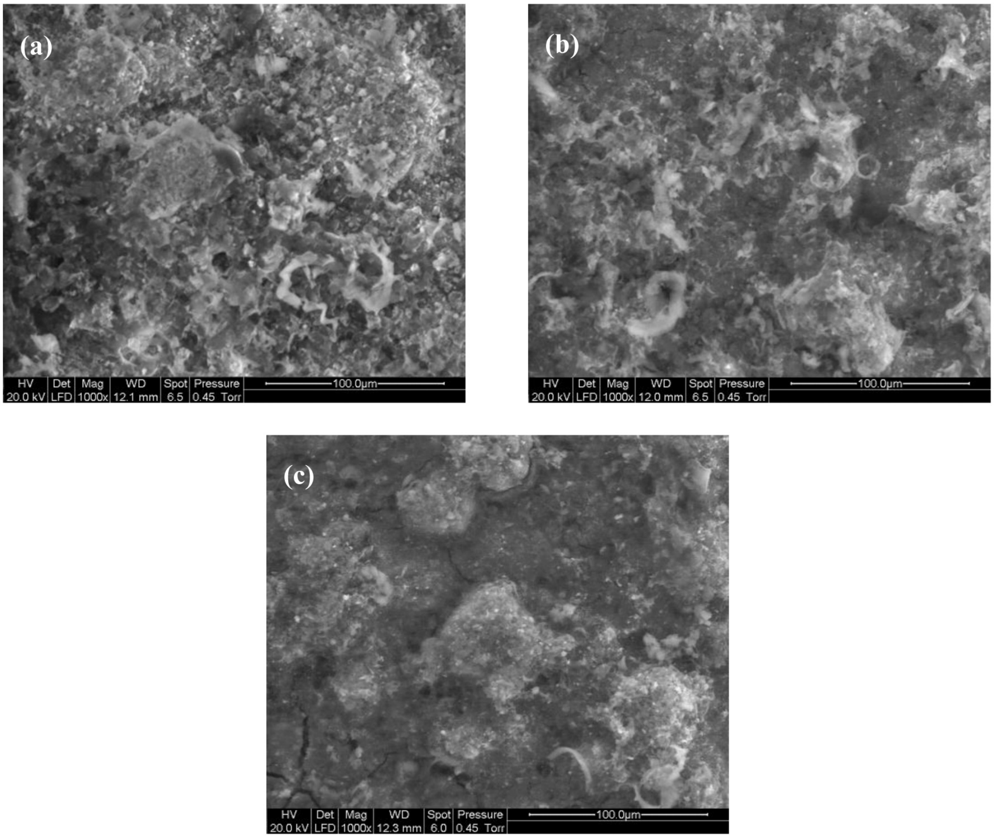


Fig. 5: The ESEM images of the coated samples immersed in SBF at 1000 X (a) 7 days, (b) 14 days and (c) 21 days

Fig. 6(a): Coated implant using EPD

Fig. 6(b): Implant before coating

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