Increasing Adhesion of Hydroxyapatite-Nanoclay Composite Coatings on Titanium Substrates by a Novel Surface Treatment

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Abstract: The recent studies on metal implants showed that modifying the surface topography enables imitation of functional proteins and growth factors from host tissues and accelerates cell adhesion, proliferation, differentiation and, subsequently, successful Osseo integration of the implants .Also Increasing coating adhesion on titanium surface among diverse methods is challenging. In this study, the surface topography and osseocuductivity of titanium were modified by applying a combination of lithography and radio frequency magnetron sputtering (RFMS) techniques .The nano structured hydroxyapatite-laponite composites were prepared in the form of disc shape with spark plasma sintering(SPS) method to form reliable dense sample as a target in RFMS method. The result of nanoscratch test has proved high adhesion rate by applying RFMS method as a consequence of using sputtering force the material in angstrom scale make sediment in Nano scale hole. The microstructure and phase of final coating were characterized by scanning electron microscopy (SEM) and X-ray diffraction (XRD), respectively.

Keywords: Magnetron Sputtering, Laponite,Hydroxyapatite, Spark plasma sintering, Adhesion

Introduction

Hydroxyapatite is a promising bioactive material that has amazing aspects for bone tissue engineering [1]. However, two crucial limitation i.e. the low fracture toughness and the high degradation rate, affect its application in load bearing conditions [2]. In the current study, the nanoclay of laponite was used as a reinforcement to improve the mechanical properties of bioceramic composites. Furthermore, surface topography of titanium was modified with lithography technique. A novel pattern on titanium substrates was treated by means of lithography and finally, the bioceramic composite comprising hydroxylapatite and laponite nanoparticles was coated by customized magnetron sputtering method (CMS). This method makes an amazing opportunity for us to be able to deposit ceramic composite nano-porous structures which are formed in the bottom of manipulated uniform macro-holes.

Materials and method

The Laponite RD nano clay was purchased from BYK Inc. The Hydroxyapatite($HCa_5O_{13}P_3$) powder was purchased from Merck Co. with CAS # 1306-06-5. Titanium plates (Grade 5) were cut into the desired size (10*20*1 mm^3).Bulk sample comprising hydroxyapatite and laponite Rd was prepared by SPS(spark plasma sintering) as a target for magnetron sputtering method (MSM). Table 1 shows the applied parameters in SPS process .The X-ray diffraction (XRD) patterns of the bulk ceramic composite sample which were prepared by SPS method were obtained using an automated X-ray powder diffractometer(XRD, PANalytical's Empyrean) with monochromatedCuKα radiation and operated at 40 kV and 30 mA with a step size of 0.05◦and a scanning rate of 4◦Min range of 10–80◦.

Results and Discussion

Fig. 1 shows the XRD spectra of the products obtained after SPS processing at 1000◦C. It is obvious that the sample exhibits the patterns of hydroxyapatite, diopside, olympite and monetite. Therefore, the high temperature process of SPS does not affect the phase transformation of hydroxyapatite phase.

Table1. Applied parameters of SPS.

Material name : Laponite&Hydroxideappitite
Finish temprature : 1000 C
Initial pressure : 30 Mpa
final pressure : 70Mpa
Temprature rate : 17.5 C
Current Steps in manual mode : 0.15 A
time steps to increase current : 3 Min
Displacement : 80.5-77.7= 2.8 milimeter

Time	Temprature	Current
3	52.5	0.3
6	105	0.43
9	157.5	0.59
12	210	0.74
15	262.5	0.85
18	315	1.06
21	367.5	1.2
24	420	1.36
27	472.5	1.5
32	560	1.6
35	612.5	1.82
38	665	1.93
41	717.5	2.07
44	770	2.22
47	822.5	2.4
50	875	2.55
53	927.5	2.7
54	945	2.72
55	962.5	2.75
56	980	2.75