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Coating of Hydroxyapatite on Ti-6Al-4V alloy prepared by radio frequency plasma sputtering

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Abstract
Titanium alloys have been used in biomedical applications because of their biocompatibility and mechanical properties. However, it has a possible toxic effect resulting from released vanadium and aluminium in the human body. The hydroxyapatite HAP coated Ti-6Al-4V alloy prevented releasing of undesirable ions. The aim of this study is to investigate the structural and mechanical properties of Ti-6Al-4V alloy by coating with (HAp). The coating was prepared by Radio Frequency Plasma Sputtering (RF) method. The layers of HAp were characterized by Field Emission- Scan Electron Microscope (FE-SEM), atomic force microscope (AFM) and Vickers hardness respectively. AFM and the Vickers hardness demonstrated different roughness and hardness of Ti-6Al-4V when uncoating, as-deposited HAp.

Keywords: Radio frequency plasma, HAP

1. Introduction

Titanium alloys are the metallic biomaterials Titanium means the enormously strong giant. It is light and transition metal on the periodic table composed of 60% iron and density of 4.5 g/cm. It is a silver material and the atomic number of it is 22 and the atomic weight of 47.90. It finds as a hexagonal close packed structure (α Ti) up to 82 C° and a body cantered cubic structure (BCC) above the temperature. The alloying elements of titanium enable it to have a wide range of properties. The pure (cpTi) titanium and its alloys as Ti-6Al-4V have been used for load bearing implants in dentistry, osteosynthesis and orthopedics due to their excellent biocompatibility, lightweight, high-strength, corrosion resistance and relatively low density. These properties are not high enough to promote direct growth of the bone tissue or reduced the healing period and also Ti-6Al-4V alloy has a possible toxic effect resulting from released vanadium and aluminium. Changes on metal surfaces have been used to controlling tissue–titanium interactions; reduce the time for bone fixation and to prevent releasing of undesirable ions from the alloy. These issues can be controlled by using coating layers from bio-inert materials as bio ceramic Hap. These materials are major inorganic part of human bone structure and have a crystal structure indistinguishable from human bone and tooth minerals. The bioceramic layers do not release particles into surrounding tissue of the body as do metallic biomaterials so that the coating layers of bioceramic on metallic biomaterials to prevent metallic particle release from orthopedic implants made of Ti6Al4V. Many methods, such as sol gel (Sajjad *et al.* & A. Balakrishnan *et al.* 2007) [18, 2], Plasma electrolytic oxidation (PEO) (Yeung *et al*, 2013) [21], Electrophoretic deposition (EPD) (Corni I *et al.* 2008 & Lovsky Y etal. 2010) [6, 13], dip coating process (Seriven, 1988 & M. Khalid *et al.* 2013) [17, 15], Ion Beam Assisted deposition (IBAD) (Zhi-Ye *et al.* 2014 & Guocheng *et al.* 2014) [23], pulsed laser deposition (PLD) (L. Torrisi *et al.* 1993) [14], plasma spray (E. Mohseni *et al.* 2014 & AGATA, 2009) [8, 3], and RF plasma magnetron sputtering can be utilized to deposit HA coatings (JZSHI *et al.* 2008 & S. Xu *et al.* 2002) [19]. RF sputtering has many useful applications, for example, high RF sputtering rates of metals and insulators at low pressures and provision of a DC bias on the substrate surface; RF could also be utilized to sputter metal, semiconductors, and insulators.

2. Objective

The study of structural and mechanical properties of Ti-6Al-4V alloy by coating with (HAp). This coating was prepared by Radio Frequency Plasma Sputtering (RF) method.

3. Material and Method

Ti-6Al-4V Samples used in this project were acquired from WG (William Gregor Ltd, London, United Kingdom). Circular (Ti-6Al-4V) Samples are cut from rod with dimensions 30mm diameter and 3 mm thickness. The specimen were abraded utilizing SiC grinding paper with grits began from 80 grit, and continued by 120, 230, 400, 600, 800, 1000 and 1200 grit to get flat and scratch free surface and then polishing with diamond suspension start (1, 3, 6, 9, 15 μm) for a smooth and mirror polished surface. A grinding and polishing machine model, metaserv 250, buehler was utilized and afterward cleaned ultrasonically and washed with acetone and deionized water. Radio frequency plasma sputtering was utilized to get HAp layer on Ti6Al4V alloy by utilizing high purity (99.99%) Hap target, a base pressure was evacuated to ($1×10^{-5}$ *mbar)* by a combination of rotary and turbomolecular pump, then argon was passed till the pressure reached, ($1×10^{-3}$ *mbar)* and after that the target was cleaned by pre-sputtering (with 30 W RF power) for 15 min. Argon gas (99.99%) was used as reactive gas at a flow ratio of 10 sccm. The distance between the samples and the target was maintained at 80 mm for all deposition experiments with a RF power 200 W for 1 h duration. During the sputtering process, the Temperature rose to approximately 80° because of self-heating.

There is many techniques for surface analysis, structure examination and properties evaluation are used to investigate modified surface such as FESEM was carried out using a (Leo-Supra 50VP, Carl Zeiss, Germany) equipped with an energy dispersive X-ray (EDX) system. Component distribution in the surface of treated and untreated samples is assessed utilizing EDX mapping. The surface roughness of the film was estimated by utilizing atomic force microscope (AFM) (Dimension Edge, Bruker) in the Tapping operation mode and a Nano Drive dimension edgetapping, image-processing software. Vickers hardness of the coated composites was assessed with AKASHI MVK-E. The estimation was occurred by utilizing a 25-g load with a diamond tip through 15 seconds.

4. Results

Figure1 shows Field Emission Scanning Electron Microscope (FESEM) images and EDX information about HAp thin films formed on the surface of Ti-6Al-4V alloy respectively. In spite of the presence α and β phases of Ti-6Al-4V alloy, The HAp thin films were created on the surface of substrate. The uncoated example, in figure (1a) appears to have numerous scratches and smooth surface because of its grinding and polishing.

Figure (1b) demonstrates surface morphology of Ti-6Al-4V example coated with HAp by utilizing a RF plasma sputtering method. HAp thin film was observed to be a porous surface because of amorphous structure of HAp.

The EDX spectrums are appeared in Figure2 which explain the elemental distribution of the Ti-6Al-4V sample uncoated, as coated with HAp by RF plasma sputtering. The EDX for the uncoated sample shows energy emission (Ti, Al and V) indicated that the substrate is Ti-6Al-4V alloy due to the existence of elements (Ti, Al and V) as indicated in Figure (2a). It can be seen from figures of calcium and phosphorus elements as well as the matrix (Ti-6Al-4V). This implies the layer formed on the surface is HAp layer which is contained of calcium and phosphorus elements and diffusion through the substrate as indicated in Figures (2b). AFM micrographs with a scanning area (5×5 $um^{2)}$ in figure 3 demonstrates the surface topography of the average surface roughness (Ra)of the substrate, as deposited and the uncoated specimen in Figure (3a) has many scratches and smooth surface with roughness (Ra)is 0.00367*um* Figures (3b) demonstrates the AFM images of the HAp coated Ti-6Al-4V alloy with (Ra) 0.104 *um*. The Vickers hardness value of uncoated sample was 348.9 HV and the hardness of coating was 423.3 HV. It was found the hardness of samples were greater after The HAp coating layer.

5. Conclusions

The study concludes that coating of Ti- 6Al-4V alloy with HAp has amorphous structure. The surface topography of uncoated Ti-6Al-4V,as deposited HAp layer is significantly difference in surface roughness and hardness where the coating of Ti-6Al-4V alloy is good methods to form excellent hardness layer and high roughness on the surface alloy.

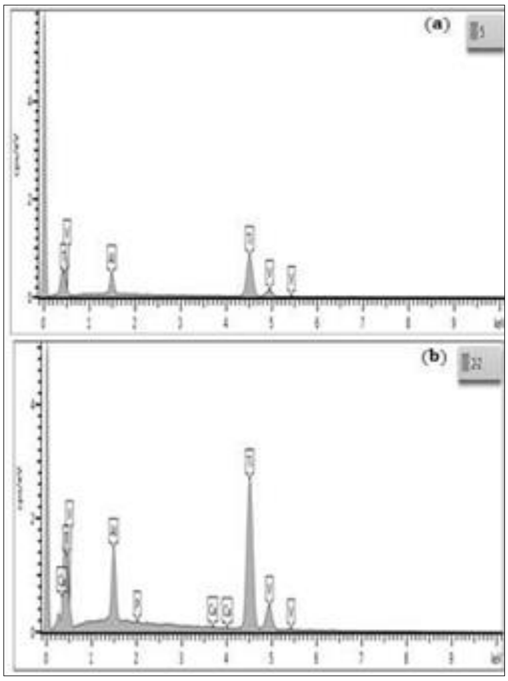

Fig 1: Field emission scanning electron microscope (FESEM) images of Ti6Al4V alloy (a) the as-received substrate (b) HAp coatings deposited on a Ti6Al4V substrate.

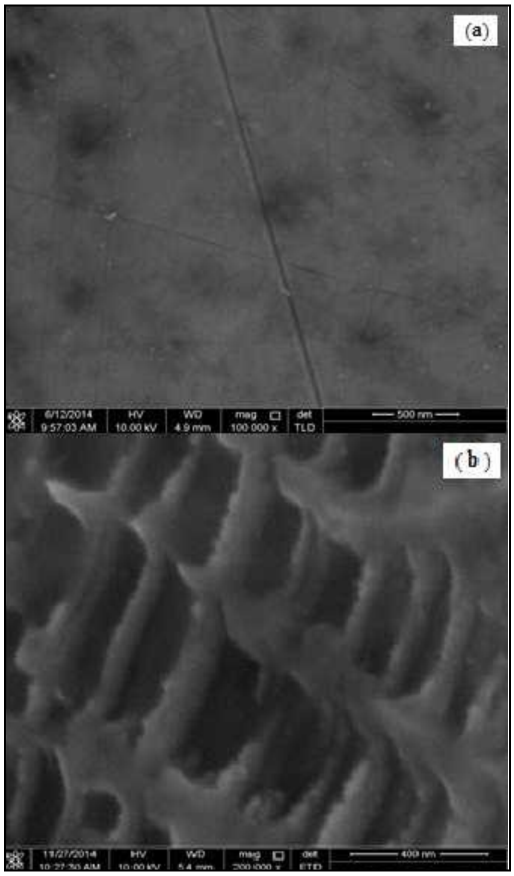

Fig 2: EDX analyses of the samples (a) the as-received substrate (b) HAp coatings deposited on a Ti6Al4Vsubstrate.

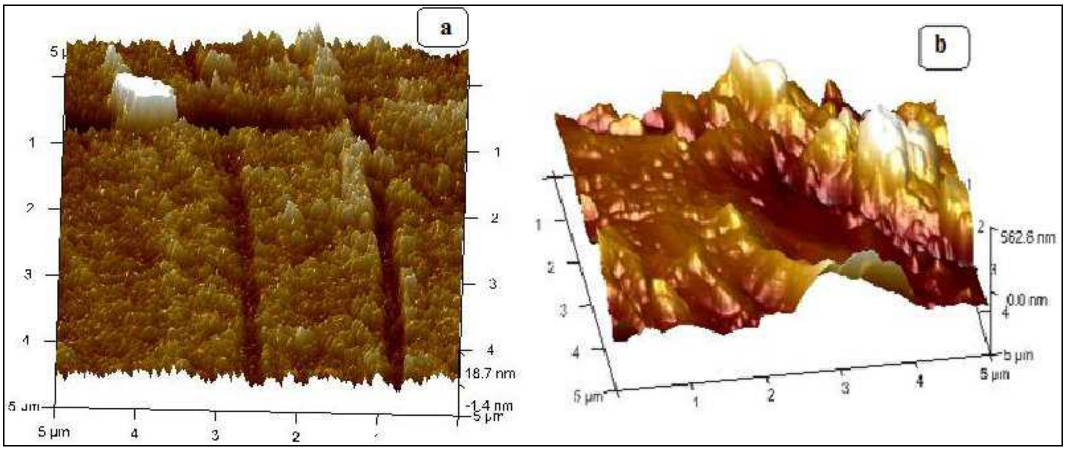

Fig 3: AFM 3D images of Ti-6Al-4V alloy (a) the as-received substrate (b) as-coated.

6. References

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