Mechano-tribological properties and in vitro bioactivity of biphasic calcium phosphate coating on Ti-6Al-4V


Abstract

Biphasic calcium phosphate (BCP) consists of hydroxyapatite (HA) and beta-tricalcium phosphate (β-TCP). BCP is mainly used in artificial tooth and bone implants due to higher protein adsorption and osteoinductivity compared to HA alone. Although, many studies have been investigated on radio frequency (RF) magnetron sputtering of HA on Ti and its alloy, however, limited studies are available on BCP coating by this process and its bioactivity and adhesion behavior. Thus, in order to obtain a better understanding and applications of BCP films, RF magnetron sputtering is used to deposit BCP films on Ti-6Al-4V in the present study. The effect of film thickness on wettability, mechanical properties and in vitro bioactivity at a particular set of sputtering parameters are investigated. BCP film thickness of 400 nm, 700 nm and 1000 nm are obtained when sputtered for 4 h, 6 h and 8 h, respectively. Although the phase compositions are almost same for all films, the surface roughness values varies around 112–153 nm with rise in film thickness. This in turn enhances hydrophilicity in accordance to Wenzel relation as the contact angle decreases from 89.6 ± 2° to 61.2 ± 2°. It is found that the 1000 nm film possess highest micro-hardness and surface scratch resistance. No cracking of film up to scratch load of 2.3 N and no significant delamination up to load of 7.8 N are observed, indicating very good adhesion between BCP films and Ti-6Al-4V substrate. There is a great improvement in wt% apatite layer formation on all films when dipped in simulated body fluid (SBF) for 14 days. Among these, 1000 nm sputtered film results the highest increase in wt % apatite layer from 44.87% to 86.7%. The apatite layer possess small globular as well as elliptical structure are nucleated and grew on all the BCP films. Thus, sputtering of BCP films improves wettability, mechanical properties as well as bioactivity of Ti-6Al-4V, which can be applied for orthopedic implants.

1. Introduction

Increasing demand of artificial implants encourages the researchers to develop and improve the quality of implant in terms of its functionality as well as durability. Because of lightness, inherent toughness, low density, high fatigue, impact strength and good corrosion resistance, pure Ti and its alloys are widely used in biomedical applications (Davim, 2014; Lauro et al., 2016; Veiga et al., 2013). Ti-6Al-4V is a preferred load bearing material for dental and orthopedic applications owing to its magnificent mechanical properties (Meng et al., 2015; Quek et al., 1999; Veiga et al., 2012). However, Hwang and Choe (2017) reported that Ti-6Al-4V is bio-inert, which cannot exhibit any positive influence on tissue and cell behavior. So, both the osteoblasts and new bone tissues cannot grow well. Therefore bonding between host tissues and the implants are not formed easily, which leads to poor osteointegration. As a result, Ti-based implant is detached from the host tissue in long-term implantation. On the other hand, hydroxyapatite (HA, Ca₁₀(PO₄)₆(OH)₂), a calcium phosphate (CaP) based biomaterial is widely used in different implants for repair or replacement of natural tissues due to its excellent osteoconductivity, biocompatibility and osteointegration (Saxena et al., 2018). Singh et al. (2018) revealed that HA has similar mineral constituents found in teeth and bones. Wei et al. (2015) demonstrated that HA has the potential to integrate with the surrounding tissues by forming strong bonds at the interface of tissue and implant. However, HA alone cannot be utilized for load bearing materials because of its higher elastic modulus and lower fatigue strength. Thus, surface modification of Ti-6Al-4V with HA is carried out in order to achieve superior mechanical performance of the metal as well as excellent bioactivity of HA simultaneously. From the findings of Branemark’s work in 1969, Ti implant surface showed excellent