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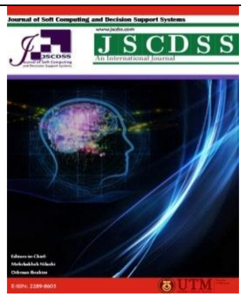

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Predicting Micro-Hardness of Post-Treated Hydroxyapatite Layer Using Surface Response Methodology

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Abstract

Micro-hardness of sol-gel-derived hydroxyapatite (HA) coating layer on Ti-13Nb-13Zr in different sintering conditions was investigated. Sintering post-treatment of coated samples was carried out based on full factorial design followed by surface response methodology. Analysis of variance (ANOVA) indicates that the sintering temperature is a more significant factor rather than sintering time in determining the Micro-hardness of the HA coating layer. Based on experiments results a mathematical model was created in order to be used for prediction of Micro-harness value in different sintering conditions. The validity of the generated model by Response Surface Methodology was confirmed through comparing the predicted values and experimental results and the close agreement was observed.

Keywords: Ti-13Nb-13Zr, Sol-gel, hydroxyapatite, Micro-hardness, Response surface methodology

1. Introduction

Titanium and its alloys are widely used in biomedical applications due to their well-established corrosion resistance, high strength-to-weight ratio, excellent fatigue resistance as well as low elastic modulus (Frank et al., 2008) (Velten et al., 2004). Nevertheless, not all titanium and its alloys can be used for all biomedical applications. For instance, Lopez reported that Ti-V alloy reveals a trace of vanadium ion release after being in contact with the body fluid for a long period of time (López et al., 2010). The existence of excessive metal-ions in the body fluid causes toxicity problems such as infections, local pain, and swelling for the host body (Aksakal et al., 2010). Ti-Nb and Ti-Zr alloys are a favourable substitution of Ti-V to overcome the toxicity problem of this alloy (Gutiérrez et al., 2008). Although these biocompatible alloys have a high strength-to-weight ratio and a good corrosion resistance, but the issue of ion release is still a great concern when these alloys are placed in a hostile electrolytic environments such as human body fluid (Yildirim et al., 2005). Therefore, Hydroxyapatite (HA), $Ca_{10}(PO_4)_6(OH)_2$, with a hexagonal structured ceramic composed of calcium phosphate groups, which is very similar to the mineral components of the bone tissue is applied to metallic implants as a coating layer. The HA coating layer provides a better osteointegration in the bone/implant interface, and protects the surface of the implant against the corrosive body fluid. Due to the excellent biocompatibility and bioactivity of HA, its coating on the surface of the metallic implants is considered as a promising method to enhance their bioactivity. Many studies have shown that using HA as the coating layer can promote the bone growth cells (osteoblast) and the bone resorption cells (osteoclast) activity after implantation, and therefore improve formation of chemical bonding at the HA/bone interface which is called osseointegration (Thian et al., 2005) (Rack et al., 2006) (Fehring et al., 2001) (Niinomi, 2002) (Rahaman et al., 2007). This provides a protection of surrounding body tissue against the metal-ion release from a metal prosthesis (Aksakal et al., 2010).

Several possible techniques have been studied and developed to produce a thin HA layer on the different kinds of implant materials. Among them the sol-gel technique seems to be a more acceptable technique in creation of a thin HA layer on the implant surface. This approach provides significantly milder conditions for the synthesis of the HA films which results in an improved structural integrity; whereas, the defects that originated from the plasma spraying method can be largely avoided21. Hence, the sol-gel method provides some benefits over the plasma spraying method, such as fine grain structure, chemical homogeneity and low processing temperature (Hayashi et al., 1994). One of the most crucial steps in HA coating using sol-gel method is the applying of heat treatment. Sintering of the samples after coating procedure results in the crystallization of the HA phase. Normally the intensity of crystalline apatite phase increases after being sintered at