

Electrochemically Fabricated TiO₂ nano-Layers on Ti-6Al-4V

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Introduction

The need for artificial implants for bone and joint problems is gaining urgency due to the growing problem of osteoarthritis which affects 8 million people in the UK alone. Ti and its alloys are commonly employed as dental and orthopaedic implants due to their corrosion stability, mechanical characteristics and favourable biological interaction with bone. It has been shown that surface topography of implants can improve osseointegration [1]. As more and more existing surface modification techniques come under scrutiny, new methods of surface modification are constantly being sought.

The effect of electropolishing Ti-6Al-4V alloys in methanol-acid solutions on the genesis and growth of osteoblasts has been reported by our group recently [2]. In that work, we showed that a nearly pure TiO₂ layer could be formed on the surface of the alloy during potentiostatic electropolishing by attainment of an equipotential surface at 9.0 V (vs. SCE). The pure TiO₂ layer was of nanometric thickness, and was formed due to the selective dissolution of V and Al from the alloy surface [2]. Experiments carried out using a Ti-alloy sheet, placed in a flat electrochemical cell, under these electrochemical conditions, showed improved cell genesis.

However, in order to carry in-vivo experimentation, it is important to achieve the same surface modification on Ti-alloys which can be implanted into animal models. Usually implants (for animal models or otherwise) are characterized by complex shapes. Imparting an equipotential surface on such complex shapes is difficult.

In this paper we report our approach in devising a method to replicate an equipotential surface on an implant – i.e. a pin. The pin is a cylindrical substrate, which can be inserted in an animal model. The advantage of this approach is that such methodologies can be adopted to scale-up electrochemical reactors to obtain equipotential surfaces to carry out potentiostatic plating or etching.

Methodology

At first an electrochemical software was used to design a reactor suitable for creating an equipotential surface on a cylinder. The Ti implant was to be located at a particular position within the reactor where an equipotential surface of 9.0 V was obtained vs. a reference electrode.

In order to carry out this analysis, at first the current and potential distribution in a flat cell, where flat sheets of Ti were processed, was analyzed. The analysis interrogated the potential distribution within the cell, using experimental data for Ti dissolution. Separate impedance

analyses and conductivity measurements were carried out to estimate the overpotential associated with ohmic drop and oxide resistance.

A new reactor was then designed to incorporate cylindrical substrates. Theoretical analysis showed the positions where the reference and working electrode should be placed such that the potential at the surface of the cylinder would be identical as that within the flat cell.

In order to verify that the reactor was capable of reproducing surfaces obtained in the flat cell, Ti-alloys were electropolished at a potential of 9.0 V vs. an SCE reference. Chronoamperometric data were collected to determine if the current density of the cylinder and flat sheet were similar at this potential.

The roughness of the films was determined from optical profilometry to determine if electro-polishing conditions were achieved. Impedance measurements provided information on the resistance of the surface oxide on the cylinder. XPS analyses showed the surface chemistry of Ti pins. These data were cross checked against the surface characteristics of the Ti-alloy sheets.

Conclusions

A combination of theoretical analyses and experimental verification show that electrochemical reactors, capable of replicating equipotential surfaces on complex (cylindrical) shapes, can be designed. Surface analytical methods showed that this approach could be employed to electropolish Ti alloys of complex geometry.

Acknowledgement

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References:

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