

Laser Surface Modification of Ti-6Al-4V for Biomedical Applications

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Introduction

Ti-6Al-4V is used in biomedical engineering due to its excellent properties: high strength to weight ratio, low density, high corrosion resistance and good biocompatibility. However, the use of the alloy under severe friction conditions is restricted due to poor tribological properties such as high coefficient of friction and low hardness [1, 2]. Laser surface modification is known for its improved mechanical and tribological properties for biomedical titanium alloys. The treatment produces minimal contamination and increases osseointegration [3-5]. The present study evaluated the effects of high speed, laser processing parameters on surface roughness, hardness, chemical composition and biocompatibility.

Materials and Methods

A 1.5KW CO₂ laser in continuous mode was irradiated on flat Ti-6Al-4V samples at three levels of irradiance 15.72, 20.43 and 26.72 KW/cm² and three levels of residence time 1.08, 1.44 and 2.16 ms. Evaluation of the surface was carried out by scanning electron microscope (SEM) examination and mechanical profilometry in accordance to ISO 4287/4288. SEM analysis of the surface topography resulting from the various laser treatments was carried out. Energy Dispersive Spectroscopy (EDS) analysis was used to determine the chemical composition of the treated areas. The effect of surface topography on cellular attachment was investigated *in vitro* using MC3T3-E1 pre-osteoblast cells. Cell attachment was determined using the Hoechst DNA assay and cell morphology was examined using SEM analysis.

Results and Discussion

An increase in residence time resulted in improved depth of processing. An increase in irradiance did not always produce an increase in depth of processing; however higher irradiance levels were found to provide for a more uniform depth of processing which reached a maximum of 80 µm. Irradiation with the scanning beam produced a single phase microstructure, see Figure 1. This single phase occurred when various constituents in the alloy have dissolved with rapid solidification thwarting segregation of the various alloying elements into high and low concentration [6]. Improved homogenous chemical composition of the laser modified region was verified by the EDS analysis. Microhardness examination revealed an increase in hardness of up to 67% after laser treatment. A relationship between irradiance and roughness was observed, roughness decreasing with increase in irradiance.

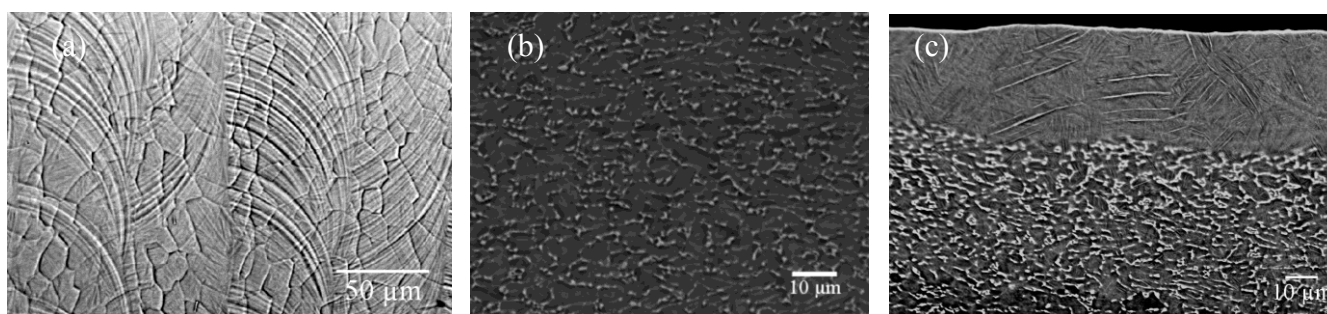


Figure 1: Ti-6Al-4V (a) topography of laser modified surface (b) cross section microstructure (CSM) of untreated sample (c) CSM of laser treated region

References

- [1] ASM Handbook, *Metallography and Microstructure*, 9, Materials International Society, USA, pp. 163. 2003
- [2] Rozmus, M., Surface modifications of a Ti6Al4V alloy by a laser shock processing, 2010
- [3] Gaggl, A., Scanning electron microscopical analysis of laser-treated titanium implant surfaces-a comparative study, *Biomaterials*, 2000
- [4] Hao, L., *Laser surface treatment of bio-implant materials*, Chichester, England; Wiley, 2005
- [5] Mirhosseini, N., *Applied Surface Science*, Vol.253 (19), pp. 7738-43, 2007
- [6] Langlade, C., *Surface and Coatings Technology*, Vol.100-101 pp. 383-387, 1998