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SURFACE MODIFICATIONS OF A Ti6AL4V IMPLANT/ALLOY BY A PICOSECOND Nd:YAG LASER

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Abstract. Interaction of an Nd:YAG laser, operating at 1064 or 532 nm, 40 ps pulse, with Ti6Al4V implant/alloy was studied. The energy absorbed from the laser is partially converted to thermal energy, which generates a series of effects, such as melting, vaporization of the molten material, shock waves, etc. The following changes were observed: (i) appearance of crater like form in the central zone of the irradiated area; (ii) resolidified droplets of the material in the surrounding outer zone, especially expressed at 1064 nm; and (iii) appearance of a periodic surface structures, also more prominent at 1064 nm. Generally, both laser wavelengths show potential of enhancing the roughness of the surface, particularly useful in implant applications, for better bio-integration. Laser interaction with the samples was accompanied by formation of plasma, which additionally helps obtaining a sterilizing effect.

1. INTRODUCTION

Laser surface modifications of materials are old almost as laser itself. Studies of titanium based alloys are of high importance. The Ti6Al4V is used in medicine, nuclear, and aero-space applications, etc. In medical applications this alloy is praised for its high bio-compatibility and bio-integration with the human body, see Long 1998, Trtica et al. 2006, Bereznai et al. 2003 and Guillemot et al. 2004. Generally, bio-integration is facilitated by surface roughness and sterile state Bereznai et al. 2003 and Guillemot et al. 2004.

Interaction of this alloy with a Nd:YAG laser beam pulsed in the picoseconds time domain has not been described in literature as that of the nanaosecond/microsecond domain. In the present paper, our emphasis is on studying the morphological effects of a picosecond laser emitting in the near-infrared (1064 nm) and the visible (532 nm) regions on a medical grade Ti6Al4V alloy.

2. EXPERIMENTAL

The samples were polycrystalline Ti6Al4V plates, face side polished, and the back was left as is. The face roughness was estimated by AFM at less than 100 nm. The laser was focused by a 12 cm focal length quartz lens, perpendicular to the surface, in air. It is a Nd:YAG system, with a 40 ps pulse, see Gakovic et al. 2007, operated in TEM_{00} mode and *p*- polarization.

The samples where characterized before and after laser irradiation by X-ray diffractometry (XRD), optical microscopy (OM), scanning electron microscopy (SEM) with EDS, and atomic force microscopy (AFM) and profilometry.

3. RESULTS AND DISCUSSION

The alloy consisted mainly of the α-Ti phase, structurally polycrystalline. The laser induced morphological changes showed dependence on laser pulse energy density (LPED), pulse duration, peak power density, number of accumulated pulses, and laser wavelength.

The effects at 1064nm and 532 nm are presented in Figures 1 and 2. The LPEDs were 31.2 and 23.6 (1064 nm) and 25.9 Jcm^{-2} (532 nm).

3. 1. Nd:YAG LASER (1064 nm)

Morphology variations induced by 1064 nm, Figure 1, can be summarized as follows: (i) appearance of a crater in the central part of the irradiated area (Fig. 1B1,2 and C1,2); (ii) resolidified droplets of the molten material (Fig. 1B1 and C1); (iii) periodic surface structures (PSS) on the rim and wider periphery (Fig. 1C5, D5). Laser radiation was accompanied by appearance of the plasma in front of the target.

Generation of PSS is known on different materials, e.g. non-metals, metals, semiconductors, etc. following various kinds of mechanisms. Parallel ones are usually attributed to interferences of the incident laser light with scattered light on the surface, Le Harzic et al. 2005.

3. 2. Nd:YAG LASER (532 nm)

Surface feature induced by 532 nm, Figure 2, can be summarized as follows: (i) ablation of the target in the central zone (Fig. 2B1, C1, D1); (ii) appearance of wave-like periodic micro- and sub-micro structures, in near and further periphery, both concentric and parallel (Fig. 2 B1, C1, D1, D2); (iii) absence of defined crater structures. Irradiation was also accompanied by appearance of plasma in front of the target. The concentric periodic structures can be attributed to capillary waves, while the parallel ones are most probably surface/laser interferences, as in the case with 1064 nm.

Both Nd:YAG laser wavelengths induced damage on sample surface. Damage induced by 1064 nm was more severe than that induced by 532 nm. Craters made by 1064 nm were 100 times deeper than the damage made by 532 nm. Particles ejected by the laser appear within the first few picoseconds of the pulse, and it is possible that they had a more pronounced screening effect at 532 nm, thus preventing full laser power to reach the surface.

4. CONCLUSION

A study of morphological changes of Ti6Al4V implant/alloy surface induced by picosecond Nd:YAG laser, operating at 1064 nm and 532 nm, is presented. Much deeper craters were made by 1064 nm than by 532 nm, probably due to a screening effect at the shorter wavelength. Both concentric (with 542 nm) and parallel (with both

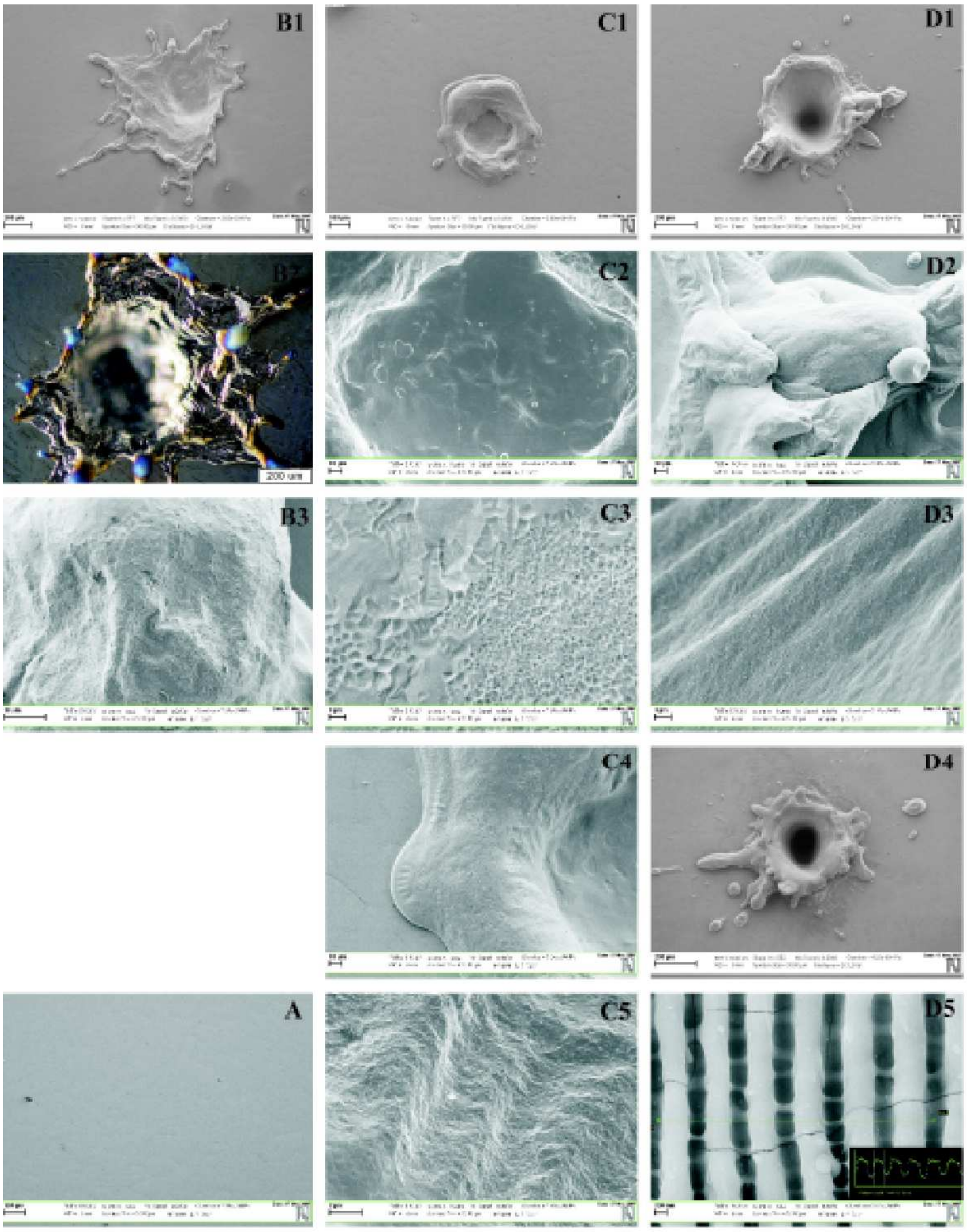

Figure 1: ps- Nd:YAG laser-induced Ti6Al4V implant morphology changes (λ=1064 nm). (A) Prior and, (B), (C) after 1 laser pulse (different LPED). (D) After 5 and 100 laser pulses. LPED = 31.2 (B) and 23.6 J/cm^2 (C) and (D).

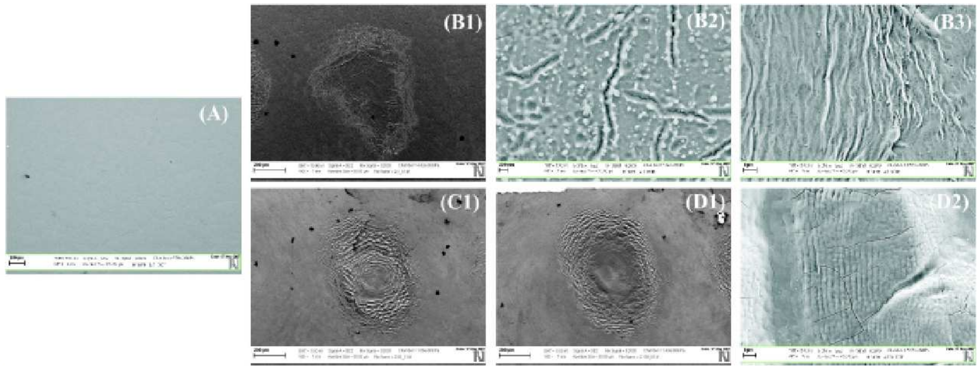

Figure 2: ps-Nd:YAG laser-induced Ti6Al4V implant morphology changes (λ=523 nm). (A) Prior to laser action; (B) 1 laser pulse, (C) and (D) after 50 laser pulses. LPED = 25.9 J/cm^2.

wavelengths) periodic surface structures were observed. Apparently, both laser wavelengths in 40 ps pulses can effectively enhance the Ti6Al4V implant/alloy roughness thus improving its bio-integration. Creation of damage at a Ti6Al4V surface is practically instantaneous, meaning that great implant surfaces can be processed in short times.

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