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PROPERTIES OF SURFACE LAYERS OF TITANIUM ALLOY TI6AL4V AFTER LASER MELTING PROCESSES

ABSTRACT

The article presents the investigation results of titanium alloy Ti6Al4V surface layer after laser melting process. The process of laser melting was performed using Nd-YAG laser. The evaluation of structure of the alloy as well as hardness and chemical composition was performed. It was shown that laser melting changes the structure and properties of titanium alloy Ti6Al4V and process parameters as scanning speed affects the thickness of zones in top layer of the material. Due to the laser melting process more wear resistive surface can be obtained that increases the wear and corrosion resistance of orthopeadic prosthesis.

Key words: *biomaterials, implants, titanium alloy, laser melting*

INTRODUCTION

There are many materials which are used in medicine, but titanium alloys thanks to their properties are widely used in implantology. The titanium alloys have excellent corrosion resistance, fatique strength and biocompatibility in long time period. Very important factor which distinguish titanium alloys is Young modulus which is lowest from all biomaterials. To increase life-time of the titanium implants many different treatment processes are used. One of such process can be laser melting. This method allows to accurate and selective treatment of the surface layer. It consists of two stages: violent melting of metal's surface layer or the cover and violent cooling to the crystallization temperature or amorphouse temperature. The result of laser melting is higher roughness and deformation of the surface [1-2]. In the other hand dendritic amorphouse, fine-grained structures are achieved. Using different type of laser, protective gas or melting parameters, various useful properties of the surface layer can be obtained. The laser melting process is the method that is utilized for precise and selective treatment of the surface layer. By concentrating a large portion of energy in a small area, laser technology allows to obtain better structures [3-5] than produced in traditional process [6].

EXPERIMENTAL

Examinations were performed for two-phase titanium alloys Ti6Al4V, which chemical composition is presented in table 1.

Table 1. *Chemical composition Ti6Al4V alloy [%]*

Fe	V	Al	N	O	N	H	B
0.16	4.05	6.40	0.01	0.185	0.05	0.035	0.001

Alloy has been provided in the form of tape 2. The alloy sheet was cut into samples with dimensions 80x20x12mm. Nd-Yag laser melting was used. The examinations were performed in air environment with different scanning speed and transfer beam. Laser melting was conducted at a constant frequency f=50Hz and laser power P=150W.

Table 2. *Parameters of laser melting process*

No.path	1	2	3	4	5	6
Scan speed	750	350	1000	850	850	650
Laser beam[%]	50	50	30	30	20	20

RESULT AND DISCUSSION

The analysis in SEM microscope of cross sections of samples obtained after laser melting, shows a clear distinction in the surface layer into three zones (Fig.1).
The first zone (surface zone) of the mixed structure of martensite and TiO_2, was created as a result of a thermal processes – the rapid heating and the rapid cooling. This zone can be characterized as area with many irregularities and cracks.

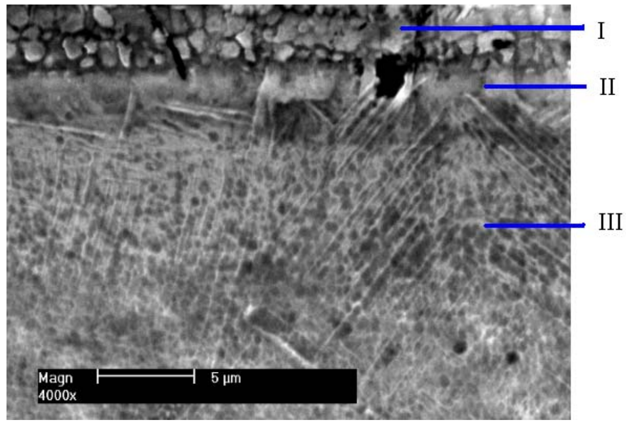

Fig. 1. Structure of samples after laser melting

The second zone (middle zone) is characterized by composed structure of martensite phase and α' phase. α' phase is created as a result of laser melting and operation of high temperature.

In all samples martensit structure had very small dispersion, even with high magnification in α' zone.

The third zone is a transition zone, contains the native material.

a) b)

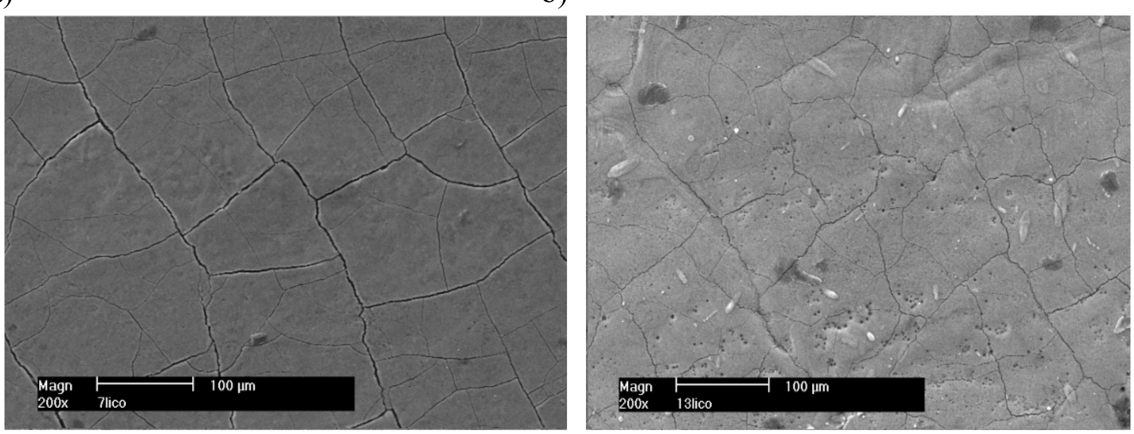

Fig. 2. Surface layer of laser melting for samples: a) no.7 ; b) no.6

Many defects were observed while analysis of the surface created during laser melting (Fig. 2). It was shown that on all tracks cracks were found.

Observation of the external surface of the samples shows that the network of cracks extends over the entire surface of all samples. Created network of cracks appears to be similar, regardless of observed samples. Laser melting parameters doesn't affect the view of the external surface. For samples no.6 additional cracks and small pores were observed. These samples were melted with low scanning speed.

Assessment of cracks which were produced after laser melting at different scanning speeds shows, that all surfaces have significant cracks. Samples melted at low speed do not differ from samples melted at high speed. It is difficult to see the differences in the number of cracks, as well as their course.

In order to assess the impact of laser melting parameters on the surface layer, the analysis was made how parameters like scan speed and the cover of the laser beam affect the size of zone. Because it was difficult to determine where transition zone ends, the measurement was made only for first and second zone. Thickness of the first and second zones surfaces are summarized in Fig. 3.

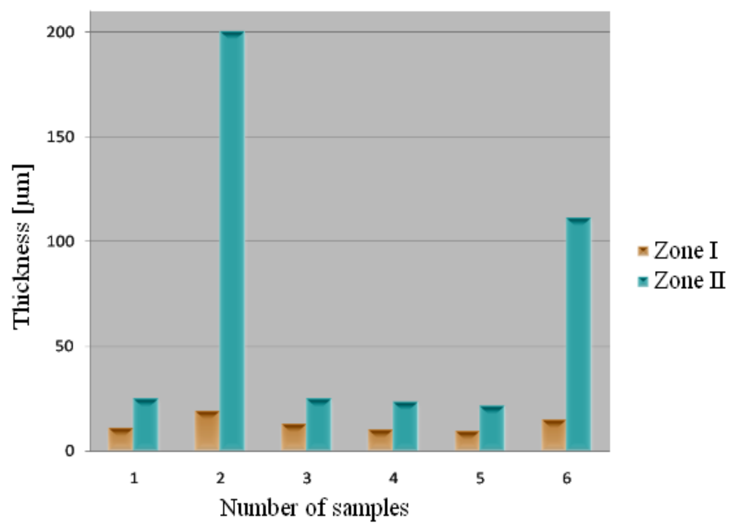

Fig. 3. Thickness of laser melted zones

The most important parameter that affects the thickness of the zone is scanning speed. Reduction of the scanning speed increases the thickness of the first and second zone. The maximum value was obtained for sample no.2, for which the thickness of second zone reached 200μm, minimum thickness was 21,5μm. There was a little difference in thickness of the zones between samples 1-5. Significant increase could be observed for samples no.6 for scanning speed of 650m/min. It was observed that between the speed of 750 mm/min and 650 mm/min, there was a critical value of the scanning speed at which a rapid increase in thickness was found. Microhardness measurements were carried out for each sample. Results were presented in figure 4.

There is a lack of measurement of the microhardness for first zone. It is because of difficulty to measure the hardness due to thickness of the zone and measurement equipment.

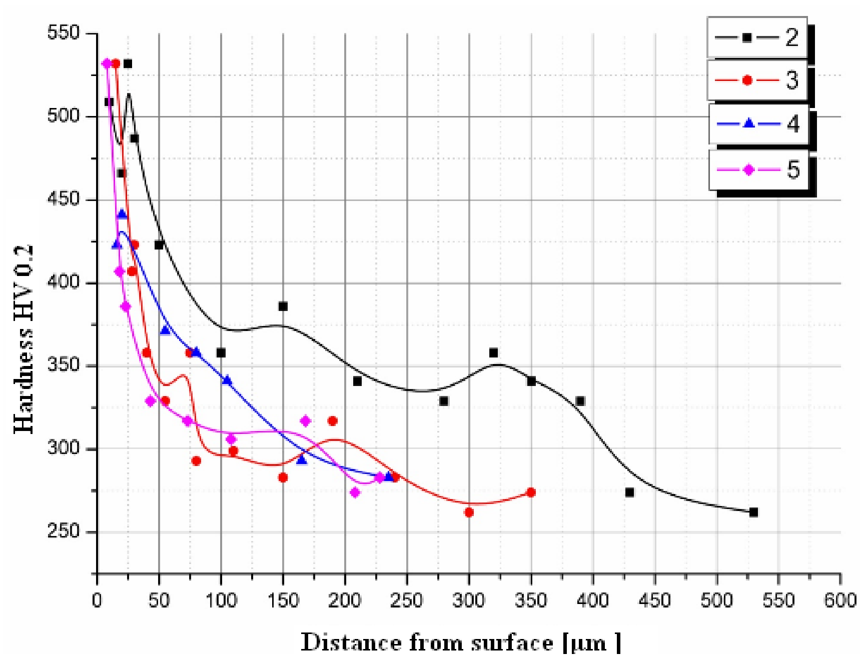

Fig. 4. Microhardness distribution at surface layers of titanium alloy samples after laser melting

The highest hardness was obtained for second zone. The picture shows the changes in the structure, sample no.2 has highest thickness in second zone and transition zone, therefore it may be expected that it has a higher microhardness in the second and third zone. The examination showed that microhardness in second zone is on average 510HV while in the transition zone on average 350HV. For the native material obtained microhardness was on average 290HV. Martensite is harder than the native material, but the transition zone shows only slightly higher hardness than in the native material, mainly due to the high dispersion of martensite in this zone.

CONCLUSIONS

The studies led to the following conclusions:

1. Laser melting changes the structure of titanium alloy Ti6Al4V. The surface layer obtained by laser melting contains three zones: surface zone, middle zone, transition zone. The surface zone is composed mainly of non-metalic particles (molecules), the middle zone of acicular martensite matrix α” and the transition zone includes needles of martensite with high dispersion and the output structure.

2. The laser scan rate significantly affects the thickness of the zones. Low speed scan increases the thickness of the middle zone.

3. The surface cracks are created as a result of laser melting in air environment.

4. Laser speed and scan rate doesn't affect the number and quality of cracks.

5. The laser melting increases significantly microhardness in all zones, even in the transition zone in which no cracks appear, so it can be used to improve tribologic properties of titanium biomaterials.

REFERENCES

1. W. Mróz, B. Major, R. Major, A. Prokopiuk, T. Wierzchoń, Deposition of hydroxyapatite thin films using laser ablation method, Engineering of Biomaterials, 47-53 (2005),117- 119.
2. R. Major, Mróz, T., Wierzchoń J.M., Lackner, W. Waldhauser, J. Bonarski, K. Haberko, A. Pawłowski, Texture and microstructure of HAp thin layer on Ti6Al4V, Proceedings of Symposium on Texture and Microstructure Analysis of Functionally Graded Materials,Kraków, Poland, 2004.
3. T.M. Yue, T.M. Cheung, H.C. Man, The effects of laser surface treatment on the corrosion properties of Ti-6Al-4V alloy in Hank`s solution, Journal Materials Science Letters 19 (2000) 205-208.
4. T.M. Yue, J.K. Yu, Z. Mei, H.C. Man, Excimer laser surface treatment of Ti-6Al-4V alloy for corrosion resistance enhancement, Materials Letters 52 (2002) 206-212.
5. F. Guillemot, E. Prima et al., Ultraviolet laser surface treatment fore biomedical applications of titanium alloys: morphological and structural characterization, Applied Physics A 77 (2003) 899-904.
6. M. Long, H.J. Rack: Titanium alloys in total joint replacement. Biomaterials 19 (1998) 1621-1639.