SURFACE TREATMENT OF DENTAL IMPLANTS WITH HIGH- POWER PULSED ION BEAMS

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The objective of the present research is development of HPPIB technology for surface processing of compact components with a complex shape. The surface state of the dental implants from titanium alloys before and after irradiation and long time operation was investigated by Auger electron spectroscopy, scanning electron microscopy, X-ray structural analysis, optical metallography methods. It is shown that the homogeneous state in the surface layer of titanium alloys is formed due to the irradiation (carbon ions and protons, energy of ions is equal to 300 keV, density of ion energy in a pulse achieves 1-5 J/cm^2). This state is characterized by a low amount of the impurities and a fine dispersional structure formed as a result of high speed crystallization. Thus, HPPIB irradiation of the dental implants leads to formation of developed microrelief and the decrease of impurities content on the surface. As a result, this treatment allows one to achieve a good cohesion between the implants and a body tissue. The latter allows the conclusion that biocompatibility of the dental titanium implants produced by can be improved using HPPIB treatment.

Introduction

The researches of last years in the materials science have given conclusive evidence that one of the determining factors in ensuring the high materials service properties is the state of its surface and near – surface zone [1-3]. The role of the physical and chemical state of a surface is particularly important in those fields of the materials application, where such properties as corrosion, erosion and wear resistance, bioinertness and etc are the determining ones. Firstly, this is the implantology, including the stomatological one.

The ion – beam irradiation, in particular, by powerful ion beams should be related to the most advanced surface irradiation methods. These irradiation methods already found extensive application in the field of semi-conductive and tool – making industry, aerospace engineering for modifying and alloying the surface layers of products made of high pure materials, single crystals, steels, Ni and Ti – base alloys. The use of ion - beam irradiation allows one to obtain the unique combination of predetermined physical and chemical properties in the part surface layers which are subjected to the irradiation. Firstly, this is the production of the surface with the microrelief of the required shape, being thoroughly controlled over its roughness-degree, high purity of surface layers from the chemical point of view, the formation of the given phase composition in it.

I. Experimental

The researches were carried out directly for the dental implants, made of VT1-0 and VT6 alloys (fig.1), as well as specimens of 15mm in diameter and 5 mm in thickness made of the preliminarily heat –treated bars by the mechanical way. The chemical composition of alloys is as follows:

VT1-0: **Ti** –base, **Al**≤0,7%, **C** ≤0,07%, **Fe**≤0,3%, **Si** ≤0,1%, **O**≤0,2%, **N**≤0,04%

VT6: **Ti** – base, **Al**≤5,7%, **V**-4,2;C ≤0,07%, **Fe**≤0,3%, , **O**≤0,26%, **N**≤0,03%.

The specimens were irradiated with the use of "Temp" accelerator by the carbon (70%) and hydrogen ions beam of elliptical cross – section with the area of ~ 100–200 cm^2, the power of 300 keV and the pulse duration of 50 ns [2]. The ion current density varied from 60 to 220 A/cm^2 and the number of pulses – from 1 to 20. The beam current control was performed by means of Faradey collimated cylinder and a sectioned calorimeter. After the irradiation some specimens examined by Auger-electron spectroscopy, X-ray structural analysis and scanning electron microscopy. The remained specimens were subjected to the vacuum annealing ($P_{res}<10^{-5}$ mm of mercury column) at the temperature of 550^{0}C, 2 hours for the structure – phase state stabilization, after which the whole examination cycle was repeated.

II. Results and discussion

The analysis of test results, including those, which are given in Fig. 1-6 points to the fact, that when using the ion beam irradiation, it's managed to obtain as follows:

- to purify a surface from impurities;
- to reduce roughness from 0.15 ±0.01μm down to 0.06±0.01μm, when irradiating with the low current densities of ~ 60 A/cm^2 (15-20 pulses);
- to stabilize the material structure in the surface layer with thickness of ~20μm at the negligible decrease of β-phase amount (low current densities);
- to achieve practically the complete β-phase decomposition at the formation of martensitic α'-phase (to 28%) and α-phase (h~20 μm);
- to obtain the significantly homogeneous melted – through layer of 2–3 μm in thickness, characterized by low microhardness values at j =60 A/cm^2;

to achieve the given developed surface microrelief of 120A/cm^2.

Fig. 1-6 show the dental implant surface after the machining, HPPIB irradiation and surface – plastic deformation with the help of fine dispersed particle. The presented data obviously illustrate the advantages of HPPIB irradiation in particular, the uniformly – developed surface without clearly defined defects in the form of cavities, pores, cracks a.o. which are available in case of both processes: the machining and surface – plastic straining.

The availability of above – pointed surface defects with the contamination of Fe, Ca, a.o. was illustrated in the concentration curves during the examination of by means of Auger – electron spectroscopy. These defects can lead to the clinical complexities during the osteointegration process (Fig. 4 – 6).

Hence, the application of HPPIB irradiation for inner bone dental implants allows not only to reduce the time of their cauterization but also considerably to decrease the percent of complexities, appearing during the post – operation period.

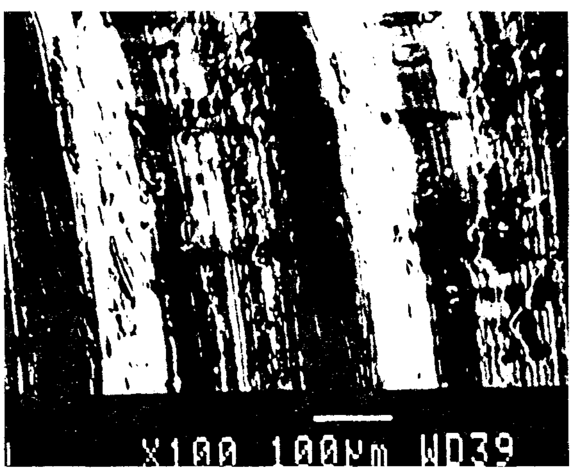

Fig.1. SEM micrograph of the dental surface after machining.

Fig.2. SEM micrograph of the dental surface after plastic straining.

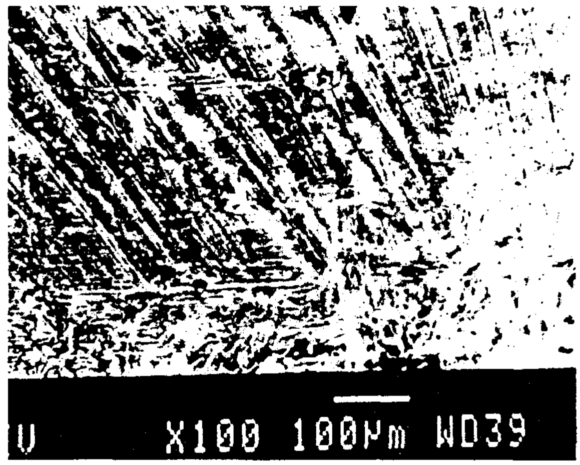

Fig.3. SEM micrograph of the dental surface HPPIB after irradiation (TEMP accelerator, E=300 keV; τ=50 ns; n=5 pulses; j=120-150 A·cm^{-2}).

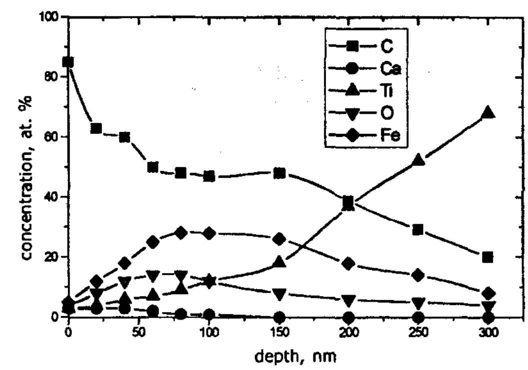

Fig.4. Element distributions on a depth of the dental implant after machining.

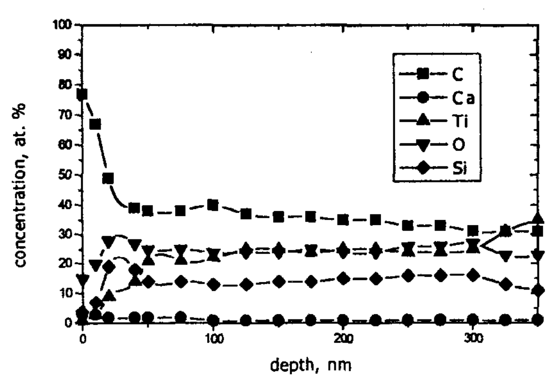

Fig.5. Element distributions on a depth of the dental implant after surface plastic straining (registration from the zone contented the conglomerate in Fig. 2).

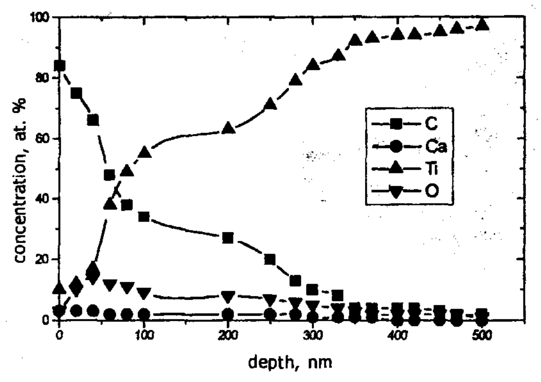

Fig. 6. Element distributions on a depth of the dental implant after irradiation (TEMP accelerator, E=300 keV; τ=50 ns; n=5 pulses; j=120-150 A·cm^{-2}).

Conclusion

The surface irradiation of inner bone dental implants, made of titanium alloys, according to the optimum conditions allows to purify the surface from impurities, to stabilize the materials structure within the layer to 20 μm in thickness, to form the given surface microrelief and, hence, to speed up the osteointegration process and to reduce the percent of the post–operation complexities.

Acknowledgements

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References

1. *Yatsui K.* // J. Laser Particle Beams. – 1989. - v. 7. – p. 733.
2. *Remnev G. E. and Shulov V. A.* // J. Laser Particle Beams. – 1993. – v. 11. – p. 707.
3. *Shulov V. A., Nochovnaya N. A., Remnev G.. Pellerin F., Monge-Cadet P.* // J. Surf. Coat. Technol. – 1998. - v. 99. – p. 74.