POLISH ACADEMY OF SCIENCES - COMMITTEE OF MATERIALS SCIENCE
SILESIAN UNIVERSITY OF TECHNOLOGY OF GLIWICE
INSTITUTE OF ENGINEERING MATERIALS AND BIOMATERIALS
ASSOCIATION OF ALUMNI OF SILESIAN UNIVERSITY OF TECHNOLOGY

Conference Proceedings

12th INTERNATIONAL SCIENTIFIC CONFERENCE
ACHIEVEMENTS IN MECHANICAL & MATERIALS ENGINEERING

Electrochemical modification of Ti6Al4V ELI surface

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In the work, the influence of electrochemical modifications of Ti6Al4V ELI on the in vitro corrosion resistance was studied. The characteristics of the grinded, the electropolished, the electropolished and electrochemically passivated specimens were evaluated by the potentiodynamic tests in Tyrode's solution. A flexibility of the passive layer was examined in potentiodynamic tests of the bended specimens. Results show that electropolishing and anodic oxidation in the examined solutions increased the in vitro corrosion resistance of the alloy. The corrosion potential of the polished and passivated specimens is much higher then the grinded samples. The increase of passive current density was not observed for the polished and passivated specimens. The passive layer was uniform that was proved by the AFM investigation. The tests proved high corrosion resistance of the passivated specimens that were bended (up to 90°) to evaluate the flexibility of passive layer.

1. INTRODUCTION

Criterions that decided about choosing a biomaterial for specific implant are mainly: biocompatibility (biological and mechanical), electrochemical and tribological properties, materials availability, the ease of fabrication and the costs. Taking into account that criterions titanium alloys are material that are perspective in the implatology.

Titanium and its alloys are corrosion resistant biomaterials that are characterized by a wide passive range [1, 2, 3]. The breakdown potentials are higher then membrane potentials of tissue in a living body (0,2-0,45V) [4]. It should be assumed that the loss of passivity in the electrochemical fluids and tissue system is rather impossible. However, a passive layer can be mechanically or chemically damaged. Metallic surface is then uncovered and corrosion processes are initiated. Currently the scientific research is focused on surface layer modification techniques in order to increase the corrosion resistance of implants. Advantages of surface machining employed to implants are as follow:

- clear surface,
- lack of surface deformed regions,
- lack of undefined and unstable surface layer,

- proper electrical properties,
- good corrosion resistance,
- good biotolerance.

It should be said that implants undergo plastic deformation. For this reason prepared layers should be characterized by the plastic deformation ability.

The aim of the work was to work out conditions of electropolishing and producing passive layers on Ti6Al4V ELI alloy surface and the evaluation of the corrosion resistance and topography.

2. MATERIALS AND METHODS

Ti6Al4V ELI was used in the research. Chemical composition and mechanical properties met the ASTM standard [5]. Surface preparation involved: grinding, electrochemical polishing and anodic oxidation. Electrochemical polishing was carried out in the bath composed of: sulfuric acid + hydrofluoric acid + ethylene glycol + acetanilide. Anodic oxidation was carried out in the solution of CrO_3. The specimens were passivated at different potentials. The corrosion resistance of layers was evaluated by potentiodynamic method in the Tyrode's solution (36,6 ± 1 °C and pH = 6,9 ÷ 7,5). Non-deformed and deformed in transverse bend test passive layers were evaluated. Topography of the surface was evaluated with the use of an AFM method.

3. RESULTS

Results of the pitting corrosion tests are compiled in the table 1. Ti6Al4V ELI alloy with grinded surface had the corrosion potential in the range of E_{cor} = +50 ÷ +59 mV, the breakdown potential was in the range of E_B = +1590 ÷ +1760 mV. Electrochemical polishing caused the increase of the corrosion potential to E_{cor} = +112 ÷ +125 mV and breakdown potential to E_B = +2240 ÷ +2310 mV – table 1. For the polished and passivated electrochemically specimens the corrosion potential increased to E_{cor} = +341 ÷ +402 mV. The increase of anodic current density in the investigation range up to +5V was not observed for the passivated specimens. Passivated samples were then deformed in transverse bend test (0 ÷ 90°). The decrease of the corrosion potential to E_{cor} = +211 ÷ +273 mV was observed for the specimens deformed about 10°. The breakdown potential was in the range of E_B = +4710 ÷ +4920 mV. The increase of the deformation angle to 45° caused further decrease of the corrosion and breakdown potentials to the value of E_{cor} = +70 ÷ +78 mV and E_B = +4300 ÷ +4918 mV. For the deformation angle 90° assigned potentials were: E_{cor} = +25 ÷ +35 mV, E_B = +3750 ÷ +4280 mV – table 1, fig. 1.

Investigation of topography with the use of the AFM method did not reveal any damages of the passive film. Roughness of the layer did not exceeded R_a = 27 nm – fig. 2.

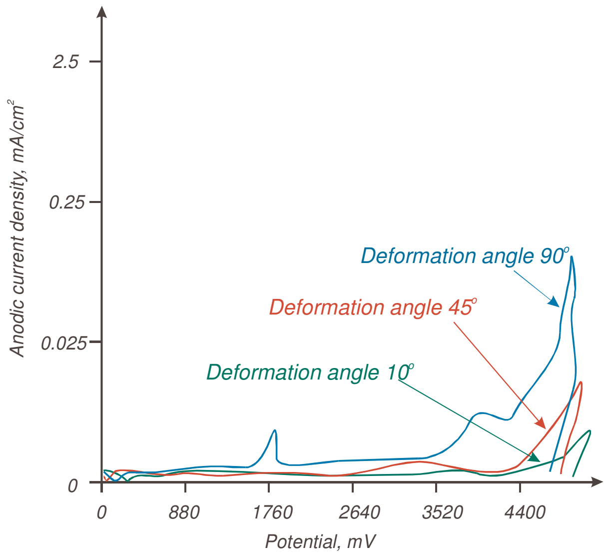

Fig. 1. Potentiodynamic curves for Ti6Al4V ELI specimens with passive film, deformed in different deformation angle

4. CONCLUSION

In the work electrochemical polishing and passivation technology for Ti6Al4V ELI alloy was elaborated. The test revealed that the passive film is uniform (fig. 2) and ensured the pitting corrosion resistance of the analyzed alloy. For the polished and passivated specimens the increase of the pitting corrosion resistance was observed in refer to grinded specimens. The corrosion potential increased by about 300 mV – table 1. Any changes of the current density on the potentiodynamic curves were not also observed for the polished and passivated specimens.

Table1

Results of potentiodynamic investigation

Specimens	Angle	Corrosion potential E_{corr}, mV	Breakdown potential, E_B, mV
Girding	0°	50÷59	1590÷1760
Polished electrochemically	0°	112÷125	2270÷2310
Polished electrochemically and passivated	0 °	341÷402	-
Polished electrochemically and passivated	10°	211÷273	4710÷4920
	45°	70÷78	4300÷4918
	90°	25÷35	3750÷4280

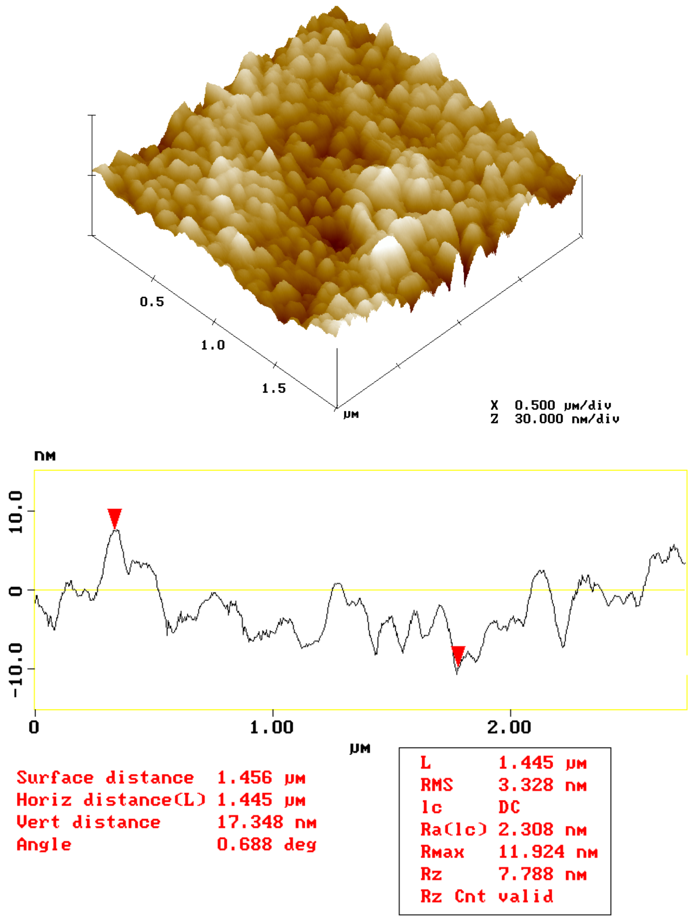

Fig. 2. The passive film topography of the Ti6Al4V ELI alloy

The alloy is often used as biomaterial, that is deformed during the implantation and the working life so, flexibility of the surface layer is essential. Additionally the corrosion resistance tests carried out on deformed specimens proved flexible properties of the layer. The specimens deformed even up to 90° had the higher breakdown potential $E_B = +3750 \div +4280$ mV – table 1, fig. 1) then polished ones ($E_B = +2240 \div +2410$ mV – table 1).

REFERENCES

1. J. P. Simpson: Electrochemical behavior of titanium and titanium alloys with respect to their use as surgical implant materials. In: Christel P., Meunier A., Lee A. J. C.: Biomedical and Biomechanical Performance of Biomaterials. Elsevier, Amsterdam 1986.
2. U. Zwicker :Titan and Titanlegierungen. Springer, Berlin Heidelberg New York 1974.
3. J. Marciniak: Biomateriały. Wydawnictwo Politechniki Śląskiej, Poland, Gliwice 2002.
4. J.Wirz, F. Schmidli, S. Steinmann, R. Wall. Swieitz. Monatsschr. Zahnmedizin 97, 1987.
5. ASTM-F136-84 (1984, USA).