IN VITRO CORROSION BEHAVIOUR OF SOME TITANIUM ALLOYS DESIGNATED TO ORAL IMPLANTOLOGY

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The paper presents a study on the corrosion behavior of some biocompatible titanium alloys designated for the use in dental implantology field. The purpose of the study was to determine the corrosion behavior of three titanium alloys with original composition: Ti-36.5Nb-4.5Zr-3Ta-0.16O, Ti-31.7Nb-6.21Zr-1.4Fe-0.16O and Ti-20Nb-5Ta, in the following simulated physiological environments: artificial saliva and Hank's solution, using the linear polarization technique. In artificial saliva Ti-36.5Nb-4.5Zr-3Ta-0.16O alloy showed the best corrosion behavior, followed by Ti-20Nb-5Ta and Ti-31.7Nb-6.21Zr-1.4Fe-0.16O alloys. In Hank's solution, Ti-20Nb-5Ta alloy had the best corrosion resistance, followed by the other two alloys, with relatively close values.

Keywords: biocompatible titanium alloys, corrosion behavior, linear polarization technique

1. Introduction

Titanium alloys have an excellent resistance to many highly corrosive environments, which has led, besides first aerospace applications, to a wide spread in many other domains [1]. Titanium materials are used in biomedical applications due to their high resistance to corrosion in body fluids, by developing a stable, continuous and highly protective adherent film on the surface [2][3]. The environmental conditions determine the thickness, nature and composition of the protective surface oxides [1]. If the oxide film is damaged or disrupted, it is repaired in the presence of air or oxidizing media. Foreign ions are released into the body when corrosion occurs. Titanium and titanium alloys have a better corrosion resistance than other implant materials, such as cobalt-chromium-molybdenum alloys or stainless steel [4].

Corrosion can adversely affect the biocompatibility and the mechanical integrity of the dental implant; small additions of certain alloying elements can significantly change the corrosion behavior of the alloys [5][6].

The purpose of the paper was to determine the corrosion behavior of three titanium alloys with original composition, designated for the use in dental implantology field, by determining the open circuit potential, the corrosion potential, the corrosion current density and the corrosion rate.

2. Materials and methods

The corrosion resistance of the studied alloys was determined through the linear polarization technique. This technique consists of plotting the linear polarization curves by applying the following steps:

• measuring the open circuit potential (E_{oc}) for a period of 20 hours;

• plotting the potentiodynamic polarization curves from -1 V (vs OC) to +1 V (vs SCE), with a scanning rate of 1mV/s.

The tests for the evaluation of corrosion resistance were performed with a Potentiostat/Galvanostat/EIS Analyser (PARASTAT 4000, produced by Princeton Applied Research) and the potentiodynamic curves were obtained with the VeraStudio v.2.4.2 software.

To carry out the tests a standard cell corrosion unit was used, which comprises a saturated calomel electrode (SCE) – as reference electrode, a platinum electrode – as recording electrode and a working electrode - consisting of the titanium alloys samples, which were mounted on a teflon support, with a 1 cm^2 area subjected to corrosion. During the corrosion tests, the electrochemical cell was introduced into a Faraday cage, in order to eliminate the electromagnetic interferences. The tests were carried out into the following simulated physiological environments: artificial saliva (A.S.) and Hank's solution, at a temperature of 37 ± 0.5^{0}C. The original chemical composition of the as studied alloys is presented in Table 1.

Table 1

Chemical composition of the as studied alloys

Number	Sample code	Element [wt%]				
		Nb	Ta	Zr	Fe	Ti
1	Sample 1- Ti-20Nb-5Ta (wt%)	20	5	-	-	residue
2	Sample 2- Ti-36.5Nb-4.5Zr-3Ta-0.16O (wt%)	36.5	3	4,5	-	residue
3	Sample 3- Ti-31.7Nb-6.21Zr-1.4Fe-0.16O (wt%)	31.7	-	6.21	1.4	residue

The curves of the open circuit potential (E_{oc}) variations of all 3 alloys can be seen in Fig.1, for the alloys in artificial saliva (A.S.) and in Fig.2, for the alloys in Hank's solution. Fig.3 reveals the six open circuit potential curves in the solutions used as electrolyte.

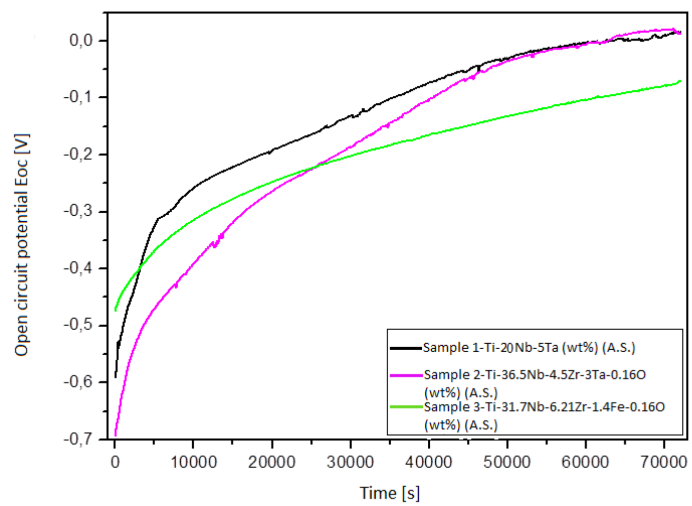

Fig.1. Evolution of the open circuit potential (Eoc) for titanium alloys investigated in artificial saliva (A.S.).

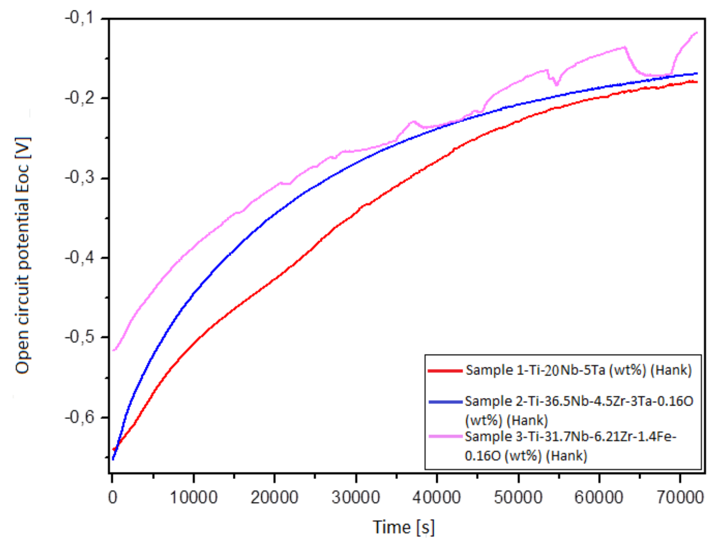

Fig.2. Evolution of the open circuit potential (Eoc) for titanium alloys investigated in Hank's solution.

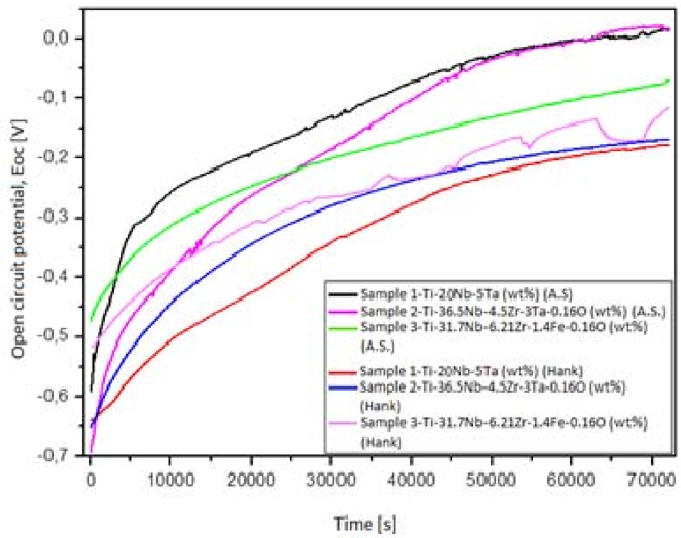

Fig.3. Evolution of the open circuit potential (Eoc) for the samples in the solutions used as electrolyte.

The potentiodynamic curves of the three alloys in artificial saliva (A.S.) can be seen in Fig.4. Fig.5 shows the potentiodynamic curves when using Hank's solution as an electrolyte. All six potentiodynamic curves can be observed in Fig. 6, in the two solutions used as electrolytes.

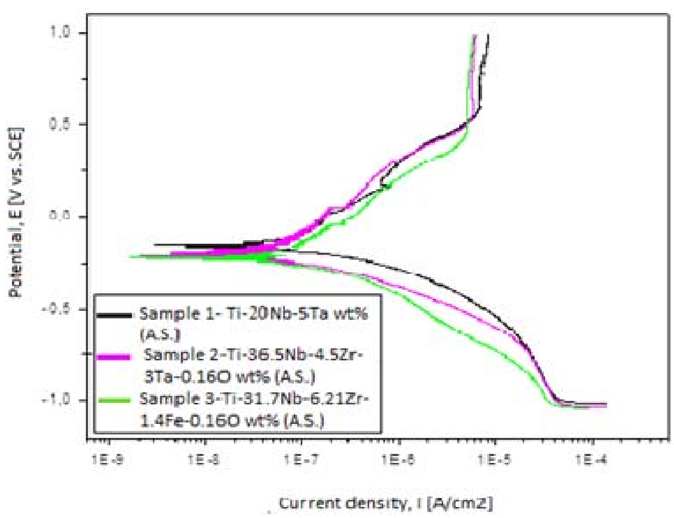

Fig.4. Potentiodynamic curves for titanium alloys investigated in artificial saliva (A.S.).

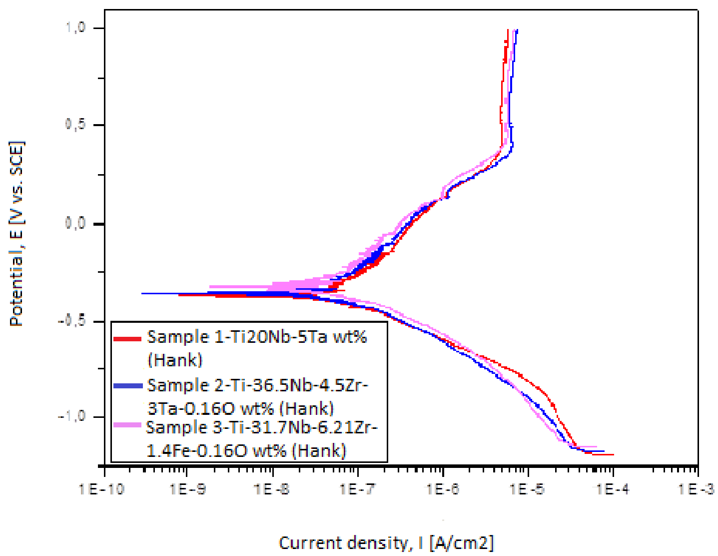

Fig.5. Potentiodynamic curves for titanium alloys investigated in Hank's solution.

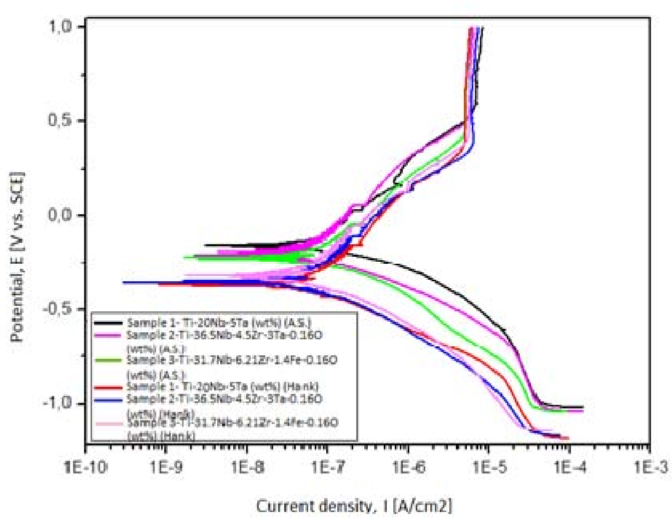

Fig.6. Potentiodynamic curves for the samples investigated in the solutions used as electrolytes.

From the polarization curves the following parameters that characterize the corrosion resistance were determined: the open circuit potential (E_{oc}), the corrosion potential (E_{i}=0), the corrosion current density (i_{cor}), the corrosion rate (CR).

Table 2

The main parameters of the corrosion process

Sample	E_{oc} [mV]		E_{cor} [mV]		i_{cor} [nA/cm^2]		CR [µm/an]	
	A.S.	Hank	A.S.	Hank	A.S.	Hank	A.S.	Hank
1	15,258	-178,862	-159,068	-369,696	83,722	69,305	0,663	0,548
2	12,575	-169,455	-204,191	-353,713	55,860	87,362	0,442	0,692
3	-70,158	-117,544	-222,602	-324,159	111,688	88,324	0,917	0,725

4. Results and discussions

The corrosion resistance of the studied alloys was examined according to several criteria.

In terms of the evolution of open circuit potential (E_{oc}), the electrochemical measurements showed that in artificial saliva the Ti-25Nb-5Ta alloy had the most electropositive value (15.258 mV) and therefore a better corrosion behavior compared to the other two alloys. On the other hand, the most electropositive value in Hank's solution was recorded for the Ti-31.7Nb-6.21Zr-1.4Fe-0.16O alloy, being equal to -117.544 mV.

If the corrosion potential value is considered (E_{cor}), it is admitted that higher electropositive corrosion potential values show a better corrosion resistance. According to this criterion, the most electropositive value for the tests performed in artificial saliva is recorded for the Ti-20Nb-5Ta alloy, having a value of -159.068 mV, being followed by Ti-36.5Nb-4.5Zr-3Ta-0.16O and Ti-31.7Nb-6.21Zr-1.4Fe-0.16O alloys, with similar values. When using Hank's solution as electrolyte, the most electropositive value corresponds to Ti-31.7Nb-6.21Zr-1.4Fe-0.16O alloy. It can be seen that the corrosion potential has approximately equal E_{cor} values for the alloys investigated in Hank's solution.

It is known that a low corrosion current density (i_{cor}) indicates a good corrosion resistance. Considering this criterion, the Ti-36.5Nb-4.5Zr-3Ta-0.16O alloy has the lowest value of current density at its immersion in artificial saliva (55,86 nA/cm^2), followed by Ti-20Nb-5Ta and Ti-31.7Nb-6.21Zr-1.4Fe-0.16O alloys. In Hank's solution, the Ti-20Nb-5Ta (wt%) alloy has a better corrosion resistance than the other two alloys. When using Hank's solution as an electrolyte, Ti-36.5Nb-4.5Zr-3Ta-0.16O and Ti-31.7Nb-6.21Zr-1.4Fe-0.16O alloys have close current density values; instead, when using artificial saliva as an electrolyte, the values are very different.

Studying the i_{cor} values of the three titanium alloys, it can be observed that Ti-20Nb-5Ta and Ti-31.7Nb-6.21Zr-1.4Fe-0.16O alloys have a better corrosion behavior in Hank's solution, while Ti-36.5Nb-4.5Zr-3Ta-0.16O alloy presents a better corrosion behavior in artificial saliva.

Regarding the corrosion rate (CR), it can be observed that Ti-36.5Nb-4.5Zr-3Ta-0.16O alloy has the lowest values in artificial saliva and Ti-20Nb-5Ta alloy has the lowest values in Hank's solution.

From the shape of the potentiodynamic curve and especially from the anodic curve, it can be also seen that after the value of 400 mV, regardless of the electrolyte used and of the elemental composition of the Ti-alloys, in all experiments the three alloys have a passivation trend, with very close values of the corrosion currents, which demonstrates that the studied alloys form an adhesive and protective oxide layer on the surface.

5. Conclusions

The corrosion resistance of three titanium alloys designated for use in the dental implantology field was examined. The method used to determine the corrosion behavior was the linear polarization technique, with two electrolyte solutions: artificial saliva and Hank's solution. The main parameters that define the corrosion resistance are as follows: the corrosion current density, the corrosion rate, the corrosion potential and the open circuit potential. The conclusion was that in artificial saliva the Ti-36.5Nb-4.5Zr-3Ta-0.16O alloy had the best corrosion behavior, while in Hank's solution the Ti-20Nb-5Ta alloy had the best corrosion behavior. All three titanium alloys showed a good corrosion resistance, being suitable for use as metallic materials for dental implants.

Acknowledgment

The work was supported by a grant of the Romanian National Authority for Scientific Research, CCCDI- UEFISCDI, project number 213/2014. R.M. Angelescu acknowledges the support of Sectorial Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/134398.

R E F E R E N C E S

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