CORROSION BEHAVIOR OF NEW TITANIUM ALLOY FOR BIOMEDICAL APPLICATIONS

Matteo Bertapelle[1], Santiago Brito-Garcia[2], Julia Claudia Mirza-Rosca[2,3], Madalina Simona Baltatu[4], Petrica Vizureanu[4]

[1]Department of Information Engineering, University of Padova, Via VIII Febbraio, 2, 35122 Padova PD, Italia
[2]Dpto. de Ingeniería Mecánica, Universidad de Las Palmas de Gran canaria, Campus Universitario Tafira, 35017, Las Palmas de gran Canaria, Spain
[3]Materials Engineering and Welding Department, Transilvania Univerity of Brasov, 29 Eroilor Blvd., Brasov, Romania
[4]Department of Technologies and Equipments for Materials Processing, Faculty of Materials Science and Engineering, Gheorghe Asachi Technical University of Ia¸si, Blvd. Mangeron, No. 51, 700050 Iasi, Romania;
e-mail: matteo.bertapelle@studenti.unipd.it

Abstract

The biomedical field is in constant evolution and improvement, for such reason we've decided to search for a possible material to overcome the limitations of some of the most common biomaterials utilized, such as Titanium, known for its high biocompatibility and corrosion resistance and used for bone implants and bone fixation parts, or such as Zirconium, a material wuth good chemical stability and mechanical properties, with orthopedical and dental applications, our proposal is a material called R4, an alloy composed of Ti15Mo7Zr15TaSi, which we belive could one day overcome the previous materials in the biomedical field.

Introduction

In this study we chose two commonly used biomaterials Titanium and Zirconium, vastly used in bone implants for their mechanical properties and resistance to biological enviroment, and our alloy called R4, Ti15Mo7Zr15TaSi, which thanks to its composition might be a perfect candidate for orthopedic applications, having mechanical properties similar to the ones of human cortical bone.

For such reason in this study we've decided to analyze a critical aspect for biomaterials, the corrosion behavior, and to compare the new Titanium alloy called R4, with both Titanium, Ti, and Zirconium, Zr.

Experimental

For the experiment we first obtained the samples from the Faculty of Material Science and Engineering at Gheorghe Asachi Technical University in Iasi, Romania, already cut and grinded so that we could have a cylinder of around 2 cm of height, composed of a metallic core and a resin casing, we then proceeded to polish them with alumina suspension in Struers TegraForce-1 polishing machine for 40 seconds. For the electrochemical experiments, a sample was placed in an electrochemical cell with three electrodes: the samples served as the working electrodes, the reference electrode was a saturated calomel electrode and the counter electrode was made of platinum. In order to conduct the experiments, the area of each sample was measured. The mmol/L concentration of the Ringer solution developed by Grifols' Laboratories (Barcelona, Spain) was as follows: Na^+ 129.9, Cl^- 111.7, K^+ 5.4, Ca^{2+} 1.8, and $C_3H_5O_3$ 27.2. Corrosion potential vs time, linear potential and electrochemical Impedance Spectroscopy were applied using the BioLogic Essential SP-150 potentiostat from Seyssinet-Pariset, France. The tests were

conducted in aerated Ringer solution at 25 °C. and to submerge the sample's part with the exposed material in Ringer solution at 25° C for a time of 24 hours, after this we exported the data from the program EC-lab and used them to obtain various graphs in Excel.
To analyze potential corrosion The "Ecorr vs. Time" method from the Ec-Lab application was used to calculate each sample's corrosion potential during a 24-hour period. Every 300 s or every time there was a 100 mV shift in potential, potential readings were obtained. The information was then gathered and a potential versus time graph was made once the data was examined.
We polished again the samples with alumina suspension in Struers TegraForce-1 polishing machine for 40 seconds and proceeded to do a microhardness test, with microhardness tester machine FM-810, using loads of 1g, 5g, 10g, for 10 measurements each, for a time of 20 seconds each measurement.

Results and discussion

Regarding the Corrosion potential (see Figure 1) we can observe how R4 possesses a tendency to passivate while both Zr and Ti tends to slowly corrode.

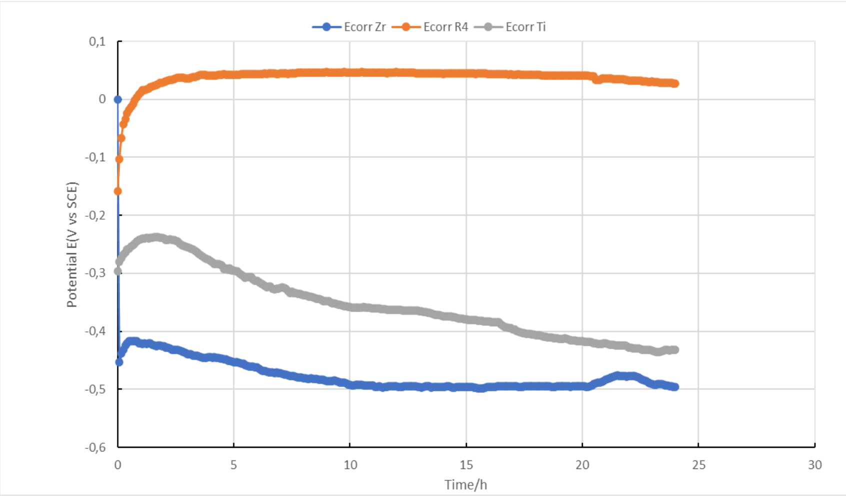

Figure 1. Corrosion Potential of the three analyzed samples in Ringer solution

While evaluationg Bode-phase (see Figure 2) we can see how in both Titanium and R4 alloy we have a large zone with high phase angle, meaning that both have high corrosion resistance poperties, while Zr presents a narrow not point dense pit which can be associated to a passivating effect not very effective that can't protect enough the material,

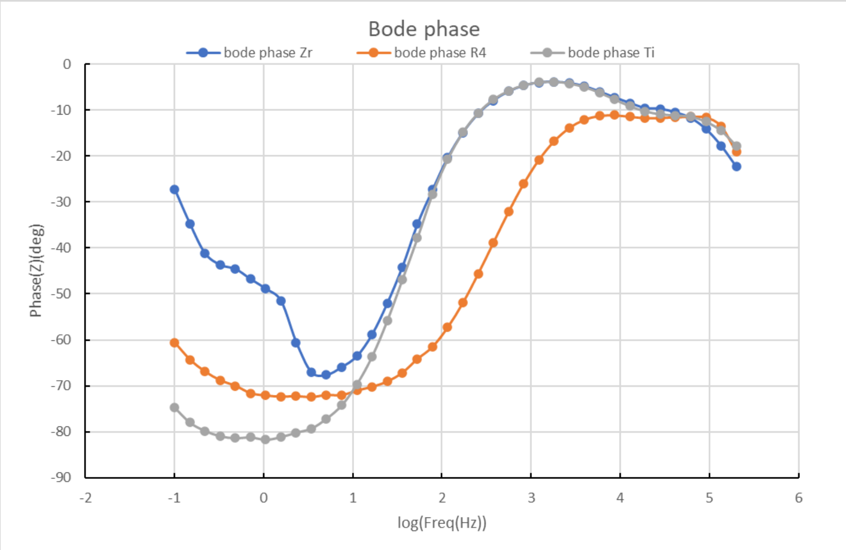

Figure 2. Bode-phase of the analyzed samples in Ringer solution

We can verify what was previously said looking at the Bode-IZI graph (see Figure 3), here we can see that Zr has a high impedence level, corresponding to good corrosion resistance, that is salso true for R4 and Ti, with R4 presenting a longer deminishment with the increase of the frequency.

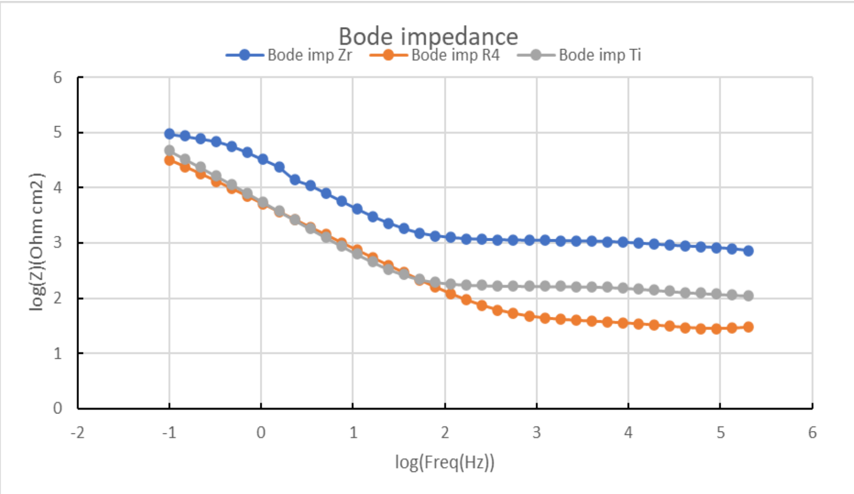

Figure 3. Bode-IZI graph of the analyzed samples in Ringer solution

Again with Nyquist (see Figure 4) we can validate what was said before, with Zr exhibiting highest Corrosion resistance, followed but Titanium and R4

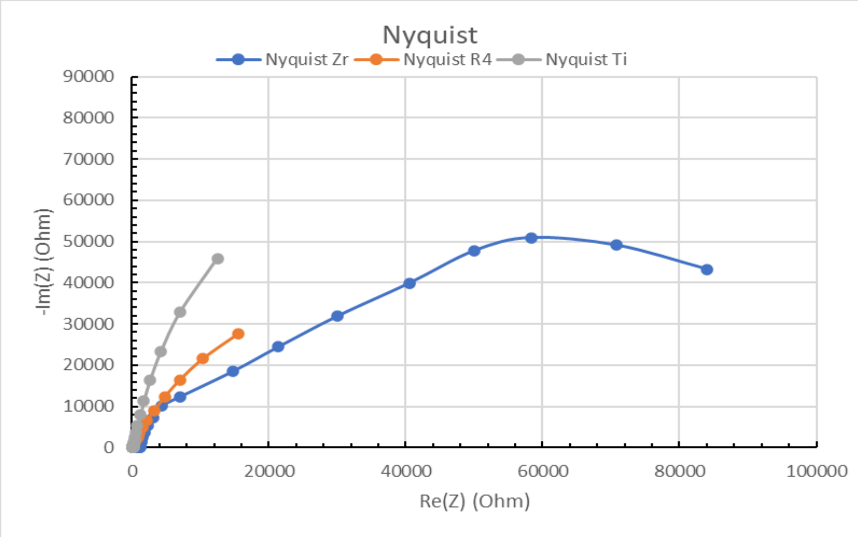

Figure 4. Nyquist of the analyzed samples in Ringer solution

We can finally see that all of the treated materials tend to passivate in some degree, forming an oxide layer that defends them from corrosion, with the most stable material being the R4 alloy. Zirconium instead presents at around 0.2 V pitting corrosion phenomena. (see Figure 5)

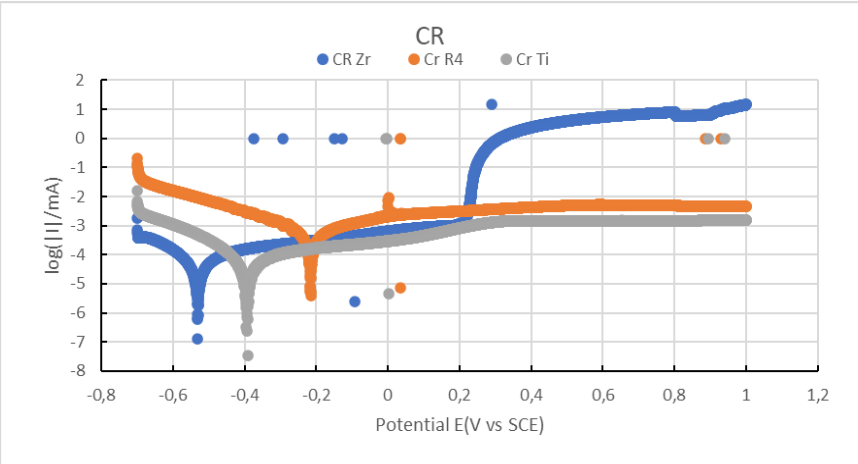

Figure 5. Polarization curves for all the 3 samples in Ringer solution

Conclusion

From our analysis we can state that the R4 alloy presents good corrosion resistance and stability, with passivating capabilityes, which make it a good candidate for biological applications, in fact, its corrosion resistance is slightly superior to the commonly used material, and if we also consider the mechanical properties, that gives us a perfect material for future biomedical applications.

Acknowledgements

I want to thank University of Las Palmas de Gran Canaria, and the University of Padova for the Erasmus+ grant for traineeship and have the opportunity to work on this project.

References

[1] Vizureanu, P. Effect of Si Contents on the Properties of Ti15Mo7ZrxSi Alloys. Materials 2023, 16, 4906.
https://doi.org/10.3390/ma16144906
[2] Baltatu, M.S.; Vizureanu, P.; Sandu, A.V.; Florido-Suarez, N.; Saceleanu, M.V.; Mirza-Rosca, J.C.
New Titanium Alloys, Promising Materials for Medical Devices. Materials 2021, 14, 5934.
https://doi.org/10.3390/ma14205934