Ta addition Effecting on the Behavior of Corrosion of Zr2.5Nb Alloy Using P/M

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ABSTRACT
This study investigated the influnce of Tantalum addition on the behavior of corrosion of Zr2.5Nb biomedical alloy. The samples were prepared by powder metallurgy approach. The corrosion investigated by using different tests, these tests including (open circuit and potentiodynamic polarization). The results show that the addition of Ta improving the resistance of corrosion of the alloy in Hank's solution.

Keywords: corrosion, P/M, Ta, biomedical, polarization

INTRODUCTION

Bone does a lot functions like body weight supporting, the organs protection, helping with movement, enhancing mineral homeostasis, making the blood supply, and saving triglycerides [1]. The different functions of bone tissue are hardly related to its hierarchical and anisotropic structure [2].
The further commonly metals used for replacement of joints are St.St, CoCr, and Ti-based alloys. Recently, alloys developed in the field of biomedicine have been used, including Nb alloys , Zr-alloys and Mg-alloys. These alloys have a relatively long tradition in replacement of joints [3].
The major utilized of Zirconium for biomedical applications is in total hip replacement (THR) and total knee replacement(TKR). The Zr2.5Nb alloy (UNS R60901) is provided for the applications of surgical implant and is regulated in ASTM F2384-10 [4]. The Zr2.5 Nb alloy is utilized for the femoral knee surface and the head of the hip joints, which was known as"Oxinium" and developed by Smith and Nephew in 1997 for TKR and in 2002 for THR.
Despite of the resistance of wear of Zirconium is little (due to its little hardness),the oxides of zr formed in thin layer when the Zr2.5-Nb alloy is heat-treated at about 500°C in the air [5].
Ta is a chemical element with the symbol Ta and it has an atomic number of 73[6]. Ta is a very hard, ductile, lustrous, blue-gray transition metal that is highly corrosion-resistant[7]. Tantalum is dark (blue-gray),[8] dense, ductile, very hard, simply fabricated, and highly conductive of heat and electricity. The Ta is famous by its corrosion resistance by acids; actually, at temp. under 150 °C, Ta is almost fully impregnable to attack by the normally aggressive environments[8] .
This research highlights to enhance the electrochemical properties of Zr2.5Nb alloy by addition various percentage of Ta(0.5, 1 , 1.5 , 2 , 2.5 , and 3)wt % .

MATERIALS AND METHODS

The materials powders used to prepare the alloy are listed in Table 1 and 2 with average particle size (measured by using Better size 2000 laser particles size analyzer), purity by XRF analyzer and and chemical composition of the alloys.
By using planetary automatic ball mill, the weighted powders were wetly mixed, different diameter steel balls were used and the mixing media was Ethanol for wet mixing. 3 hours for mixing process.

Table 1 : Purity and average particle size of materials

Materials	Purity(%)	Average particle size(μm)	Chemical composition(%)
Zr	98.19	46	97.5
Nb	99.79	46.6	2.5

Table 2: alloy code and chemical composition

Alloy code	Chemical composition
A	(Zr2.5Nb)
B1	(Zr2.5Nb)+0.5wt%Ta
B2	(Zr2.5Nb)+ 1wt%Ta
B3	(Zr2.5Nb)+1.5wt%Ta
B4	(Zr2.5Nb)+2wt%Ta
B5	(Zr2.5Nb)+2.5wt%Ta
B6	(Zr2.5Nb)+3wt%Ta

By using an electric hydraulic press, the powder mixture was compacted the to produce a cylindricalsample with diameter of 13 mm and thickness of 5mm , the compacting pressure was 800 MPa and the period was 4 min. To reduce the friction during the pressing process ,Graphite was used as a lubrication . Under vacuum tube furnace, the sintering process was done.
The sample of sintering process include the following steps: heating from room temperature to 500 ∘ C , soaking for 1 hour, then heating from temperature 500 to 1100 ∘ C and soaking for 7 hours , slow cooling in the furnace with continuous vacuum circumstances to the room temperature.

Electrochemical Test
The corrosion behavior of Zr2.5Nb studied in Hank's solution. The PH of Hank's solution at 37 ∘ C was 7.4 .The chemical composition of Hank's solution is shown in Table 3[9].

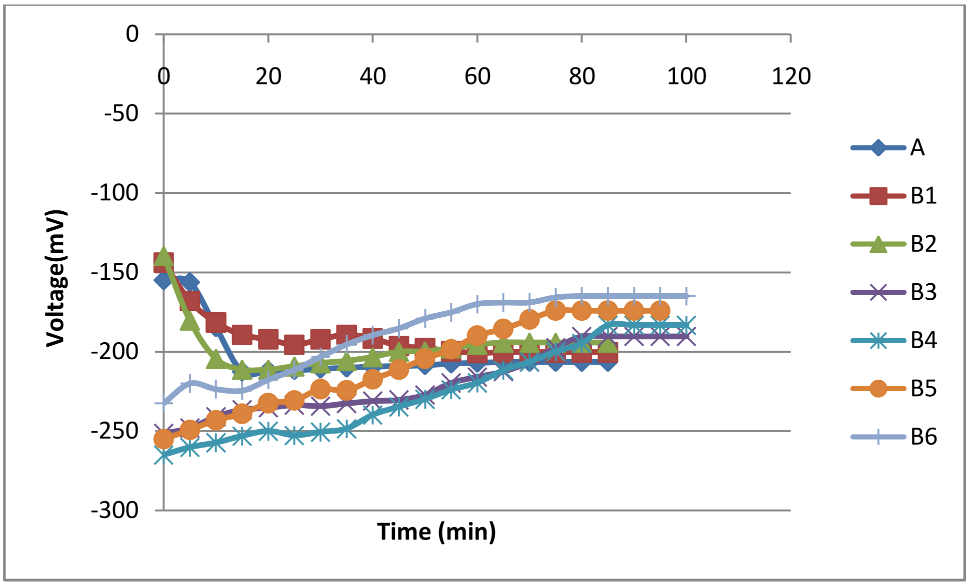
NO.	Constituent	g/L
1	NaCl	8
2	CaCl2	0.14
3	KCl	0.4
4	NaHCO3	0.35
5	Glucose	1
6	MgCl2.6H2O	0.1
7	Na2HPO4.2H2O	0.06
8	KH2PO4	0.06
9	MgSO4.7H2O	0.06

Open circuit potential Test
The tests were done by immersing the samples in Hank's solution . Related to a Saturated Calomel electrode (SCE), the working electrode potential was measured.

Potentiodynamic polarization
Electrochemical tests were carried out in three electrode cell containing and electrolytes ,which is Hank's solution .Pt was the counter electrode and SCE was the reference and the specimen was the working electrode according to the American Society for Testing and Materials (ASTM). The test started from initial potential of (-250mV) below the open circuit potential and the scan continued up to(+800 mV) above the open circuit potential. The measurement of the corrosion rate is obtained by the following equation [9]:

$$\text{Corrosion rate (mpy)} = 0.13\ I_{corr}.Ew/\rho A$$

RESULTS AND DISCUSSION
The time of the OCP was measured in Hank's solution for all alloys at 37°C, fig.1 shows the development of corrosion potential of the alloys through time. The duration of time was from 0-100 min with interval of 5 min were potentially reported.



From fig.1it can be noted that during 25-30 min the corrosion potential increases at highest speed , this is because of the forming of metal oxide on the surface of the sample , then the corrosion potential raises slowly due to the growth of oxide film which improving corrosion protection ability. Also, it can be noted that the potential of corrosion extents a level at which the potential of corrosion is stabilize. The stableOCP means that there is a balance between dissolution and deposition (fig. 2-8)

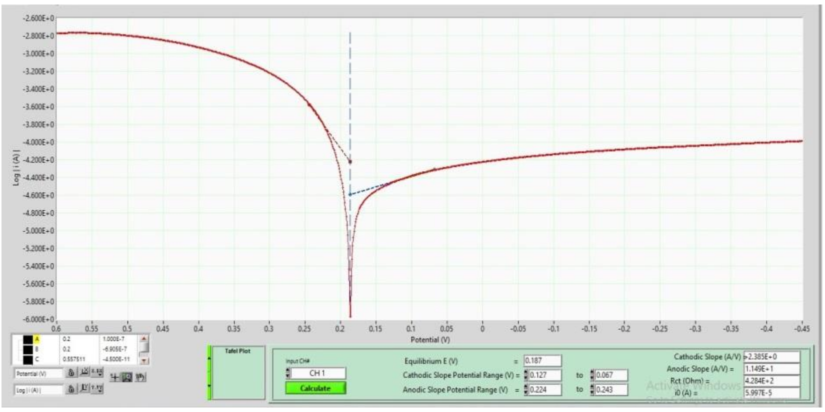


Fig 2: Potentiodynamic Polarization for A alloy in Hank's Solution

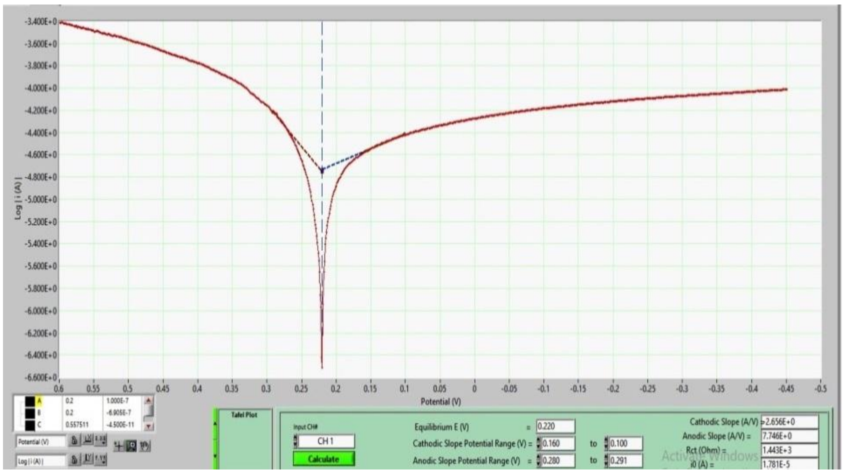


Fig 3: Potentiodynamic Polarization for B1 in Hank's Solution

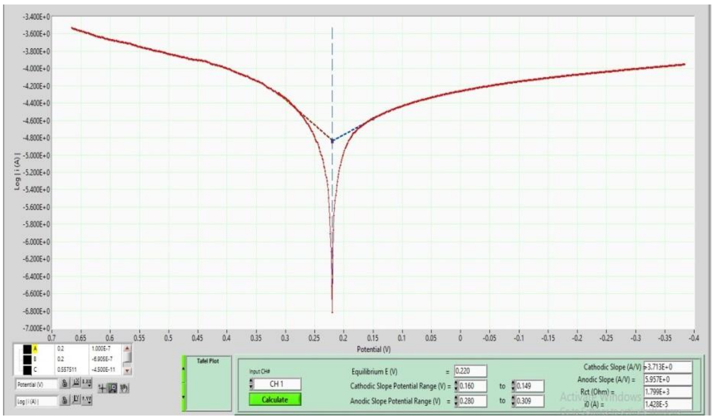


Fig 4: Potentiodynamic Polarization for B2 alloy in Hank's Solution

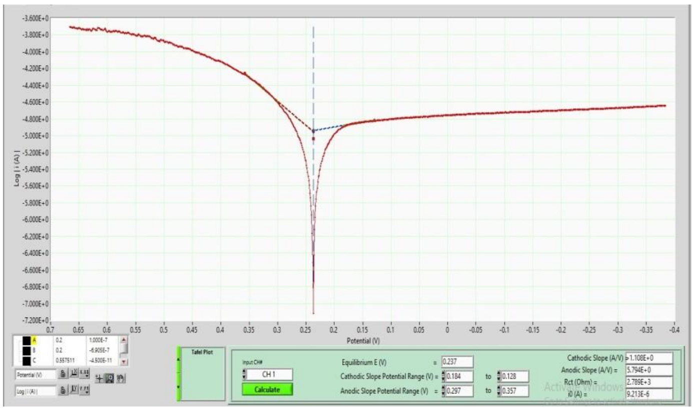


Fig 5: Potentiodynamic Polarization for B3 alloy in Hank's Solution

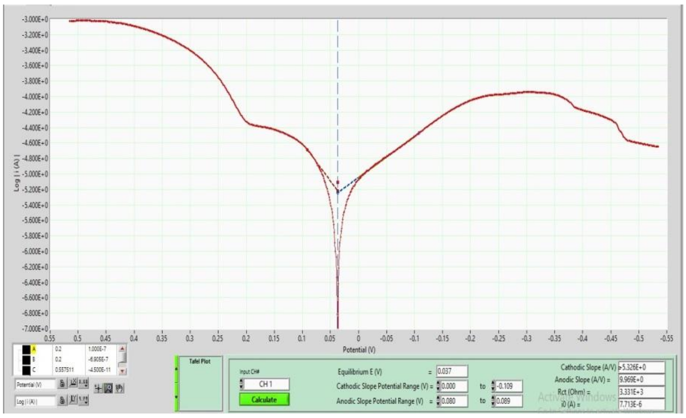


Fig 6: Potentiodynamic Polarization for B4 alloy in Hank's Solution

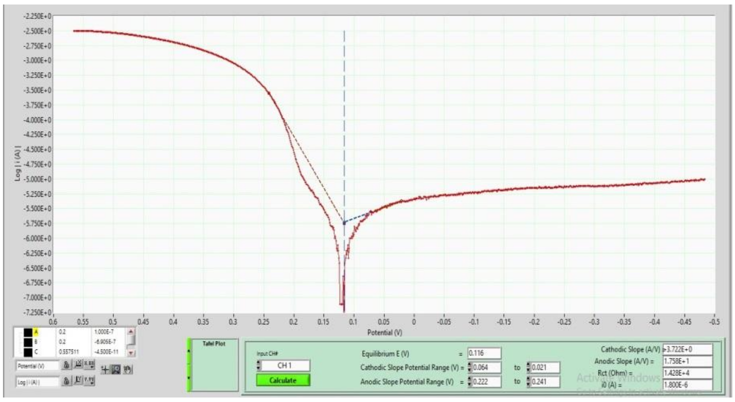


Fig 7: Potentiodynamic Polarization for B5 in Hank's Solution

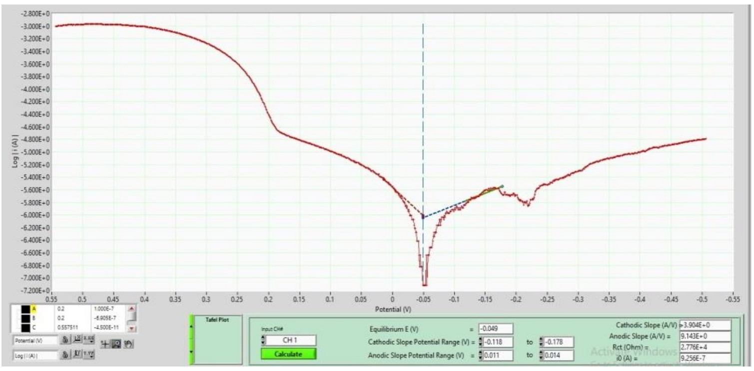


Fig 8: Potentiodynamic Polarization for B6 alloy in Hank's Solution

Table 4: Current of corrosion (Icorr.), Potential of corrosion (Ecorr.), the rate of corrosion and Improvement for all alloys in Hank's solution at ±37°C

Alloy	Icorr. (A)	Ecorr. (mV)	Corrosion rate(mpy0	Improvement (%)
A	20.89	-206	19.237	--
B1	17.81	-200	16.542	14
B2	14.28	-194	13.474	29.9
B3	9.213	-190	8.792	54.3
B4	7.713	-183	6.339	67
B5	1.800	-174	1.523	92
B6	0.925	-165	0.783	95

Table 4 shows that there is a clear improvements in the resistance of corrosion of Zr2.5Nb alloy with various additives of Ta (0.5, 1, 1.5, 2, 2.5 and 3)wt. %, Icorr. for samples is ranged from (17.81μA) for B1 alloy to(0.925μA) for B6 alloy which are lower than that Icorr. for A alloy which is (20.89μA) and Ecorr. for the alloys is ranged from (-200 mV) for B1 alloy to (-165 mV) for B6 alloy which are higher than Ecorr. for A alloy which is (-206 mV). Table 4 shown that that the current of corrosion of samples with Ta addition is lower than the base sample. This is because of the Ta element enhances the resistance of corrosion of Zr2.5Nb alloy by the formation of passive film.

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