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Scientific paper
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Corrosion behavior of Cu-Ni-Ti alloy in artificial blood plasma in presence of Amoxicillin

The Corrosion inhibition of Cu-Ni-Ti alloy in artificial blood plasma in absence and presence of 50ppm and 100ppm of Amoxicillin were studied by potentiodynamic polarization study and AC impedance spectra. The inhibition efficiencies of Amoxicillin for the corrosion of Cu-Ni-Ti alloy increased with increasing concentration. Potentiodynamic polarization study shows that the corrosion of metal surface is greatly reduced with presence of Amoxicillin. This may occur due to the formation of passive film formed on the metal in presence of Amoxicillin.

The polarization study leads to the corrosion inhibition of Cu-Ni-Ti in artificial blood plasma in absence and presence of 50 ppm of Amoxicillin and 100 ppm of Amoxicillin is in the following decreasing order.

Cu-Ni-Ti + artificial blood plasma + 100 ppm of Amoxicillin > Cu-Ni-Ti + artificial blood plasma + 50 ppm of Amoxicillin > Cu-Ni-Ti + artificial blood plasma

The AC impedance spectra study reveals that the corrosion inhibition of Cu-Ni-Ti in artificial blood plasma in absence and presence of 50 ppm of Amoxicillin and 100 ppm of Amoxicillin is in the following decreasing order.

Cu-Ni-Ti + artificial blood plasma + 100 ppm of Amoxicillin > Cu-Ni-Ti + artificial blood plasma + 50 ppm of Amoxicillin > Cu-Ni-Ti + artificial blood plasma

Key words: *polarization, alloy , copper, passive film, corrosion*

1. INTRODUCTION

Corrosion is one of the major problems affecting the life and service of orthopedic devices made of metals and alloys used as implants in the living body. The first requirement for any material to be placed in the human body is that it should be biocompatible and not cause any adverse reaction in the body [1]. The material must withstand the body environment and should not degrade to a point that it cannot function in the body as indented [2, 3]. The corrosion of metal implants is critical because it can adversely affect the biocompatibility and mechanical properties. The materials used should not cause any adverse biological reaction in the body and simultaneously they must be stable to retaining their functional properties. Extensive release of ions from implants can result in adverse biological reactions leading to mechanical failure of the device. For example, release of nickel ion from 316L VM implant alloy may cause allergic effects in some plants [4] that is why metals used in human body must have a high corrosion resistance. Stain less, titanium alloys and cobalt alloys commonly used as biomaterials. Titanium base alloys have paid more attention recent years due to their excellent biocompatibility low density excellent corrosion resistance and good balance of mechanical property [5, 6].

Copper base alloys also are commonly used as biomaterials due to its high corrosion resistance . Amoxicillin is used in the treatment of a number of infections including: acute otitis media, streptococcal pharyngitis, pneumonia, skin infections, urinary tract infections, *salmonella*, lyme disease, and chlamydia infections. It is used to prevent bacterial endocarditis in high risk people who are having dental work done, to prevent *strep pneumococus* infections in those without a spleen, and for both the prevention and the treatment of anthrax. It is also a treatment for cystic acne [5-10]. People who have undergone implantation with weak immunity power are recommended by medical practitioners to take amoxicillin antibiotics to improve their immunity. Eating balanced nutritional food and by taking amoxicillin antibiotics orally increases immunity level in our body. This study reveals whether the implantation materials are affected or corroded due to the intake of amoxicillin.

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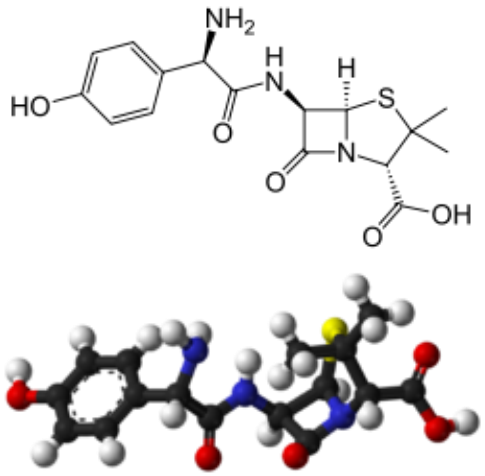

Structure of Amoxicillin

- The aim of this work was undertaken to study the corrosion inhibition of Cu-Ni-Ti alloy in artificial blood plasma in absence and presence of 50 ppm and100 ppm of amoxicillin ***by potentiodynamic polarization study and AC impedance spectra.***
- Corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}) linear polarization resistance (LPR) the charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) have been derived from these studies
- This study reveals whether the implantation materials are affected or corroded due to the intake of amoxicillin.

II. MATERIALS AND METHODS

The metal specimens, namely, Cu-Ni-Ti has been chosen for the present study. The composition of is (wt %) 42.50%, Ti-50%, Cu-7.50%[5]. The metal specimen was encapsulated in Teflon. The metal specimen was polished to mirror finish and degreased with trichloroethylene. The metal specimen was immersed in artificial blood plasma. The chemical composition of the artificial plasma according to PN-EN ISO 10993-15 standard (g/l distilled water) was NaCl 6.8, $CaCl_2$ 0.200, KCl 0.4, $MgSO_4$ 0.1, $NaHCO_3$ 2.2, Na_2HPO_4 0.126, NaH_2PO_4 0.026 [7, 8]. In electrochemical studies the metal specimen was used as working electrode and artificial blood plasma was used as electrolyte (10 ml). The temperature was maintained at 37°.

Inhibitor

Amoxycillin was purchased from medicine shop a trade name Amoxicillin capsules and used without further purification.Amoxvcillin is a N-S heterocyclic compound containing five oxygen atoms, three nitrogen atoms and one sulphur atom.

Hence it is expected to act as a good inhibitor [9,10].

Potentiodynamic Polarisation:

Polarization studies were carried out in a CHI – Electrochemical workstation with impedance, Model 660A. A three-electrode cell assembly was used. The working electrode was the metal specimen. A saturated calomel electrode (SCE) was the reference electrode and platinum was the counter electrode. From the polarization study, corrosion parameters such as corrosion potential (E_{corr}), corrosion current (I_{corr}) and Tafel slopes (anodic = b_a and cathodic = b_c) were calculated.

AC Impedance Spectra:

The instrument used for polarization study was used to record AC impedance spectra also. The cell setup was also the same. The real part (Z') and imaginary part (Z") of the cell impedance were measured in ohms at various frequencies. Values of the charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated from Nyquist plots, impedance log (Z/ohm) value was calculated from bode plots.

III. RESULTS AND DISCUSSION POTENTIO-DYNAMIC POLARIZATION STUDY

The potentiodynamic polarization curves of Cu-Ni-Ti immersed in artificial blood plasma in the absence and presence of Amoxicillin are shown in Figure 1a to 1. Corrosion parameters namely, corrosion potential, (E_{corr}), corrosion current (I_{corr}), Tafel slopes, b_a, b_c, and linear polarization resistance (LPR) are given in the Table 1. Polarization study has been used to confirm the formation of protective film formed on the metal surface during corrosion inhibition process [11-16]. If a protective film is formed on the metal surface, the linear polarization resistance (LPR) increases and the corrosion current value (I_{corr}) decreases [17, 18].

When the Cu-Ni-Ti is immersed in artificial blood plasma in the absence of Amoxicillin the corrosion potential is -421 mV vs SCE Figure 1a. The LPR value is 6.97 x 10^6 ohm cm^2 and the corrosion current (I_{corr}) is 6.037x10^{-9} A/cm^2. The Tafel slopes (b_c=145 mV/decade, b_a=290 mV/decade) indicate that the rate of change of corrosion current with potential is higher during the anodic polarization than during cathodic polarization [19].

The polarization study reveals that the corrosion resistance of Cu-Ni-Ti in artificial blood plasma increases in presence of 50 ppm of Amo-

xicillin. When Cu-Ni-Ti is immersed in ABP in presence of 50 ppm of Amoxicillin the corrosion potential is shifted from - 421 to -596mV vs SCE Figure b. The Tafel slopes (b_c=127 mV/ decade, b_a = 416 mV/decade). Further the LPR value increases from 6.97 x 10^6 ohm cm^2 to 1.180x10^7 ohm cm^2. The corrosion current (I_{corr}) decreases from 6.037 x 10^{-9} A/cm^2 to 3.577 x 10^{-9} A/cm^2. Thus the polarization study confirms the formation of a protective film on the metal surface. When 100 ppm of Amoxicillin is added, the corrosion potential is increased from -421 (in absence of Amoxicillin) to -596 and in presence of 50 ppm of Amoxicillin the corrosion potential remains same Fig.1.(c). LPR value increases from 6.97 x 10^6 (in absence of Amoxicillin) and 1.180 x 10^7 (in presence of 50 ppm of Amoxicillin) to 1.19 x 10^7 ohm cm^2 and I_{corr} value decreases from 6.037 x 10^{-9} (in absence of Amoxicillin) and 3.577 x 10^{-9} (in presence of 50 ppm of Amoxicillin) to 3.544 x 10^{-9} ohm cm^2.

Thus the polarization study leads to the corrosion resistance of Cu-Ni-Ti in ABP is in the following decreasing order: Cu-Ni-Ti+ ABP+100 ppm of Amoxicillin > Cu-Ni-Ti +ABP+50ppm of Amoxicillin >Cu-Ni-Ti+ABP.

Table 1 - Corrosion parameters of Cu-Ni-Ti is immersed in artificial blood plasma (ABP) in the absence and in the presence of 50 ppm and 100 ppm of Amoxicillin, obtained from polarization study

Metal	System	E_{corr} mV vs SCE	b_c mV/decade	b_a mV/decade	LPR ohm/cm^2	I_{corr} A/cm^2
Cu-Ni-Ti	ABP	-421	145	290	6.97 x 10^6	6.037 x 10^{-9}
	ABP + Amoxicillin 50 ppm	-596	127	416	1.180 x 10^7	3.577 x 10^{-9}
	ABP + Amoxicillin 100 ppm	-596	125	435	1.19 x 10^7	3.544 x 10^{-9}

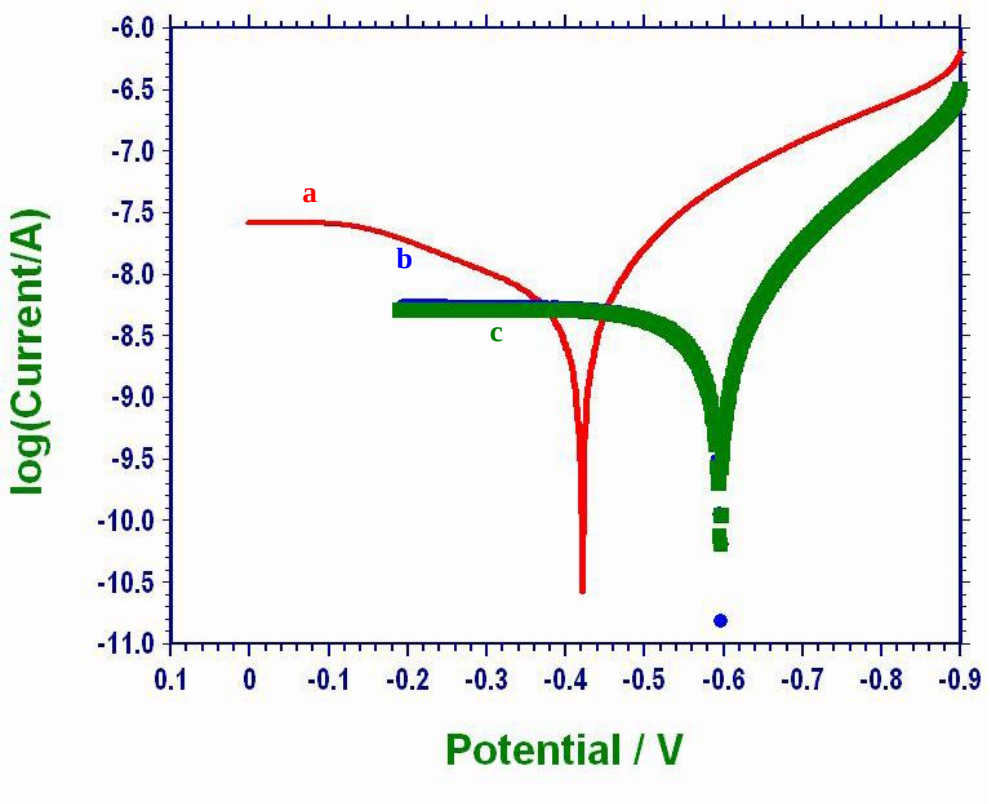

Figure 1 - Polarization curves of Cu-Ni-Ti immersed in various test solutions: (a) Cu-Ni-Ti + Artificial blood plasma (blank), (b) Cu-Ni-Ti + ABP + 50 ppm of Amoxicillin, (c) Cu-Ni-Ti + ABP + 100 ppm of Amoxicilli

AC impedance spectra

The AC impedance spectra of metal specimens immersed in artificial blood plasma in the absence and in the presence of 50 ppm and 100 ppm of Amoxicillin are shown in Figure 2a to Figure 2c (Nyquist plots) and Fig.3a to Fig.3c) (Bode plots).

AC impedance spectra have been used to confirm the formation of protective film on the metal surface [20]. If a protective film is formed on the metal surface, charge transfer resistance (R_t) increases, double layer capacitance value (C_{dl}) decreases and the impedance log (z/ohm) value increases [21].

The AC impedance parameters namely charge transfer resistance (R_t) and double layer capacitance (C_{dl}) derived from Nyquist plots are given in Table 2. The impedance log (z/ohm) values derived from Bode plots are also given in Table 2.

When Cu-Ni-Ti is immersed in ABP in the absence of Amoxicillin, the charge transfer resistance R_t is 57770 ohm cm^2 Figure 2a. The double layer capacitance value is 8.82 x 10^{-11} F/cm^2 (Figure 2a). The impedance value is 5.3 (Figure 3a). Bode-phase diagram shown in Figure 3a shows two time constant. The phase angle approaches 75° suggesting that a very stable film is formed on Cu-Ni-Ti. It is also support that in the Bode plot the slope value is 0.5. So that a very stable film is formed on the metal [22].

When Cu-Ni-Ti is immersed in ABP containning 50 ppm Amoxicillin, the charge transfer resistance R_t increases from 57770 ohm cm^2 to 238200 ohm cm^2 Figure b.

The C_{dl} value decreases from 8.82 x 10^{-11} F/cm^{-2} to 2.14 x 10^{-11} F/cm^{-2}. The impedance value log (z/ohm) increases from 5.3 to 5.5. Bode plots shown on the Figure 3b the slope value is 0.5. So that a very stable layer is formed on the Cu-Ni-Ti surface. The phase angle approaches 63°. So the corrosion inhibition is more [23-25].

Table 2 - Corrosion parameters of Cu-Ni-Ti is immersed in artificial blood plasma (ABP) in the absence and in the presence of 50 ppm and 100 ppm of Amoxicillin obtained from AC impedance spectra

Metal	System	Nyquist plot		Impedance log (z/ohm)
		R ohm cm^2	Cu F/cm^2	
Cu-Ni-Ti	ABP	57770	8.82 x 10-11	5.3
	ABP+50 ppm Glu	238200	2.14 x 10-11	5.5
	ABP+50 ppm Glu	240700	2.22 x 10-11	5.6

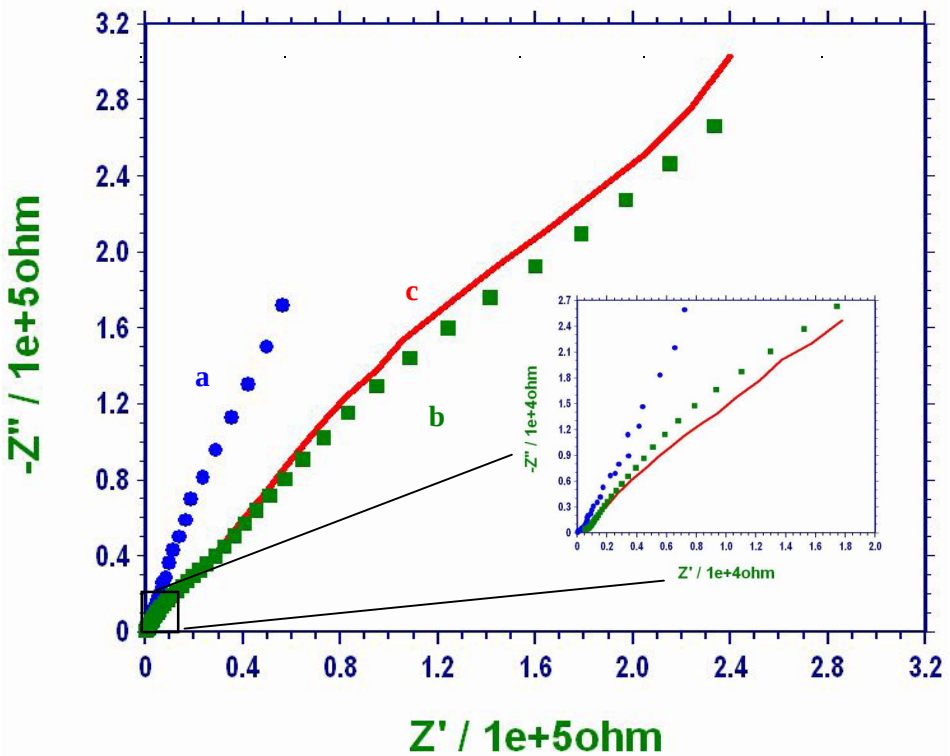

Figure 2 - AC impedance spectra of Cu-Ni-Ti is immersed in artificial blood plasma (Nyquist plot): (a) Cu-Ni-Ti + Artificial blood plasma (blank), (b) Cu-Ni-Ti + ABP + 50 ppm of Amoxicillin, (c) Cu-Ni-Ti + ABP + 100 ppm of Amoxicillin

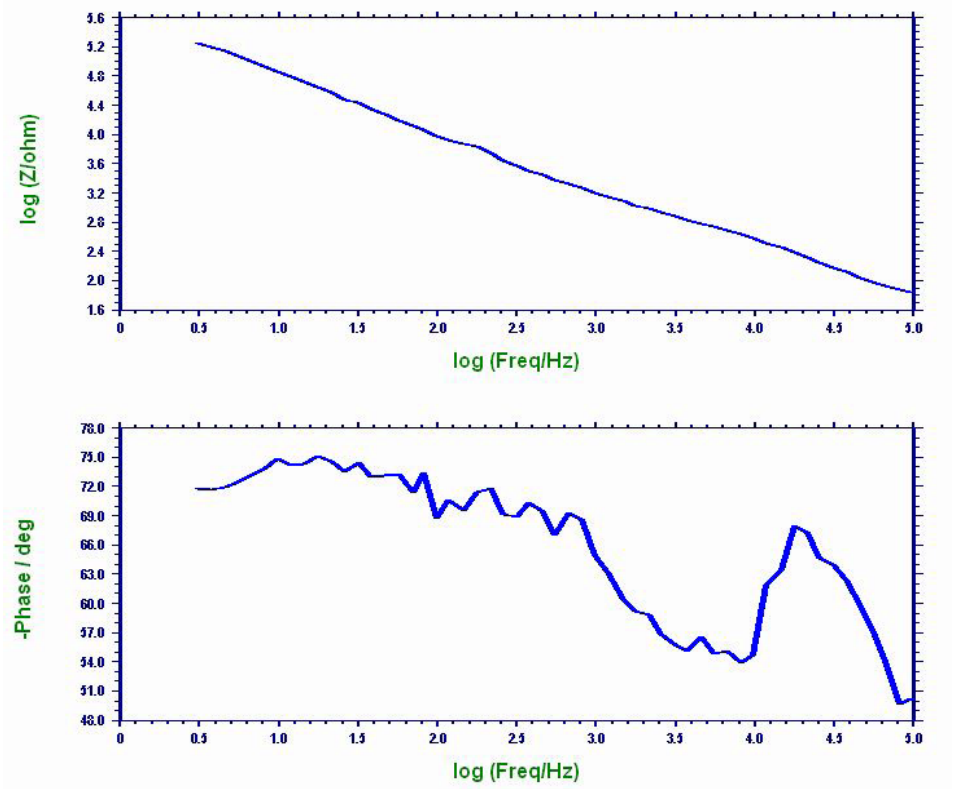

Figure 3a - Bode plots of Cu-Ni-Ti is immersed in various test solutions containing: (a) Cu-Ni-Ti + artificial blood plasma (blank)

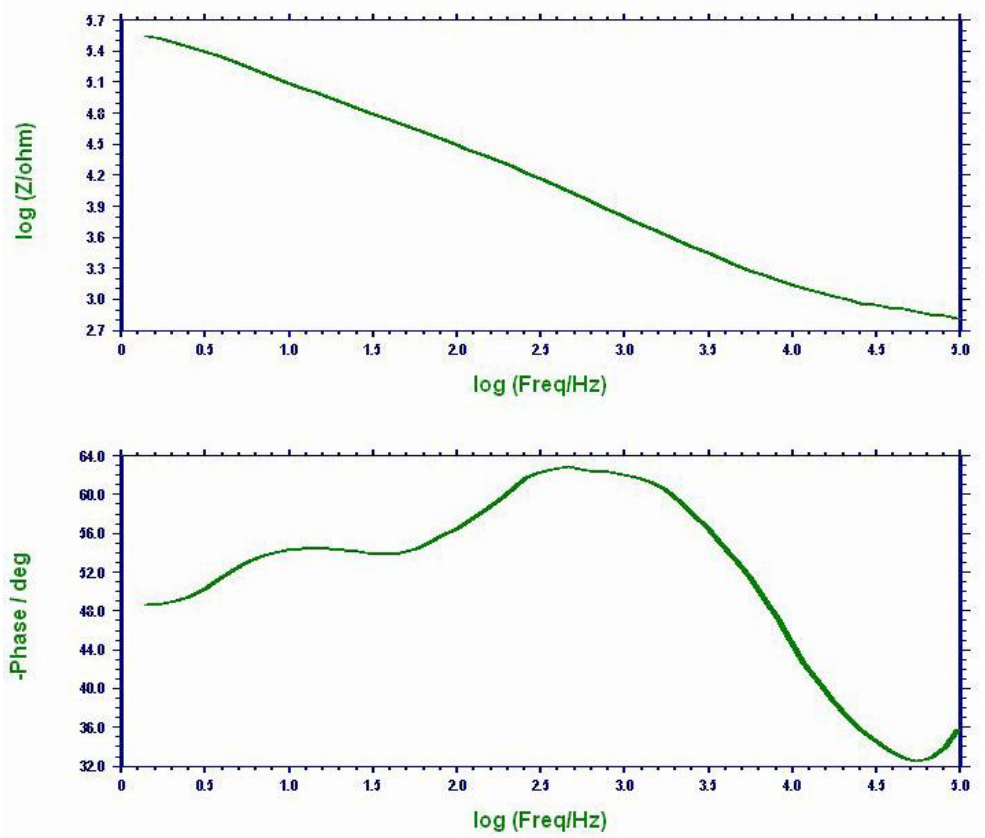

Figure 3b - Bode plots of Cu-Ni-Ti is immersed in various test solutions containing: (b) Cu-Ni-Ti + ABP + 50 ppm of Amoxicillin

When 100 ppm Amoxicillin is added the R_t value increases from 57770 (in absence of Amoxicillin) and 238200 Figure 2b (in presence of 50 ppm of Amoxicillin) to 240700 ohm cm^2 Figure 2c respectively. The C_{dl} value decreases from 8.82 x 10^{-11} (in absence of Amoxicillin) and 2.14 x 10^{-11} (in presence of 50 ppm of Amoxicillin) to 2.11 x 10^{-11} F/cm^2. The impedance value increases from 5.3 (in absence of Amoxicillin) and 5.5 (in presence of 50 ppm of Amoxicillin) to 5.6 log(z/ohm) Figure 3b and 3c. In presence of 100 ppm amoxicillin R_t value is increased and C_{dl} value is decreased. There was an increase in the value of impedance. This observation is indicated that in the presence of amoxicillin in artificial blood plasma the corrosion rate of Cu-Ni-Ti was reduced, due to the formation of a protective film formed on the metal surface. Because of the presence of protective film on the metal surface, electron transfer from the metal surface to the bulk of the solution was restricted. These results in an increase of charge transfer resistance and a decrease in double layer capacitance since they are related to each other investigated [26]. The phase angle approaches 58°, so, the corrosion is inhibited. Thus, the AC impedance spectral study reveals that the corrosion resistance of Cu-Ni-Ti in ABP is in the following decreasing order:

Cu-Ni-Ti + ABP + 100 ppm Amoxicillin > Cu-Ni-Ti + 50 ppm Amoxicillin > Cu-Ni-Ti+ ABP 32

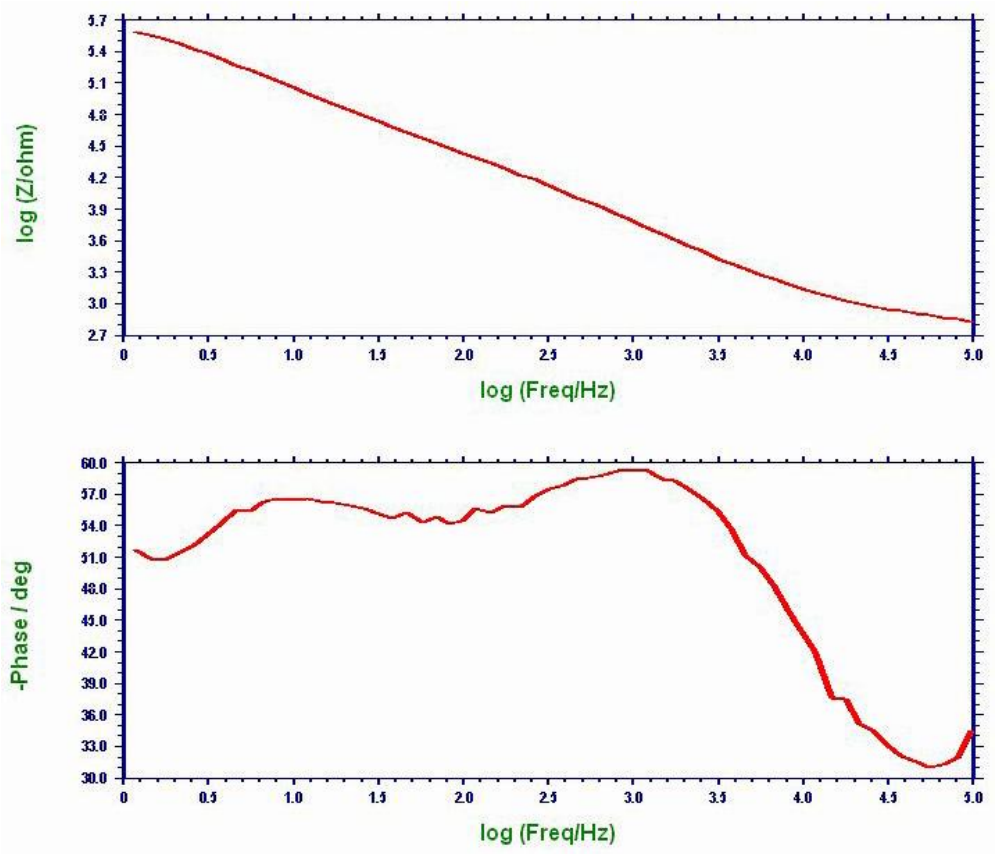

Figure 3c - Bode plots of Cu-Ni-Ti is immersed in various test solutions containing: (c) Cu-Ni-Ti + ABP + 100 ppm of Amoxicillin

CONCLUSION

Amoxicillin can be used as environmentally, safe inhibitors for the corrosion of Cu-Ni-Ti in artificial blood plasma for the implantation. The corrosion inhibition efficiencies of the Amoxicillin depends on it is chemical structure and the constituents of the artificial blood plasma and composition of Cu-Ni-Ti alloy. The corrosion inhibition process is based on the adsorption of the amoxicillin molecules on the metal surface in the artificial blood plasma. The polarization study leads to the corrosion inhibition of Cu-Ni-Ti in artificial blood plasma in absence and presence of 50 ppm of Amoxicillin and100 ppm of Amoxicillin is in the following decreasing order:

Cu-Ni-Ti + artificial blood plasma + 100 ppm of Amoxicillin > Cu-Ni-Ti + artificial blood plasma + 50 ppm of Amoxicillin > Cu-Ni-Ti + artificial blood plasma

The AC impedance spectra study reveals that the corrosion inhibition of Cu-Ni-Ti in artificial blood plasma in absence and presence of 50 ppm of Amoxicillin and 100 ppm of Amoxicillin is in the following decreasing order:

Cu-Ni-Ti + artificial blood plasma + 100 ppm of Amoxicillin > Cu-Ni-Ti + artificial blood plasma + 50 ppm of Amoxicillin > Cu-Ni-Ti + artificial blood plasma

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IZVOD

KOROZIJSKO PONAŠANJE Cu-Ni - Ti LEGURE U VEŠTAČKOJ KRVNOJ PLAZMI U PRISUSTVU AMOKSICILINA

Inhibicija korozije Cu-Ni-Ti legure u veštačkom krvnoj plazmi u prisustvu i odsustvu 50ppm i 100ppm Amoksicillina su proučavani potentiodinamičkom polarizacijom i AC impedansnim spektrima. Inhibicija efikasnosti u Amokicillinu za koroziju Cu -Ni-Ti legure raste sa povećanjem koncentracije . Potentiodinamika polarizacijska studija pokazuje da se korozija metalne površine znatno smanjuje u prisustvu amoksicilina. Ovo se može desiti zbog formiranja pasivnog filma na metalnoj površini u prisustvu amoksicilina. Polarizacijska studija ukazuje da inhibicija korozije legure Cu-Ni- Ti u veštačkoj krvnoj plazmi u prisustvu i odsustvu 50 ppm Amokicillin i 100 ppm Amoksicilin je u sledećem opadajućem redosledu:

Cu-Ni-Ti + veštačka krvna plazma + 100 ppm of Amoxicillin > Cu-Ni-Ti + veštačka krvna plazma + 50 ppm of Amoxicillin > Cu-Ni-Ti + veštačka krvna plazma

AC impedansa otkriva da je inhibicija korozije Cu-Ni-Ti u veštačkoj krvnoj plazmi u prisustvu i odsustvu Amokicillin 50 ppm i 100 ppm Amoksicilin u sledećem opadajućem redosledu:

Cu-Ni-Ti + veštačka krvna plazma + 100 ppm of Amoxicillin > Cu-Ni-Ti + veštačka krvna plazma + 50 ppm of Amoxicillin > Cu-Ni-Ti + veštačka krvna plazma

***Ključne reči**: polarizacija, legura, baker, pasivni film, korozija*

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