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

The Corrosion behaviour of Cu-Ni-Ti in artificial blood plasma in absence and presence of 50ppm and 100ppm of Cholesterol were studied by potentiodynamic polarization study and AC impedance spectra. The inhibition efficiencies of Cholesterol for the corrosion of Cu-Ni-Ti is increased with increasing concentration. Potentiodynamic polarization study shows that the corrosion of metal surface is greatly reduced with presence of Cholesterol. This may occur due to the formation of protective layer formed on the metal in presence of Cholesterol. The polarization study leads to the corrosion inhibition of Cu-Ni-Ti in artificial blood plasma in absence and presence of 50 ppm of Cholesterol and100 ppm of cholesterol is in the following decreasing order:

Cu-Ni-Ti + artificial blood plasma + 100 ppm of Cholesterol > Cu-Ni-Ti + artificial blood plasma + 50 ppm of Cholesterol > 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 Cholesterol and100 ppm of Cholesterol is in the following decreasing order:

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

***Keywords:** Corrosion, artificial blood plasma, Cu-Ni-Ti, Cholesterol*

INTRODUCTION

Cu-Ni-Ti is the most commercially successful implantation material in biomedical [1]. Cu-Ni-Ti alloys are important materials for biomedical and dental devices because of their unique properties, comparatively high corrosion resistance and good biocompatibility. The alloy has been used for making orthodontic dental arch wires and medical guide wires for diagnostic and therapeutic catheters for many years. Corrosion reduces strength and causes premature failure of implants and may also impose harmful effects on the surrounding tissues. Stainless steels, titanium alloys and cobalt alloys are commonly used as biomaterials [2]. Cholesterol is a waxy, fat-like substance that occurs naturally in all parts of the body. Our body needs some cholesterol to work properly. But if we have too much in our blood, it can stick to the walls of our arteries. Cholesterol is present in higher concentrations in tissues which either produce more or have more densely-packed membranes. Cholesterol plays a central role in many biochemical processes, but is best known for the association of cardiovascular disease with various lipoprotein cholesterol transport patterns and high levels of cholesterol in the blood.

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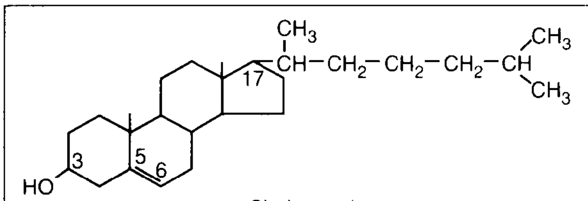
Cholesterol is required to build and maintain cell membranes; it makes the membrane's fluidity - degree of viscosity - stable over wider temperature intervals. Some research indicates that cholesterol may act as an antioxidant. Cholesterol also aids in the manufacture of bile (which helps digest fats), and is also important for the metabolism of fat-soluble vitamins, including vitamins A, D, E and K. It is the major precursor for the synthesis of vitamin D and of the various steroid hormones. People who have undergone implantation with high level cholesterol are recommended by medical practitioners to take proper nutritional food to reduce the cholesterol. By eating balanced nutritional food leads to increase or decrease of cholesterol level in our body. The present study reveals whether the implantation materials are affected or corroded due to the intake of cholesterol containing nutritional food.

Structure of Cholesterol



Cholesterol

MATERIALS AND METHODS

The metal specimens, namely, Cu-Ni-Ti has been chosen for the present study. The composition focus Cu-Ni-Ti is Ni– 55.5%, Ti –37%, Cu-7.50% balance [2]. 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 plasma. The pH of artificial blood plasma was 7.0. 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[3]. In electrochemical studies the metal specimen was used as working electrode plasma was used as electrolyte (10 ml). The temperature was maintained at 37°C.

Potentiodynamic Polarization

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 Cu-Ni-Ti alloy.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.

RESULTS AND DISCUSSIONS

Analysis of Potentiodynamic Polarization curves

The corrosion parameters of Cu-Ni-Ti in artificial blood plasma (ABP) are given in Table 1. The potentiodynamic polarization curves are shown in Figs. 1 to 3.

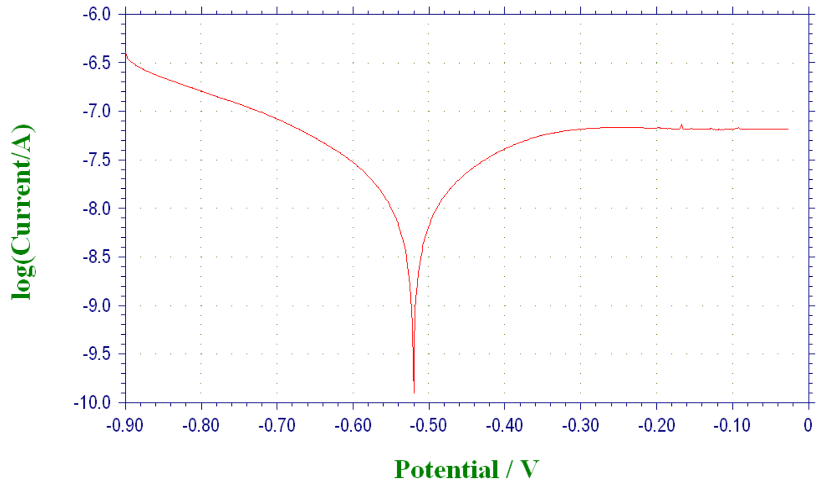


Figure 1 - Polarization curves of Cu-Ni-Ti immersed in artificial blood plasma in absence of Cholestrol.

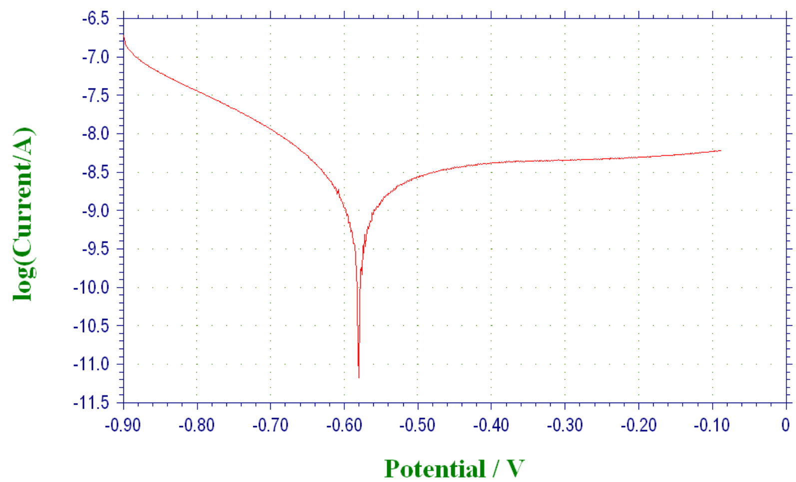


Figure 2 - Polarization curves of Cu-Ni-Ti immersed in artificial blood plasma in presence of 50 ppm Cholesterol.

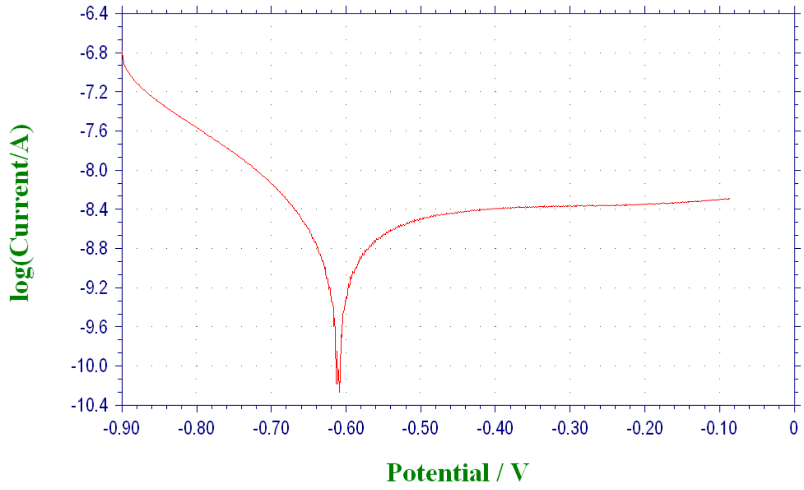


Figure 3 - Polarization curves of Cu-Ni-Ti immersed in artificial blood plasma in presence of 100 ppm Cholesterol.

Cu-Ni-Ti immersed in Cholesterol

The Potentiodynamic polarization curves of Cu-Ni-Ti immersed in artificial plasma in absence and presence of 50ppm Cholesterol and 100 ppm Cholesterol are shown in fig 1, 2 and 3. The corrosion parameters namely corrosion potential, corrosion current (I corr), Tafel slopes ba, bc, (LPR) linear polarization resistance are given in the Table 1.

Table 1 - Corrosion parameters of Cu-Ni-Ti immersed in artificial blood plasma in the absence and presence of Cholesterol obtained by polarization study

System	E_{Corr} mV vs SCE	b_c mV/ decade	b_a mV/decade	LPR ohmcm^2	I_{Corr} A/cm^2
Cu-Ni-Ti +ABP	-520	173	195	3.0 x 10^6	1.329 x 10^{-8}
-Ni – Ti +ABP +50ppm Cholesterol	-580	137	324	9.88 x 10^6	2.109 x 10^{-9}
Cu-Ni – Ti +ABP +100ppm Cholesterol	-609	148	348	2.0 x 10^7	2.104 x 10^{-9}

Cu-Ni-Ti immersed in artificial plasma in the absence of Cholesterol

When Cu-Ni-Ti immersed in artificial plasma, the corrosion potential is -520mV Vs SCE. The LPR value is 3.0 x 10^6 ohmcm^2 and the corrosion current (I corr) is 1.329 x 10^{-8} A/cm^2. The Tafel slope values bc = 173 mV/decade ba = 195 mV/decade indicate that the rate of change of corrosion current with potential is much higher during the cathodic polarization than during the anodic polarization.

Corrosion behavior of Cu-Ni–Ti in artificial blood plasma in presence of 50 ppm of Cholesterol

When Cu-Ni-Ti immersed in ABP in presence of 50 ppm of Cholesterol the corrosion potential is shifted from -520to -580 mV Vs SCE. The Tafel slopes are bc = 137 mV/decade and ba = 324 mV/decade .The LPR value increases from 3.0 x 10^6 ohms cm^2 to 9.88x 10^6 ohm cm^2. The corrosion current (I corr) decreases from 1.329 x 10^{-8} A/cm^2 to 2.109 x 10^{-9} A/cm^2. Thus polarization study confirms the formation of a protective film on the metal surface. The polarization study reveals that the corrosion resistance of Cu-Ni-Ti in ABP increases in presence of 50 ppm of Cholesterol.

Corrosion behavior of Cu-Ni-Ti in artificial blood plasma in presence of 100 ppm of Cholesterol

When Cu-Ni-Ti is immersed in artificial blood plasma in presence of 100 ppm of Cholesterol the corrosion potential is shifted from -520 to -609mV Vs SCE. The Tafel slopes are bc = 148 mV/decade and ba = 348 mV/decade. The LPR value increases from 3.0 x 10^6 to 2.0 x 10^7ohmcm^2. The corrosion current (I corr) decreases from 1.329 x 10^{-8}to2.104 x 10^{-9} A/cm^2. Thus the polarization study confirms the formation of a protective film on the metal surface.

The polarization study reveals that the corrosion resistance of Cu-Ni-Ti in ABP in presence of 100 ppm increases. The corrosion resistance of Cu-Ni-Ti in artificial blood plasma is in the following decreasing order:

Cu-Ni-Ti + plasma +100 ppm Cholesterol > Cu-Ni-Ti + plasma+ 50 ppm Cholesterol > Cu-Ni-Ti +plasma

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. The Values of the charge transfer resistance (R_t) and the double layer capacitance (C_{dl}) were calculated.

Table 2 - Corrosion parameters of Cu-Ni- Ti immersed in artificial blood plasma in the absence and presence of Cholesterol obtained by AC Impedance spectra.

Metal	System	Nyquist plot		Bode plot
		R_t ohm cm^2	C_{dl} F/cm^2	Impedance log (z/ohm)
Cu-Ni-Ti	Cu-Ni-Ti +ABP	4588	1.11x 10^{-11}	5.5
Cu-Ni-Ti	Cu-Ni-Ti +ABP +50ppm Cholestrol	50094	1.0x 10^{-10}	4.9
Cu-Ni-Ti	Cu-Ni-Ti +ABP +100ppm cholesterol	52260	9.7 x10^{-11}	4.9

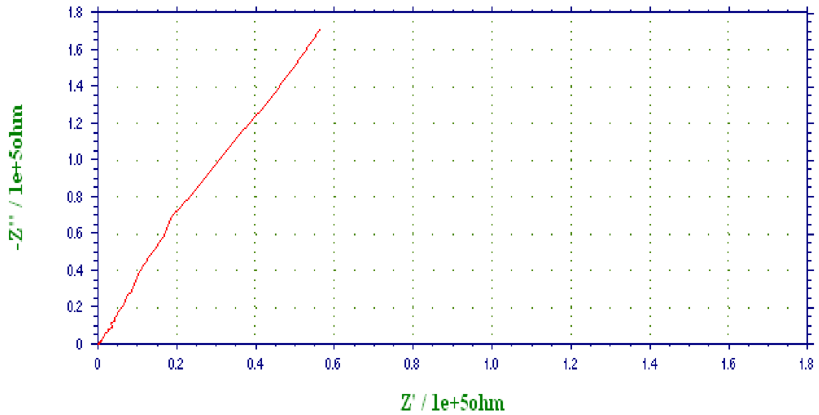


Figure 4 - AC impedance spectra of Cu-Ni-Ti immersed in ABP in absence of Cholesterol (Nyquist Plot).

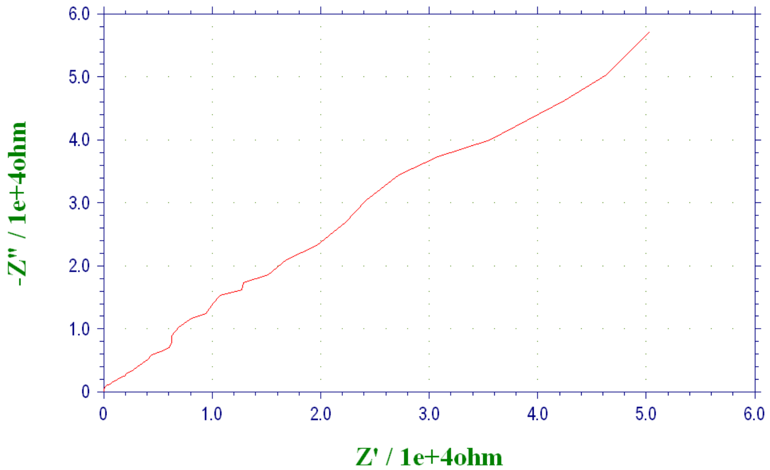


Figure 5 - AC impedance spectra of Cu-Ni-Ti immersed in ABP in presence of 50 ppm Cholesterol (Nyquist Plot).

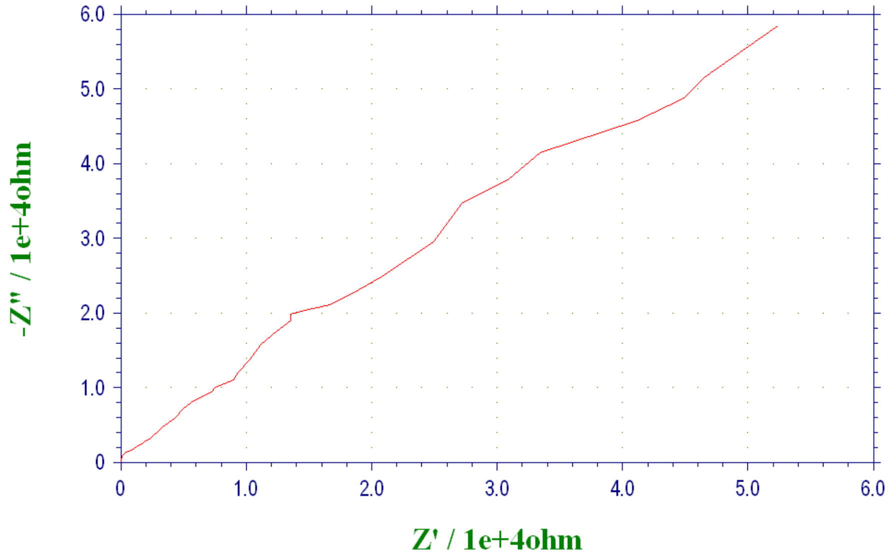


Figure 6 - AC impedance spectra of Cu-Ni –Ti immersed in ABP in presence of 100 ppm Cholesterol (Nyquist Plot).

Cu-Ni-Ti immersed in ABP in absence of Cholesterol

When Cu-Ni-Ti immersed in ABP, the change transfer resistance Rt is 4588 ohmcm^2. The double layer capacitance value is 1.11 x 10^{-11} F/cm^2 Fig. 4. The impedance value is 5.5 Fig. 7.

Cu-Ni-Ti immersed in ABP presence of 50 ppm of Cholesterol

When Cu-Ni-Ti is immersed in ABP containing 50 ppm Cholesterol the charge transfer resistance R_t increases from 4588 ohmcm^2 to 50094ohmcm^2. The C_{dl} value decreased from 1.11 x10^{-11} F/cm^2 to 1.0 x 10^{-10}F/cm^2. The impedance value log (Z/ohm) decreases from 5.5 to 4.9 These results lead to the conclusion that the protective film is stably formed.

Cu-Ni-Ti immersed in ABP presence of 100 ppm of Cholesterol

When 100 ppm Cholesterol is added the R_t value increases from 4588 to 50094. The impedance value decreases from the5.5 to 4.9The C_{dl} value shifted from 1.11 x10^{-11}F/cm^2 to 9.7 x 10^{-11}F/cm^2 Thus the AC impedance study leads to the conclusion that a protective film is formed. When a protective film is formed on the metal surface the face angle value increases. The electron flow through the film from the metal is restricted .It is obtained from phase bode plots the phase angle value decreases in the order of:

Cu-Ni-Ti + plasma +100 ppm Cholesterol > Cu-Ni-Ti + plasma+ 50 ppm Cholesterol > Cu-Ni-Ti + plasma

The equivalent circuit diagram Cu-Ni-Ti is immersed in various test solution is shown in fig. (6).

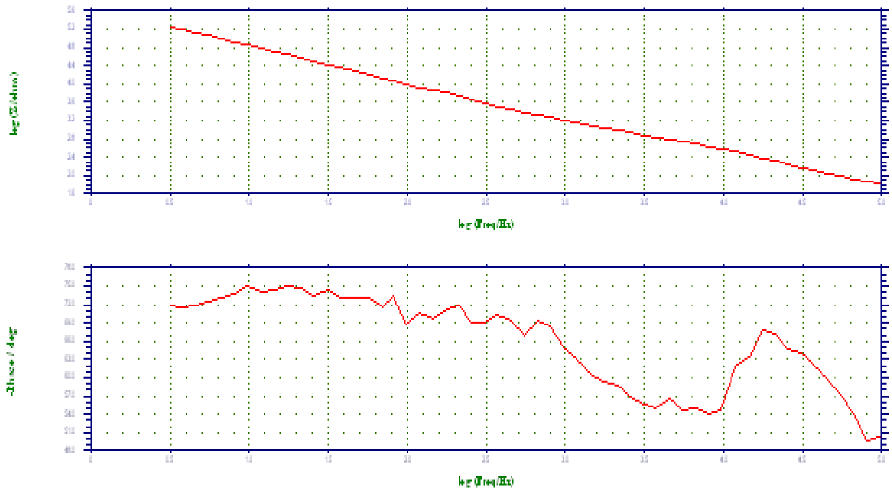


Figure 7 - AC impedance spectra of Cu-Ni-Ti immersed in ABP in absence of Cholesterol (Bode plot).

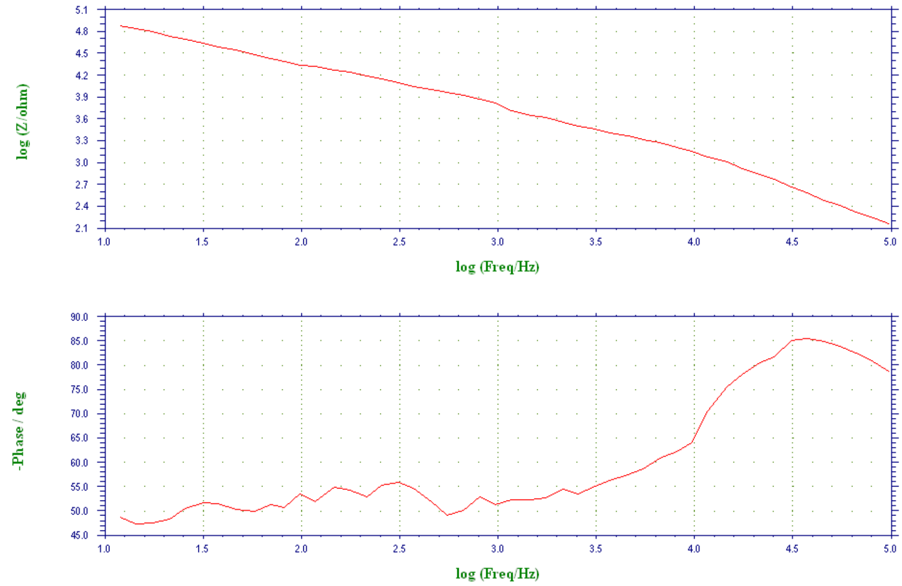


Figure 8 - AC impedance spectra of Cu-Ni-Ti immersed in ABP in presence of 50ppm Cholesterol (Bode plot).

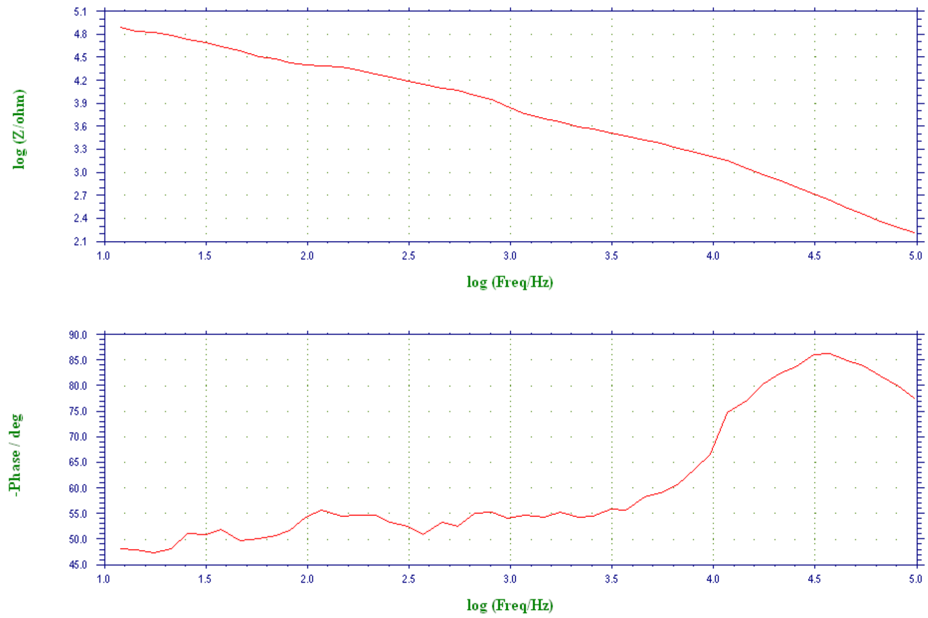


Figure 9 - AC impedance spectra of Cu-Ni Ti immersed in ABP in presence of 100ppm Cholesterol (Bode plot).

CONCLUSION

The corrosion behavior of Cu-Ni-Ti immersed in ABP in absence and presence of 50 ppm of Cholesterol, 100 ppm of Cholesterol have been studied.

Polarization study leads to the following conclusions:

Cu-Ni-Ti + plasma +100 ppm Cholesterol	>	Cu-Ni-Ti + plasma +50 ppm Cholesterol	>	Cu-Ni-Ti + plasma

AC impedance leads to the following conclusions:

Cu-Ni-Ti + plasma +100 ppm Cholesterol	>	Cu-Ni-Ti + plasma+ 50 ppm Cholesterol	>	Cu-Ni-Ti + plasma

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IZVOD

KOROZIONO PONAŠANJE LEGURE Cu-Ni-Ti U VEŠTAČKOJ KRVNOJ PLAZMI U PRISUSTVU HOLESTEROLA

Koroziono ponašanje Cu-Ni-Ti u veštačkoj krvnoj plazmi u odsustvu i prisustvu 50ppm i 100ppm holesterola su proučavani potentiodinamičkom polarizacionom metodom i AC impedancom. Efikasnost inhibicije holesterola za koroziju Cu-Ni-Ti se povećava sa povećanjem koncentracije. Potentiodinamička polarizaciona metoda pokazuje da je korozija površine metala u velikoj meri smanjena uz prisustvo holesterol. To se može desiti zbog formiranja zaštitnog sloja na metalu u prisustvu holesterola. Studija polarizacije dovodi do inhibicije korozije Cu-Ni-Ti u veštačkoj krvnoj plazmi u odsustvu i prisustvu 50 ppm i 100 ppm holesterola i nalazi se u sledećem opadajućem nizu:

Cu-Ni-Ti + veštačka krvna plazma + 100 ppm holesterola	>	Cu-Ni-Ti + veštačka krvna plazma + 50 ppm holesterola	>	Cu-Ni-Ti + veštačka krvna plzma

Studija AC impedance otkriva da inhibicija korozije Cu-Ni-Ti u veštačkoj krvnoj plazmi u odsustvu i prisustvu 50 ppm i 100 ppm holesterola je u sledećem opadajućem nizu:

Cu-Ni-Ti + veštačka krvna plazma + 100 ppm holesterola	>	Cu-Ni-Ti + veštačka krvna plazma + 50 ppm holesterola	>	Cu-Ni-Ti + veštačka krvna plzma

Ključne reči: *korozija, veštačka krvna plazma, Cu-Ni-Ti, holesterol*

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