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Corrosion Behavior of SS316L in Artificial Blood Plasma in Presence of D-Glucose

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Abstract—The Corrosion resistance of SS316L in artificial blood plasma in absence and presence of 50ppm and 100ppm of D-Glucose has been evaluated by electro chemical studies such as polarization study AC impedance spectra. Potentiodynamic polarization study and AC impedance spectra have been used to investigate the corrosion behaviour of SS316L. The order of corrosion resistance of SS316L in artificial blood plasma in absence and presence of 50ppm of D-Glucose and presence of 100 ppm of D-Glucose is

SS316L + plasma + 100 ppm D-Glucose > SS316L + plasma+ 50 ppm D-Glucose > SS316L + plasma

Keywords—Corrosion, artificial plasma, SS316L, D-Glucose

I. INTRODUCTION

The performance of any material in the human body is controlled by two sets of characteristics: biofunctionality and biocompatibility. There are wide ranges of materials available for implantation. Many metals and alloys have been used in implantation. The corrosion behaviour of Artificial Blood Plasma has been investigated. Influence of PH and corrosion inhibitors D-Glucose in ABP has been investigated. The selection of materials for medical applications is usually based on considerations of biocompatibility. When metals are considered, the susceptibility of the material to corrosion and the effect the corrosion has on the tissue are the central aspects of biocompatibility. The human body is not an environment that one would consider hospitable for an implanted metal alloy. The materials for the devices generate less concern in their biocompatibility with human body than those for implants. The basic knowledge of metal composition, microstructure and processing is necessary to select a metallic material for a specific application. Metallic materials can have serious corrosion problems in aqueous solution, such as in contact with physiological fluids. Corrosion results in releasing toxic metals ions to body and also weakening implants. An electrochemical reaction involves removing electrons from the anodic to the cathode. When the metal is surrounded by an aqueous solution, oxidation may occur at the location on the metal surface. For the past hundred years various metals are used for implantation in the human body, such as aluminum, copper, zinc, iron and carbon steels, silver, nickel, and magnesium. Corrosion resistance of implant materials may involve qualitative measurements or quantitative electrochemical measurements in simulated body fluid. Now a day's various alloys and metallic materials are found and are used as implantation material in human body for long period. Corrosion is one of the major issues resulting in the failure of biomedical implant devices. The nature of the passive oxide films formed, and the mechanical properties of the materials form some of the essential criteria for selection of alternative or development of new materials. Commercially available D-Glucose (Indian pharmacopeias grade) was used in this study. 0.05g and 0.10g of D-Glucose was used in artificial plasma (AP). The present work was undertaken to study the corrosion behaviour of SS316L in artificial blood plasma in absence and presence of D-Glucose, by polarization study and AC impedance spectra. Corrosion parameter such as corrosion potential, corrosion current, linear polarization resistance, charge transfer resistance and double layer capacitance have been derived from these studies.

II. MATERIALS AND METHODS

The present work is undertaken. The metal specimens, namely, SS316L has been chosen for the present study. The composition of SS 316L is (wt %) 18 Cr, 12 Ni, 2.5 Mo, < 0.03 C and balance iron. 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. 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°

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.

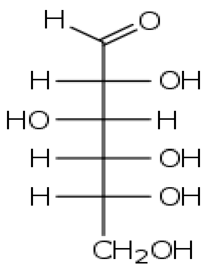
AC Impedance Spectra:

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 DISCUSSIONS

Analysis of potentiodynamic polarization curves

The corrosion parameters of SS316L in artificial blood plasma (ABP) are given in Table 1. The potentiodynamic polarization curves are shown in Figs. 1 to 3. To study the corrosion behaviour of SS316L in artificial blood plasma in absence and presence of D-Glucose by polarization study and AC impedance spectra. Corrosion parameters such as corrosion potential, corrosion current, linear polarization resistance, charge transfer resistance and double layer capacitance have been derived from these studies. Glucose $C_6H_{12}O_6$ also known as D-Glucose, dextrose,or grapesugar)is simple sugar (monosaccharide) and an important carbohydrate in biology. Cells use it as the primary source of energy and a metabolic intermediate. D-Glucose is one of the main products of photosynthesis and fuels for cellular respiration. D-Glucose is the human body's key source of energy, through aerobic respiration, providing approximately 3.75 kilocalories (16 kilojoules) of food energy per gram. It is dissolved in water. The main objective of present study is to investigate how the intake of a D-Glucose solution affects the diabetic people who have undergone implanation. Hence the corrosion behaviour of SS316L in absence and presence of 50 ppm and 100 ppm D-Glucose is studied.



Structure of D-Glucose

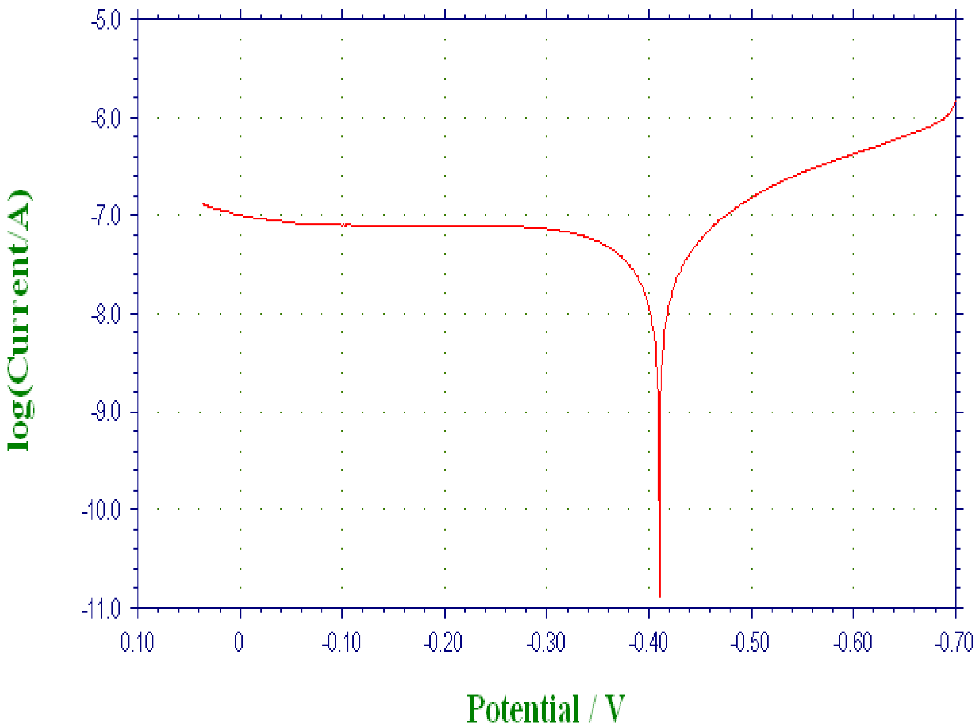


Figure1: Polarization curves of SS316L immersed in artificial blood plasma in absence of D-Glucose

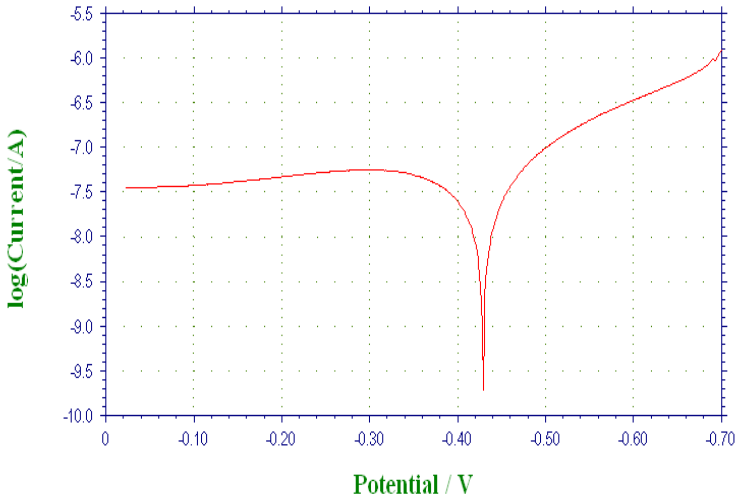


Figure2: Polarization curves of SS316L immersed in artificial blood plasma in presence of 50 ppm D-Glucose

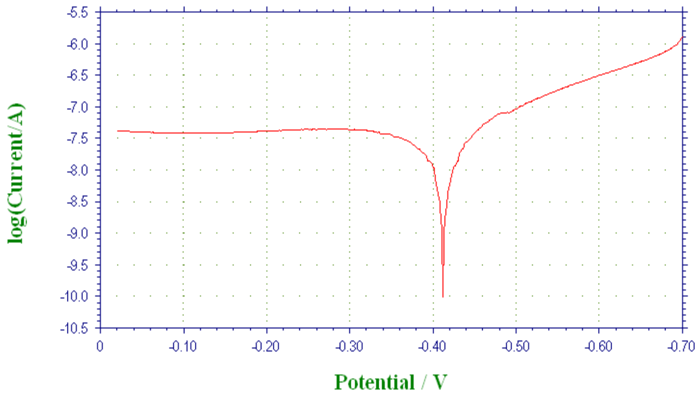


Figure3: Polarization curves of SS316L immersed in artificial blood plasma in presence of 100 ppm D-Glucose

IV. ANALYSIS OF POTENTIODYNAMIC POLARISATION CURVES

SS316L immersed in D-Glucose

The Potentiodynamic polarization curves of SS316L immersed in artificial plasma in the absence and presence of 50ppm D-Glucose and 100 ppm D-Glucose are shown in fig 1 to 3. The corrosion parameters namely corrosion potential, corrosion current, (I corr) Tafel slope ba, bc, LPR linear polarization resistance are given in the table (1)

Table 1: Corrosion parameters of SS316L immersed in artificial blood plasma in the absence and presence of D-Glucose obtained by 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
SS316L	SS316L +ABP	-410	154	460	8.23 x10^5	6.097x 10^{-8}
SS316L	SS316L +ABP +50ppm D-Glucose	-429	152	523	9.99 x 10^5	5.144 x 10^{-8}
SS316L	SS316L +ABP +100ppm D-Glucose	-412	182	612	1.30 x 10^6	4.691x 10^{-8}

SS316L immersed in artificial plasma in the absence of D-Glucose.

When SS316L immersed in artificial plasma, the corrosion potential is -410 mV Vs SCE. The LPR value is 8.23 x 10^5 ohmcm^2 and the corrosion current (I corr) is 6.097 x 10^{-8} A/cm^2. The tafel slope values (bc = 154 mV/decade ba = 460 mV/decade) indicate that the rate of change of corrosion current with potential is much higher during the anodic polarization than during the cathodic polarization. During anodic polarization oxide film is formed on metal surface in presence of SS316L.

Corrosion behaviour of SS316L in artificial blood plasma in presence of 50 ppm of D-Glucose.

When SS316L immersed in ABP in presence of 50 ppm of D-Glucose the corrosion potential is shifted from -410 to -429 mV Vs SCE. The tafel slopes bc = 152 mV/decade ba = 523 mV/decade further the LPR value increase from 8.23 x 10^5 ohm cm^2 to 9.99 x 10^5 ohmcm^2. The corrosion current (I corr) decreases from 6.097 x 10^{-8} A/cm^2 to 5.144 x 10^{-8} 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 SS316L in ABP increases in presence of 50 ppm of D-Glucose.

SS316L immersed in artificial blood plasma in the presence of 100 ppm of D-Glucose.

When SS316L immersed in artificial blood plasma in presence of 100 ppm of D-Glucose the corrosion potential is shifted from -410 to -412 mV Vs SCE. The tafel slopes bc = 182 mV/decade ba = 612 mV/decade. Further the LPR value is increased from 8.23 x 10^5 to 1.30 x 10^6 ohmcm^2. The corrosion current (I corr) shifted from 6.097 x 10^{-8} A/cm^2 to 4.691x 10^{-8}. Thus the polarisation study confirms the formation of a protective film on the metal surface.

The polarization study reveals that the corrosion resistance of SS316 in ABP in presence of 100 ppm increases.

SS316 L+ plasma + 100 ppm D-Glucose > SS316L + plasma+ 50 ppm D-Glucose > SS316 L+ 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 ohm at various frequencies. Values of the charge transfer resistance (Rt) and the double layer capacitance (Cdl) were calculated.

Table 2: Corrosion parameters of SS316L immersed in artificial blood plasma in the absence and presence of D-Glucose 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)
SS316L	SS316L +ABP	129200	3.94 x10^{-11}	5.4
SS316L	SS316L +ABP +50ppm D-Glucose	177300	2.87 x 10^{-11}	5.5
	SS316L +ABP +100ppm D-Glucose	179600	2.83 x 10^{-11}	5.6

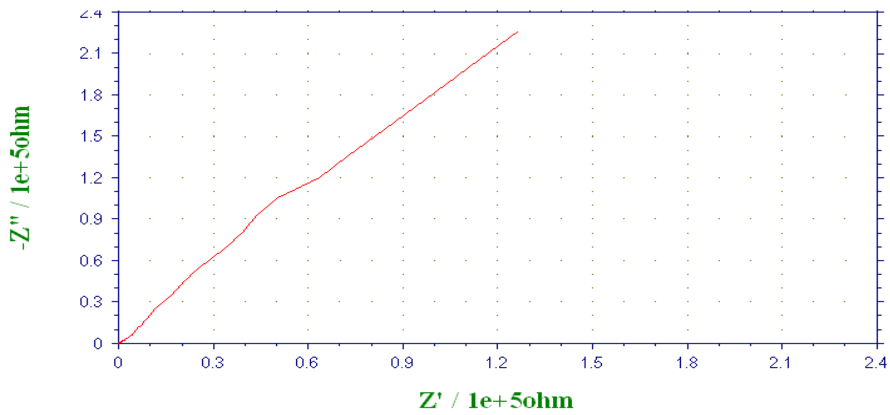


figure 4. AC impedance spectra of SS316L immersed in ABP in absence of D-Glucose

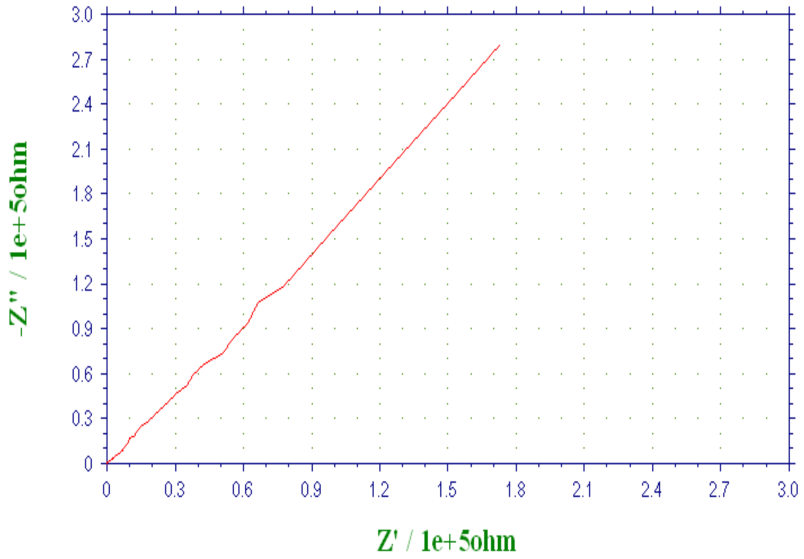


Figure 5. AC impedance spectra of SS316L immersed in ABP in presence of 50 ppm D-Glucose

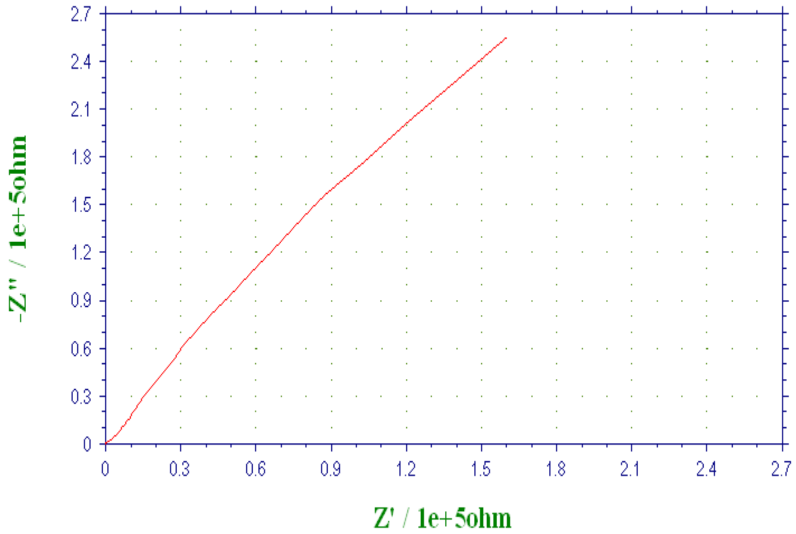


Figure 6. AC impedance spectra of SS316L immersed in ABP in presence of 100 ppm D-Glucose

SS316 immersed in ABP in absence of D-Glucose:

When SS316L immersed in ABP, the change transfer resistance Rt is 129200 ohmcm^2. The double layer capacitance value is 3.94 x 10^{-11} F/cm^2 Fig(4). The impedance value is 5.4 Fig 4, 5, and 6 and the corresponding Bode plot is shown in Fig 7, 8, and 9.

SS316 immersed in ABP presence of 50 ppm of D-Glucose:

When SS316L immersed in ABP containing 50 ppm D-Glucose the charge transfer resistance Rt increases from 129200 ohm cm^2 to 177300 ohm cm^2. The Cdl value decreases from 3.94 x 10^{-11} F/cm^2 to 2.87 x 10^{-11} F/cm^2. The impedance value log (2/ohm) increases from 5.4 to 5.5. These results lead to the conclusion that the protective film is formed.

SS316 immersed in ABP presence of 100 ppm of D-Glucose:

When 100 ppm D-Glucose is added the Rt value increases from 129200 to 177300 ohm cm^2 the cdl value decreases from 3.94 x 10^{-11} to 2.87 x 10^{-11} F/cm^2. The impedance value increases from the 5.5 to 5.6. Thus the AC impedance study leads to the conclusion that the protective film is formed.

Thus AC impedance spectra lead to the conclusions that in the absence and presence of D-Glucose, the order of corrosion resistance is

SS316L + plasma + 100 ppm D-Glucose	>	SS316 L+ plasma 50 ppm D-Glucose	>	SS316L + plasma

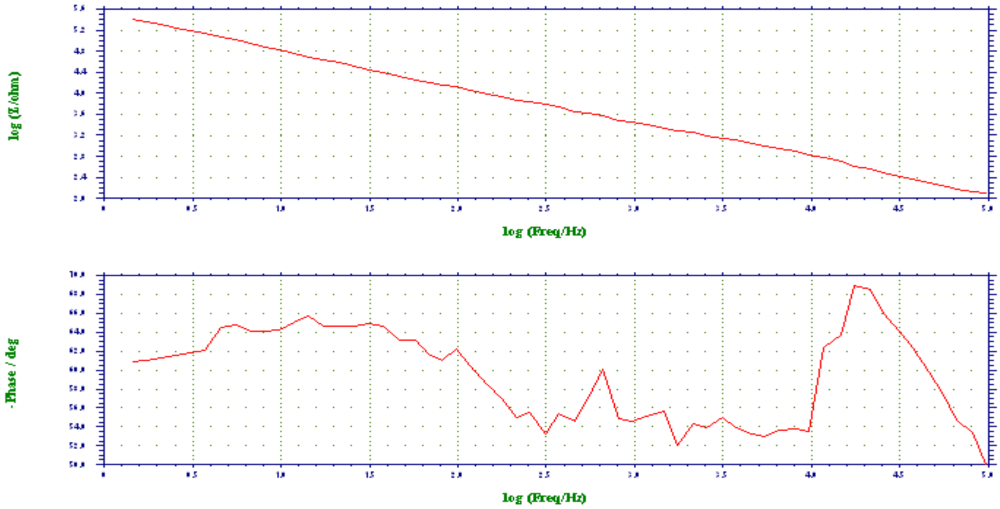


Figure 7. AC impedance spectra of SS316L immersed in ABP in absence of D-Glucose(Bode plot)

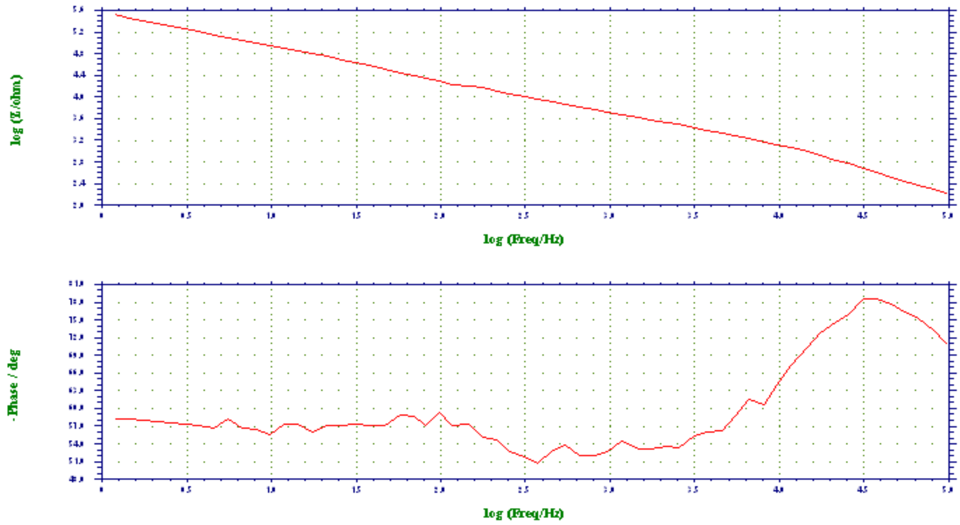


Figure 8. AC impedance spectra of SS316L immersed in ABP in presence of 50ppm D-Glucose (Bode plot)

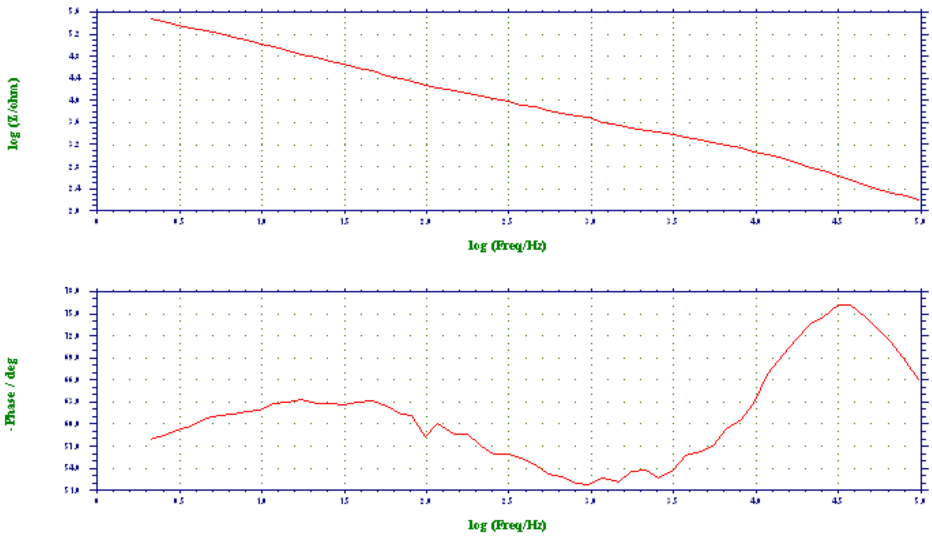


Figure 9. AC impedance spectra of SS316L immersed in ABP in presence of 100ppm D-Glucose (Bode plot)

V. CONCLUSION

The corrosion behaviour of SS316L immersed in ABP in absence and presence of 50 ppm of D-Glucose, 100 ppm of D-Glucose have been studied.

Polarization study leads to the following conclusions.

SS316L + plasma + 100 ppm D-Glucose > SS316L + plasma > 50 ppm D-Glucose SS316L + plasma

AC impedance leads to the following conclusions.

SS316L + plasma+ 100 ppm D-Glucose	>	SS316L + plasma 50 ppm D-Glucose	>	SS316L + plasma

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